Compiling Stereoscopic 3D Animations from 2D Video Sequences and Virtual Computer Models Exploiting Open Source Software

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Abstract

The year 2010 should see the breakthrough for 3D television. All major manufacturers in the computer and entertainment industry presented 3D products. Polarization still competes with shutter technology; auto-stereoscopic systems are furthermore under development. Due to the HDMI interface PC, TV and data-projection are connected together. This contribution covers the principles of current developments in hardware for recording and playback of stereoscopic animations.   There is a demand for content creation in 3D formats. Software tools for the conversion from 2D to 3D video sequences are presented. Particular computer models are suitable for presentations as stereoscopic 3D animations. Attention is given to the modeling of a stereo camera rig for creating left and right animations and mounting them together for stereoscopic presentation.

1. INTRODUCTION

The development of the stereoscope began in 1830 already. Viewing stereo cards was a popular pastime at the end of the 19th century. 1897 the *Kaiserpanorama* became an attraction in Germany. Further development caused today to auto stereoscopic video displays or virtual reality environments like caves and workbenches.

Stereoscopy is used in photogrammetry and computer vision for applications in science and technology. Automatic matching algorithms generate depth maps for image based 3D modeling. The entertainment industry is reinventing stereoscopy from time to time in cinema, print media or game industry. The cinema presented 1922 *Power of Love* in anaglyph technique, later around 1950 polarizing technique became popular.

The year 2010 should see the breakthrough for 3D television.   On the occasion of CES Las Vegas and IFA Berlin all the major manufacturers of the entertainment industry presented 3D TV products. Games of the soccer World Cup were broadcasted in 3D on pay TV channels. On 28 August the biggest boulevard newspaper in Germany was printed completely using anaglyph technique. The computer industry made steps forward as well. Notebooks equipped with a polarized panel are now being offered. The cinemas have already announced 5D movies. 3D mobile phones are coming to the market.

What does that mean for the production of   content for cultural heritage presentations? About ten years ago the author presented a paper about stereoscopy on PCs [3]. Polarization and shutter glasses were already common at that time. New today are the high definition standard and the HDMI interface that connects PC, TV and data-projector. Focusing to current developments of hardware, data formats and interfaces has to include the availability of software tools for the production of stereoscopic 3D animations from 2D videos and computer models. Apart from industrial tools a wide range of freeware and open source enables researchers and scientist for creation of 3D animated content.
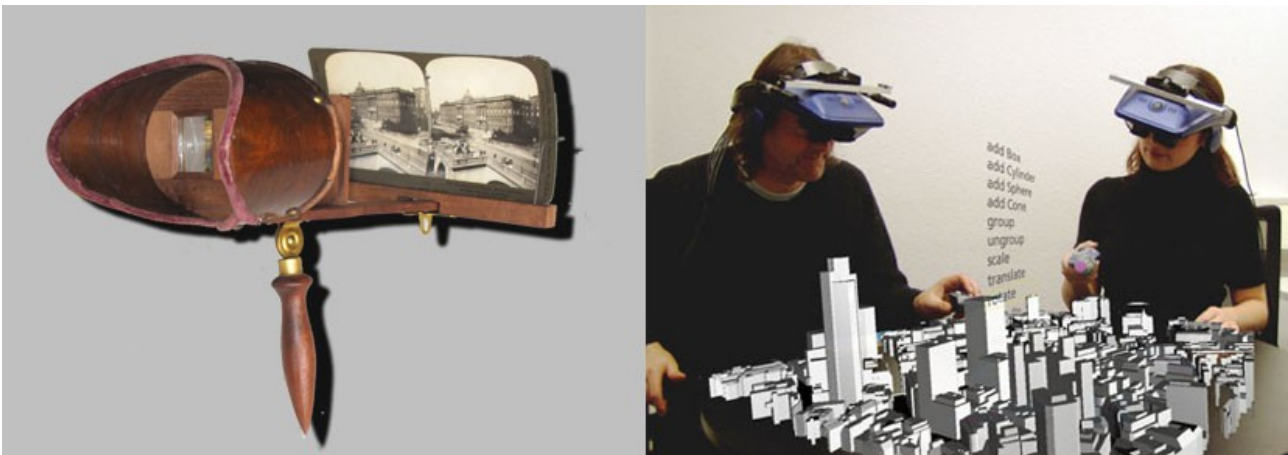
Figure 1: Holmes Stereoscope from the beginning of the 20th century and today's augmented reality

Artificial stereoscopic viewing is based on the slightly horizontal parallax of objects in two perspectives. Image separation is carried out by spatial positioning, time difference and filtering. Shutter glasses and polarizing filters are still in use for stereoscopic viewing on all media. If not available, the good old anaglyph glasses provide spatial impression. Since we are talking here about animation, two questions have to be answered. How can I get 3D impression from 2D material and what is the most effective setup for virtual cameras in 3D computer models to avoid the possible 3D thickness? The first question will be answered by movement; objects or camera. The latter question has to consider the baseline length between the two cameras and the setting of the stereoscopic window. Reading this article imparts introduction into utilisation of AviSynth, VirtualDub, Stereo Movie Maker and Sketchup Software.Including a first step into RUBY scripting for interfacing Sketchup designs.

2. STEREOSCOPIC VIEWING AND IMAGE SEPARATION

The perception of spatial environments by people has its reason due to three phenomena:

- focusing the eye to various distances

- depth perception due to complex inter-relationships between the human eye and brain

- analyzing the slightly different images between the eyes

The latter has its cause in the binocular disparity. Due to the human eyes distant a spatial object is projected to different positions on the retina. Talking about natural viewing this offset is named disparity. Artificial stereoscopic viewing is reached by two different perspectives and separation of viewing of those single images with the according eye. The difference of the viewing angle between the nearest point and the farest point should not extend 70 arcminutes. Calculating images in virtual worlds applying computer graphic methods require a stereo rig of cameras as used in real worlds as well. Two cameras with different positions provide differences in the image coordinates of identical object points for the left and the right image. Image separation during viewing is achieved by filtering (anaglyph, polarization), temporal separation (shutter glasses, page flipping), local separation (stereoscopes, HMDs).

2.1 Local Image Separation

In the beginning of stereoscopy mechanical methods for image separation dominated the development. 1838 introduced Charles Wheatstone the stereoscope, 100 years later the Viewmaster was brought to the market. Various kinds of stereoscopes are known as there are: lens stereoscope, mirror stereoscope, prism assemblies and lenticular sheets first used as collecting cards of sport events and today a principle of auto-stereoscopic displays.

A pair of lenses with the displacement of the human eye distance apart of the focal length from a stereoscopic image pair is known as a lens stereoscope. This setup limits the image size. Larger formats can

be viewed by applying prism lenses or mirrors. Mirror stereoscopes repeatedly redirect the optical path. The latter were used for image separation in connection with computer applications. Layout of the images will still be reflected in digital formats as side-by-side or above-and-below. Today there is no more relevance of that kind of equipment in connection with digital imaging.

2.2 Filter Techniques

Filtering by wavelength is still common in stereoscopy. In early times gray images were known as red-green anaglyphs. New combinations of red-cyan or yellow/orange-blue like ColorCode 3D and optimized colors are used in several media. The cardboard glasses are sheep and can be used for publication to the crowd. There is no need for extra projection facilities. Anaglyph technique is named sometimes *poor men's virtual reality* , but it is still a low effort media for getting spatial impressions on screens, projection and print media.

Loss of color information is not given in case of polarization. Passive stereoscopic projection applying polarization needs a particular projection surface, which reflects the polarized light direction in the same way as it receives it. In case of computer screens, the image resolution is reduced to the half since horizontal or vertical lines of the screen have to share both images.

During linear polarization light oscillates in one plane, predefined by the filter. The filters for the left image and the right image must right-angled disposed against each other. Polarization direction of the glasses must fit to the filters. Thereby every eye sees only the complementary image. Circular polarization is not that easy in its description. Compared to linear polarization circular filters provide advantages in the viewing position. Also good image separation is provided while viewing with a great amount of tilt.

2.3 Temporal Image Separation

Temporal image separation techniques alternate in displaying the left and the right field on the projection surface. Shutter glasses are driven in synchronized mode to the signal. The liquid crystals change from opaque to transparent in the frequency of the image projection. The screen will display flicker-free images at an image rate with minimum 120 Hz. Since every eye receives only half of the images the frame rate is reduced to 60 Hz. The NVIDIA 3D vision kit for Windows Vista / Windows 7 including graphic board, 120 Hz monitor and emitter with shutter glasses is standard today in the consumer market. It competes with polarized monitor systems. Both have their pros and cons.

3. RECORDING OF 3D STILL PICTURES AND MOVING IMAGES

Video recording with digital cameras could not compete with camcorders due to low resolution and mass storage requirement so far. Today DSLR cameras store longer video sequences in full HD resolution as well. Design aspects become a criteria for the decision of the one or other device. Camcorders like mobile phones are used for quick recordings and replace the established units. It is obvious that in the field of consumer equipment the boundaries between the equipment classes are fluid. Also the performance of mobile phones is increasing. End of February 2011 the first 3D smart phones were announced. In the meantime the performance of web cams increased and can be considered as a suitable device.

We can't mention here the complete field of available hardware in detail but focus to the principles of modern stereo recording systems. We look at three construction principles: a camera with two lenses, a camera with a changeable beam splitter in front of the lens sharing one sensor and two synchronized cameras, named sometimes as side cars. The latter are mounted on a stereo bar for changing the stereo base. All principles can be observed at digital cameras and camcorder likewise.

Fuji's Real 3D camera stores images in MPO format (multi photo object) and as one additional JPG. Applying Fuji's software MyFinePixStudio or the freeware StereoPhotoMaker [5] reads, displays and splits the MPO images. Image resolution comes for a still single image with 3648 x 2736 px. Fuji offers a service for printing lenticular cards on-line under [10]. Maximum 3D video resolution is 1280 x 720 px

Since 1982 Loreo from Hong Kong offers lens accessories as beam splitters already. Nowadays digital SLR cameras of the major manufacturers are serviced with macro lenses and 3D accessory lenses. Due to the

beam splitting the sensor takes both fields at one time. Panasonic presents an alternative with a two in one lens. The Lumix G 12 lens has two separate lenses sharing one sensor. The mini lenses have a focal length of 65 mm.

Figure 2: DCC with two lenses and two sensors and a camcorder with a changeable accessory lens

Particular roles play webcams. Webcams are simple recording units directly transferring the images to the Internet. High resolution web cams display images of 1280 x 1024 px of public areas, construction sites and are used for security and conference purposes. Due to the low pricing web cams are easy to set up as 3D systems. Video capture software that can handle two cameras simultaneously is required. Hytek Stereo 3D Camera Driver from [12] is such a solution.

4. PLAYBACK SYSTEMS

4.1 Computer Hardware and Software

Shutter technology, polarization systems and auto stereoscopic displays are available on PC and TV platforms today. Besides that, anaglyph technique works anyway but with the loss of color information. The well-known companies NVIDIA and AMD offer a wide range of graphic cards. 3D Vision from NVIDIA with shutter glasses, infrared transmission under Windows 7 on 120 Hz monitors is a standard solution for GeForce boards. AMD just came with the Open Stereo 3D Initiative, a standard that should be used by all manufacturers. AMD included in its Radeon driver a so called Quad-Buffer function for flicker-free displaying. Other components as stereo 3D driver, monitors and glasses should come from OEMs.

While viewing in shutter technology, the complete image changes with 120 Hz. The half-image of a stereo pair is presented with 60 Hz to the user. A good 3D impression requires perfect synchronization between screen and glasses. Outside light distracts the spatial effect of the shutter technique. Shutter technique allows watching stereo 3D under normal viewing distance.

3D panels equipped with polarization technique are polarized by rows or columns. The complete stereo image shares the screen. A half-image is therefore presented only with half of its resolution. Polarizing filter glasses are cost-effective but need a viewing distance greater as the normal viewing distance to merge the images for a spatial impression.

Manufacturer of notebooks offer shutter technique as well as polarization. Devices without a 3D panel can be connected to a 3D capable television monitor via the HDMI 1.4 interface. Anaglyph technique is included within all graphic card drivers and need no further technical effort. The colors of the half-images are filtered and merged to one image on standard monitors. Auto stereoscopic monitors are still not common due to lack in technology and pricing.

Replaying animations requires a stereoscopic player that takes the left and the right animation in two files or in a stereoscopic format (e. g. side-by-side) and converts it to the appropriate output format in real-time. One of the common players is the Stereoscopic Player from 3dtv.at [5]. Consider that polarized projection needs special projection walls to keep the polarization directions.

4.2 High Definition Television

HDTV (high definition television) stands for a couple of television standards for a higher resolution than before. The nomenclature for HDTV is comprised by the number of lines, image display mode and image refresh rate.

Common image resolutions today are 1280 x 720 px and 1920 x 1080 px in full frame mode (progressive p). Compared to interlaced technique (interlaced i) with a half-image frequency of 50 or 60 Hz counts the image frequency in full frame mode 25 or 30 Hz. The aspect ratio of an image is 16:9. A technical description in short writes the number of lines and the mode, e. g. 1080p for full HD.

3D television transmits stereo images in one frame of the HDTV format 1280 x 720 px or 1920 x 1080 px. Thereby the horizontal or vertical resolution of the half-images is reduced. 3D transmission follows the 2D structure, the final image will be mounted together at the receiver site.

Applying frame packing, a mega frame of 1920 x 2205 px will be transmitted. This format contains both half -images with full resolution and a 45 lines gap. That format is supported by Blu-ray players and follows the HDMI 1.4 interface convention.

Connecting a 3D television with a computer's graphic card with 1080p60 in stereo mode requires a HDMI compatible 120 Hz monitor and the appropriate graphic board equipped with HDMI interface.

4.3 3D Projection

So far active or passive stereo projection took place with two beamers. Passive (polarized) back projection applying two beamers connected to one graphic card is known in the scientific community as a Geowall [11]. The major advantages of projection compared to monitors are the large format image and watching in a community.

Since end of 2010 full HD beamer are coming to capture the market. In general beamer technology differ in image generation technology: LCD (liquid crystal displays) and DLP (digital light processing). DLP was the technique for high end devices, in the meantime it came down to the consumer market.

JVC and Sony offer full HD shutter technique beamer for home entertainment in a higher price segment. ACER is offering alternatives with 720p at a consumer price now.

Test reports certify reasonable results for all stereo 3D beamers, which complete the transcription systems for computer, television, video and Blu-ray. But the development of beamers for stereo 3D is just in the beginning.

5. 2D TO 3D CONVERSION OF MOVIES

In case of a left and a right perspective we are talking about real 3D. On the basis of animation 2D movies can be converted to pseudo 3D. Compared to real 3D there is a loss of quality but the spatial impression may be sufficient enough. Consider a fixed camera moving in a vehicle, image pairs arise by a time offset of the frames. Another situation is given by a more or less fixed camera and moving objects. Common video cutting software or DVD burning software is today equipped with functions for converting 2D into 3D. A complex problem is solved by a simple solution. The quality of the result differs in dependency from the characteristic of the starting material.

The major manufacturers of the entertainment industry announce for their 3D TV algorithms and hardware for getting the depth information from 2D material. Movement, perspective, occlusions or illumination are indicators in single images for depth information. Sophisticated on line conversion needs very high computing power and will not reach the quality of a real 3D video. Therefore some companies don't follow this way, they want to offer quality products without generating headache for the viewer.

5.1 Commercial Conversion Software

For the purposes of software testing three small video clips were selected to convert them from 2D to 3D applying commercial software products. MAGIX, MakeMe3D and 3Dfier are software products with

licenses assigned to the shareware segment. Figure 4 displays as anaglyphs the different conditions. The left example is taken with a fixed camera during a boat ride and produced very good results. In the middle a fixed camera took pictures from a fixed surrounding while people left the train. And in the right example all combinations of moving objects and camera and zooming took place. Access to the video clips is given via [7] with links to YouTube.

3Dfier Real-time 2D to 3D Conversion Directshow Filter, is a software that can be downloaded from [6] and works together with common stereoscopic players. In the setup menu of the Stereoscopic Player [5] 3Dfier has to be selected as the video filter. The results from 3Dfier showed reasonable quality in the on-line conversion in combination with the Stereoscopic Player.
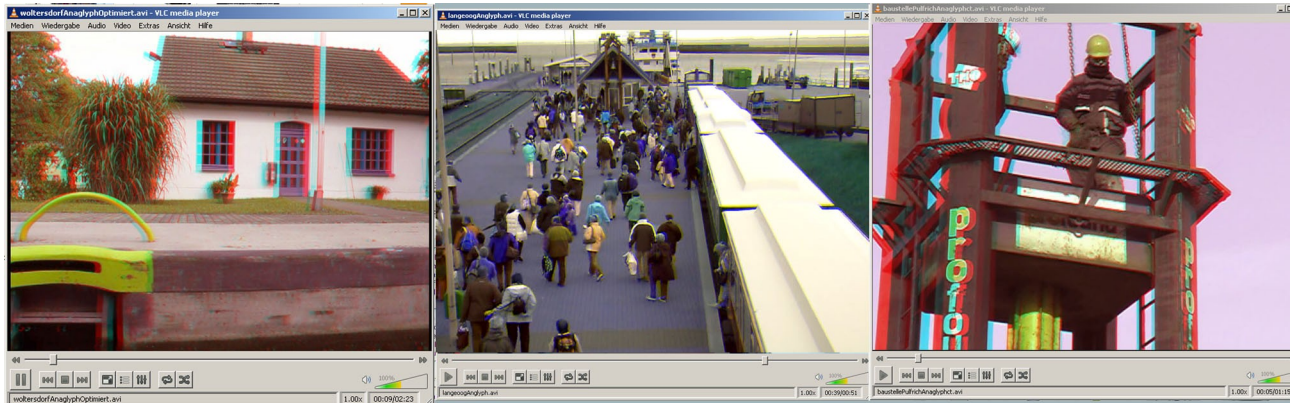

Figure 3: Video clips with different movement conditions converted from 2D to 3D

5.2 AviSynth and Virtual Dub

AviSynth is an open source tool for post-processing videos. It works as a frame server without an own user interface. A script file, extension avs, stores the commands for AviSynth and sends the frames to a video software as it would be by opening a video file. The source for AvisSynth including documentation and utilities is [9].

Very popular software for working with videos under Windows is VirtualDub [18]. It acts as a linear video cutting program and is able to perform different filters and format conversions. VirtualDub works perfect in combination with AviSynth, AVI files and codecs like XviD.

As a demonstration how an AviSynth script file serves VirtualDub, two videos of a left and a right stereo camera should be mounted to an optimized anaglyph video. As described in [2] the color filter for optimized anaglyphs takes red for the left image with a weight of 0.7 from green and 0.3 from blue. The discussion of the script should explain how AviSynth works in the background of a video software. The first character # in a line is a comment . With AVISource the AVI source files will be loaded. MergeRGB merges the colors of the two sources, RGBAdjust scales the values and final is the handle to the frames. The complete script reads as follows:

```
#       Real-time conversion of left and right camera into
#       an optimized red-cyan anaglyph clip
#       Input left and right video
clipL = AVISource("left.avi")
clipR = AVISource("right.avi")
#       Delete red from the left image,keep green with factor 0.7,
#       blue with factor 0.3, RGBAdjust scales the colors
clipL = RGBAdjust(clipL,0, 0.7, 0.3)
#       Produce a new clip and fill with clipL (no more red)
clipLa      = MergeRGB(clipL.ShowGreen, clipL.ShowRed,clipL.ShowRed)
clipLb      = MergeRGB(clipL.ShowBlue, clipL.ShowRed, clipL.ShowRed)
#     Merge the colors with 50% each
clipLc      =  Merge(clipLa,clipLb)
```

```
#       Scale red with 2 because of 50% from a and b
clipLc       = RGBAdjust(clipLc,2.0,0,0)
#       Adjust brightness, contrast,gamma,
clipLc       = Levels(clipLc,0,1.2,255,0,255,coring=false)
#       Delete red from the right image
clipR = RGBAdjust(clipR,0, 1, 1)
#       Merge final clip
final = Merge(clipLc, clipR)
final = RGBAdjust(fertig,2.0,2.0,2.0)
return final
```

The script file is stored under filename.*avs* and selected as the input file for VirtualDub. After installation of AviSynth , VirtualDub must be loaded and from the menu File>Open video file the script has to be called. Conversion runs on-line. The output video can be configured from the VirtualDub menu by frame rate, compression and resolution settings.

Since the reader has now a simple example how AviSynth and VirtualDub work together, a more complex script first introduced in [8] and published in [1] by Janssen and Zota takes advantage from the Pulfrich-Effect The Physicist Carl Pulfrich detected 1922, that dark optical stimuli are realized by the human eye before lighter stimuli. If one observes sideways moving objects with one eye dimmed, a parallax emerges and leads to depth perception. Taking a video with a horizontal panning camera should give 3D perception if the frames will be mounted with a time delay. An AviSynth script would read like this:

```
videoR = DirectShowSource("pan.avi")
videoL = deletFrame(videoR,0)
StackHorizontal(videoL, videoR)
```

DirectShowSource loads the source video via the DirectShow interface, deleteFrame moves the images about one frame and StackHorizontal displays the video side-by-side. Fast vertical movements would generate faults. That can be minimized by calculation of intermediate images. In Detail the procedure is described in [1] as well as the application of the MVTools for Avisynth. Applying the MVTools makes it possible to double the frame rates for compensation of movement. Furthermore multi-threading must be activated for AviSynth. Testing the script from [1] with a video of a dynamic bored pile stress concluded good 3D perception but is not recommended for viewing longer scenes due to sometimes appearing disturbing effects. For viewing the video clips and downloading the here mentioned AviSynth scripts please visit [7].

6. CALCULATING IMAGE PAIRS FROM CAD MODELS

In general a computer graphic is a transformation from 3D world co-ordinates into 2D image co-ordinates. A camera model defines the viewer's position, viewing direction and the field of view. A walk-through or fly-over animation requests a path. Along that path camera positions with unique distances have to be interpolated. Animation time between two path positions and the number of frames per seconds are responsible for the amount of frames. The single images are presented to the viewer like a flip-book. More frames will display a smoother animation. It is obvious that object details and the environment settings, like lights or fog, impact rendering time. The final rendering should be not performed before a series of tests with lowest resolution and frame rate indicates the intended result. Rendered frames are stored as single images or in container files like AVI formats including compression for smaller file size.

6.1 Defining a Camera Path

An animation path is usually defined as a key-frame animation. Only a few key positions have to be fixed by the user, the rest is done by interpolation of camera positions and directions. Applying the popular Sketchup software slightly differs from other concepts. In Sketchup key positions are given as a scene in the user interface. One scene includes all the settings for camera, environment and appearance of the frame. The animation settings require a time value for interpolation between two scenes. Even movement needs equal distances between the scenes. Therefore the user has to subdivide the path into equal distances a and must set a camera to every new vertex. For this task the plug-in SU Animate from Cadalog Inc. [13] is a very helpful tool. In a first step lines and arcs are divided into segments of the same length with the divide

function of SU. Afterwards a curve has to be created from all the segments. The group must be selected and with the command Assign Group named *cameras*. For every segment a camera is generated and displayed in a scene tab. Having now the center line of the camera path, the left and right offset for the stereo camera rig is needed.

6.2 Determining the Base Length of a Stereo Camera Rig

Selecting parallel views instead of slightly convex views avoids problems in stereoscopic viewing. What distance should both cameras have? A distance of 65 mm like the human eyes provides parallax values for near distances between 2 and 5 meter. Extension of the camera distance will extend the parallax value but should not extend the 70 arcminutes or 1/30 of the image format. Let's say that we calculate a frame of 2048 px, the parallax should not extend 62 px or in terms of the 35mm small image format cameras 1.2 mm. The term for calculating the camera base is a function of the parallax, the distance to the near point, the distance to the far point and the focal length

$$b = dev * (near*far)/(far-near) * 1/f$$

Taking values for near = 5 m, far = 100 m, dev =1.2 mm, f = 28 mm calculates a base line of 225 mm. Some good helpers for the base calculation can be found in the Internet e.g. under [16] or [17].
.

6.3 Setting a Stereo Camera Rig

Placing now the cameras with the distance b/2 left and right from the center line of the path is a task for a small Ruby plug-in written by the author of this article [7]. Figure 4 displays the access to the S3DAnimin plug-in from the Plugin menu of Sketchup. For every scene tab a left and a right camera is generated and stored in a new scene tab. Small camera symbols are drawn on a camera layer. Using the scene manger enables including or excluding scenes from the animation. Final animation setting needs definition of time delay between two scenes, frame rate per second, resolution and the video codec.
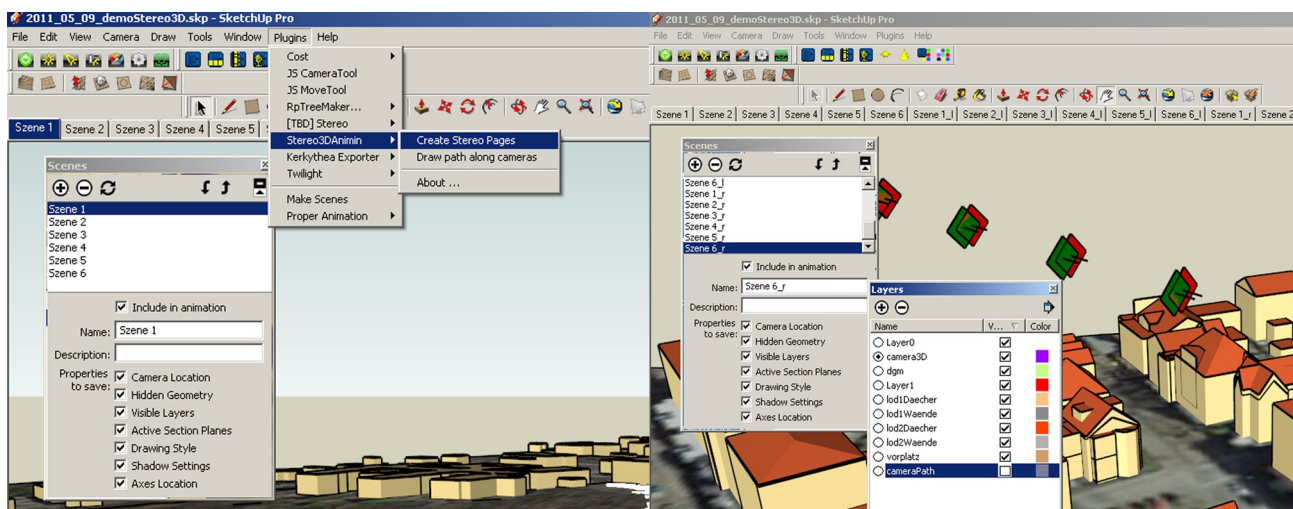

Figure 4: S3DAnimin Ruby plug in for Sketchup. Left menu, right symbols for stereo camera positions

A short inspection to the S3DAnimin plug-in explains the principles of access to a Sketchup design. Sketchup provides access to the entities of a model by a Ruby API. Inspection of the Ruby code shows that scenes in the user interface are pages in the API. Access to the entities and pages container needs the following statements:

```
model      = Sketchup.active_model
entities   = model.entities
pages      = model.pages
size       = pages.size
```

A method pages applied to the active model object is a handle to the pages container; the method size returns the number of active pages. ARuby iterator goes through the pages and positions new left cameras; a second loop generates the right cameras.

```
i=0
pages.each do|p|
  createNewPage(pages,p.name,"_l",-basis/2.to_m,p.camera,camMat)
  i++
end
```

The method createNewPage applies the Ruby geometric transformation methods for positioning the cameras, naming and setting up new scene tabs. Another small helper is a line drawer between cameras. This method is used to connect free selected camera positions for the definition of a path and realizing a smooth movement as mentioned above. The complete code of S3DAnimin can be downloaded from [7].

6.4 Post Processing

Viewing a stereoscopic projection is a perception of a spatial image behind an apparent window. If the left border of the left and right frame and the right border of the left frame and right frame of an image pair correspond and the frames fit together, the stereoscopic window comes with the null parallax on the projection surface. All other objects appear with negative parallax behind that window.

Null plane and projection plane can be decoupled by moving the images against each other. If the boundary of the stereoscopic window lies in front of the null plane, we are talking about a floating stereoscopic window. Objects of the 3D scene may move in front of the projection plane. But those objects should not violate the image boundaries to avoid 3D thickness.

With StereoMovieMaker from [14] the frames can be moved to select the null plane at any position in the spatial object. Left and right video or the mounted video can be saved in an AVÌ file for final cutting. Saving the left and right video in separate files for playback with a stereoscopic viewer is more flexible in handling the animation.
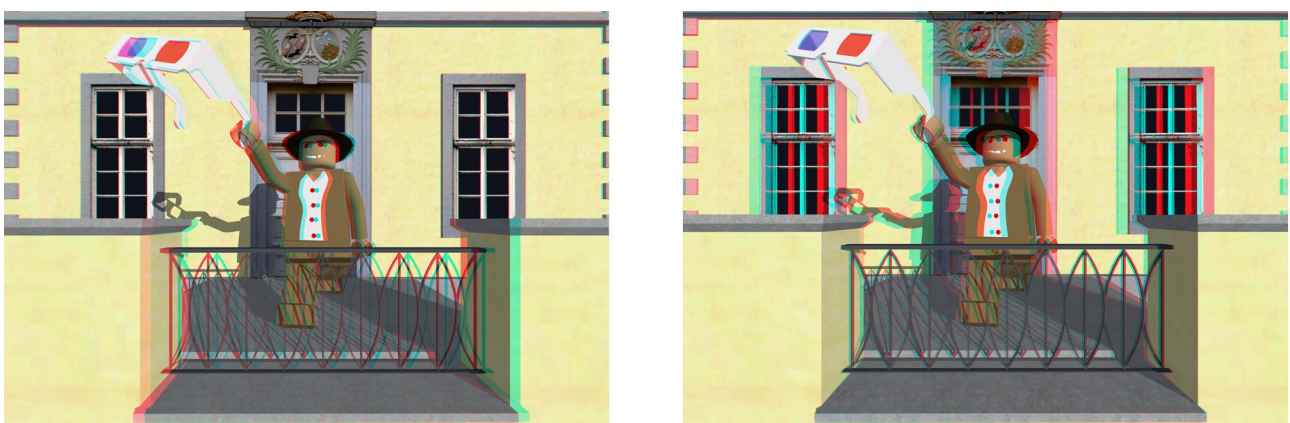

Figure 5: Positive and negative parallax. Left image violation of the apparent window, right image null plane and apparent window fit together

7. CONCLUSION

Stereo 3D is a topic today in all fields of entertainment and science. Mobile phones, gaming, television, desktop PCs, notebooks and cinema - nothing works without 3D. Shutter competes with polarizing; auto stereoscopic is not now available for the mass market. If 4k panels will become standard, polarization will be spread. Shutter technology in full HD is available for PC, TV and projection. The development for 3D technology will proceed. There is a demand for 3D content. This contribution demonstrated the facilities of recording 3D videos, converting existing 2D material to 3D and the calculation of virtual S3D animations.

The pros and cons between S3D presentations with armed eyes or flat presentations should be carefully balanced. In case of missing depth perception as in terrain imagery or immersive walk-throughs, the decision for S3D is easier. To what extend ultra-high (3D) computer graphics will benefit from stereoscopic environments must be answered in every single case.

Access to the moving pictures mentioned in this article and other 3D applications is available via the URL *www.3D.imagefact.de.* This Web blog was established on the occasion of the Prague CIPA Symposium 2011.

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[8] http://3D-vision-blog.com: *Blog with valuable information about 3D*
[9] http://www.avisynth.org: *Video processing software*
[10] http: www.fujifilmreal3d.com: *Fuji Real 3D camera*
[11] http://www.geowall.org: *3D projecti0n in geosciences*
[12] http://www.hytekautomation.com: *Multiple webcam driver*
[13] http://www.ohyeahcad.com/index.php: *Sketchup plug-in SUAnimate*
[14] http://stereo.jpn.org/eng/stvmk: *Stereo Movie Maker*
[15] http://stereo.jpn.org/eng/stvphmkr: *Stereo Photo Maker*
[16] http://www.stereoeye.jp/software/sbcalc_e.html: *Calculating the stereo base line*
[17] http://triaxes.com/products/stereometer: *Calculating the stereo base line*
[18] http://www.virtualdub.org: *Video cutting and conversion software*

8.3 Picture credits
[19] Figure 1, right image: *http://aponaut.org/index.php?/archives /21465-Erweiterte-Realitaet-oder-derWeg-in-die-Bedeutungslosigkeit.html*
[20] Figure 3, right video: *Courtesy of Friedhelm Weber, FH Bielefeld*
[21] Figure 5: *Indiana Jones from the Google 3D warehouse, goldenfrog*
[22] All other images: *Property of the author*