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Autodesk Solutions for Efficient 2D to Stereoscopic 3D Conversion

Converting mono footage into stereoscopic 3D (S3D), or "re-dimensionalization", is generally known to be a labor intensive and time-consuming process. This document discusses common techniques currently used by the industry at large and how Autodesk solutions Autodesk® Flame® Premium, Autodesk® Flare™, and Autodesk® Maya® software provide a more efficient workflow for re-dimensionalizing 2D footage.

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Market Dynamics

While stereoscopic cinema is not a new technology, it has only been in the last few years that it has become more available and demand for it has reached a critical mass for wider adoption. Many movies are now released in S3D at the cinema, and there are large libraries of movies that can be converted to S3D and re-released for new audiences to enjoy. As more content is made available, it's expected that the demand for S3D will increase. Furthermore, stereo-enabled hardware such as televisions and computers are becoming available to consumers, helping to fuel demand.

With this upswing in demand, there remains the challenge of the intensive labor requirements involved in re-dimensionalizing 2D footage. Even though the technology exists to shoot directly in stereo, this can be cost prohibitive or in some cases undesirable. Having the added option of converting 2D to S3D is a benefit to a production toolset. In the case of older 2D footage, re-shooting in 3D is obviously impossible. There needs to be a cost effective way of converting footage to S3D.

Autodesk Digital Entertainment Creation Solutions

Autodesk provides digital entertainment creation solutions for film, games and television. This white paper explores how the following Autodesk applications are used in re-dimensionalization:

- Autodesk® Flame® Premium software. 3D visual effects compositing software combined with color grading and an integrated timeline workflow.
- Autodesk® Flare™ software. 3D visual effects compositing software based on Flame for expanding a team of visual effects artists.
- Autodesk® Maya® software. 3D modeling, animation, effects, and rendering software.

It's pertinent to note that Flare is based on Flame. They both share the same tools: such as Batch and the Action 3D compositing environment, and project, setup and media files are compatible with each other. Flare is intended to be a software-only solution that is used by Flame Premium customers to expand their teams. A re-dimensionalization workflow might have several Flare seats for artists to tackle 3D visual effects work, and a Flame Premium seat for aggregating the shots on a timeline and color grading.

Stereoscopy Background

The basic concept of stereoscopy is to create the illusion of depth by displaying two offset images, representing the left and right eyes. The slight differences between the left and right eyes (called 'binocular disparity') causes the brain to merge the two with a perception of depth.

In the case of 2D to 3D conversion, we only have images representing a single eye and the challenge is in creating one or both of the offset eyes. There are two general approaches to this, with varying pros and cons for each. Depending on the needs of a given shot, the artist may find one method more beneficial than the other. The two approaches are:

1. Use the original footage as one eye and create one offset eye.

Pros: Only create one eye

Cons: The offset eye is at the full divergence width, which may require more clean up on the resulting parallax effect

2. Create two new offsets representing the left and right eyes.

Pros: Only half the amount of divergence

Cons: Two new eyes required

Flame Premium is able to work with both workflows in a flexible manner, enabling the artist to mix and match the techniques according to what is best for the shot.

General Workflows for Re-Dimensionalization

The process of converting 2D footage to 3D can be approached in a number of ways:

1. **2D displacements and distortions of footage.** In this method, the user produces depth maps that displace an otherwise flat image in 3D space. Once a stereo camera rig is in place and the artist applies the appropriate depth maps, the software can be used to generate the illusion of depth. Because this involves a certain amount of guesswork on the part of the artist, the resulting stereo effect may not accurately represent the real-life dimensions of the scene. Despite this, the method is a quick and effective way of converting simple 2D shots to 3D as artists can hand paint depth information. On simple scenes such as a building skyline, artists can use luminance information to generate a depth map and distort the footage appropriately.
2. **Cards in 3D space.** This method is more involved than 2D displacements and distortions of footage. The artist roscopes the footage and isolates objects into cards. Each card can be positioned closer/further from the camera. The main advantages of this method are that artists are utilizing real 3D space, the stereo camera field of view can be set and artists can position each card according to real-life dimensions to obtain a more accurate representation of the scene. One

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of the challenges with this approach is that there might be areas that need to be filled in when converted to stereo due to parallax effects.

3. **Match-moved geometry with texture projections.** The basis of this method involves re-creating the 3D scene with basic geometry that matches the set and objects in the scene. Footage is projected onto the geometry, which provides more accurate depth information to create the stereoscopic effect. While this method creates more accurate stereoscopic results, it is more labor intensive and requires a 3D artist to create the sets. With characters, 3D representations of the character have to be created and match-moved to the footage.

The above three approaches to stereo conversion are viable and have various pros and cons. Using Flame Premium, artists can use all these approaches and mix them where appropriate.

Examples

The following examples are also available as a video presentation here:

<http://www.youtube.com/watch?v=eXSXJCtB29c>.

2D Displacements and Footage Distortion

In this simple example, footage of a city skyline, an artist can use Flame Premium or Flare to create the stereo effect relatively easily by generating a displacement map based on the luminance of the pixels, distorting the footage and using a stereo camera. By using displacement maps, creating the illusion of depth becomes relatively trivial as the artist can use paint and image processing tools (i.e. a histogram) to vary the relative depths for each pixel. In a few minutes, the artist is able to create a convincing stereoscopic effect on the footage.



Figure 1. Using displacement maps, the artist can distort the footage in 3D to create the illusion of depth. In this example, the artist derives a basic 2D displacement map from the luminance of the pixels, then uses paint tools to refine and achieve the desired depth effects.

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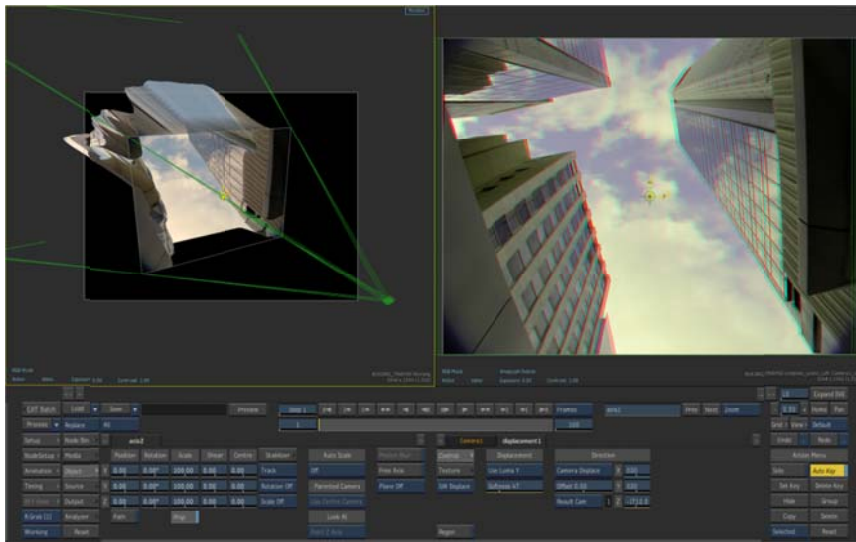


Figure 2. Here, the footage is actually distorted in 3D. Once a stereo camera is added to the scene, the artist can use Flame to generate the appropriate left and right eye offsets. In total, creating a convincing stereo effect for such a shot only takes a few minutes.

Cards in 3D Space

In this example, the artist has a relatively complex shot with a close-up of a character. The character's hand and head moves slightly as it nurses the pigeon, thus the artist needs to somehow isolate these elements and create the depth illusion.

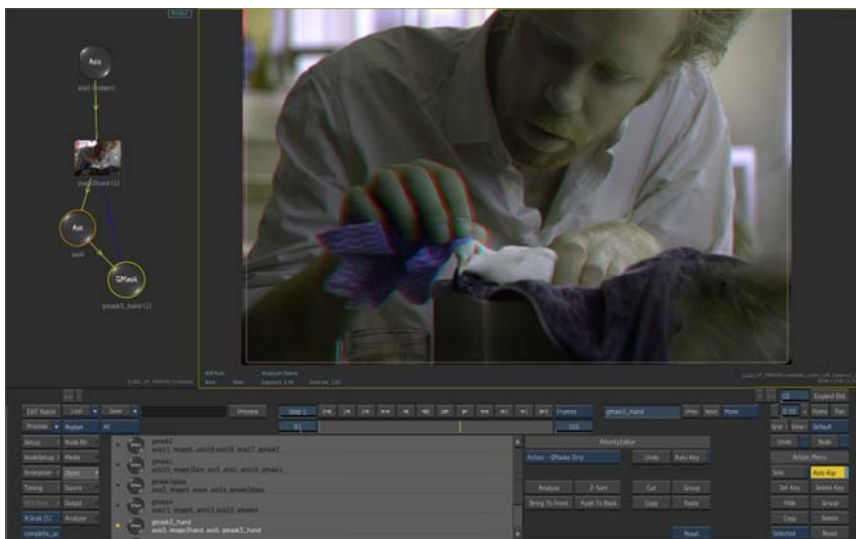


Figure 3. In this example, the artist wants to generate a stereo effect on a close up of a character. Multiple elements are moving: the character's hands and head.

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Rotoscoping tools in Flame and Flare are generally faster and artist-driven using the GMask tool. Once an outline of the character's hand is created, the artist can apply the Shape Tracker tool that analyses its movement across multiple frames. The Shape Tracker attempts to vary the mask across the frames and captures the movement in the scene. With a bit of refinement, the artist is able to achieve a good rotoscope result.

Once the artist has rotoscoped an element, the artist can isolate it into its own layer or 'card', then add a stereo camera to the scene. By moving the cards forward and backwards, the artist can generate the illusion of depth. One of the advantages of moving elements in 3D space in Flame is the auto-scaling feature. As cards are moved forward and backwards, the software automatically scales the cards so that they appear at the correct size to the viewer.

The artist can mix and match approaches to generating the stereo effect. For example, the artist can utilize a 2D displacement map for the character's face and using tracking tools, match the movement of the displacement map to the face across multiple frames.

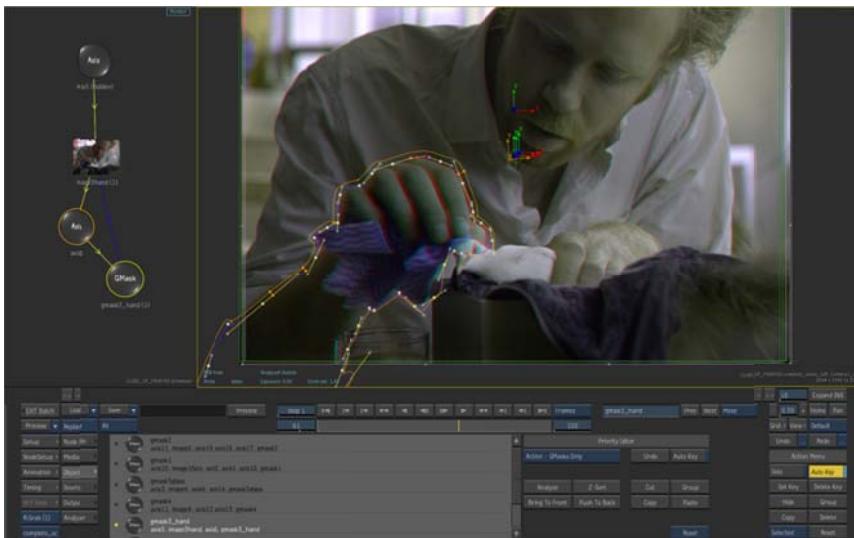


Figure 4. Using Autodesk Flame or Flare, artists are able to create masks of elements relatively quickly. If the element is moving, the artist can utilize built-in tracking tools to match the movement of the element. Furthermore, changes to the outline can be tracked using the Shape Tracker tool.

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Figure 5. The artist can mix and match approaches to stereo generation. In the case of the character's face, the artist can use a simple 2D displacement map and track the map to the movement of the face.

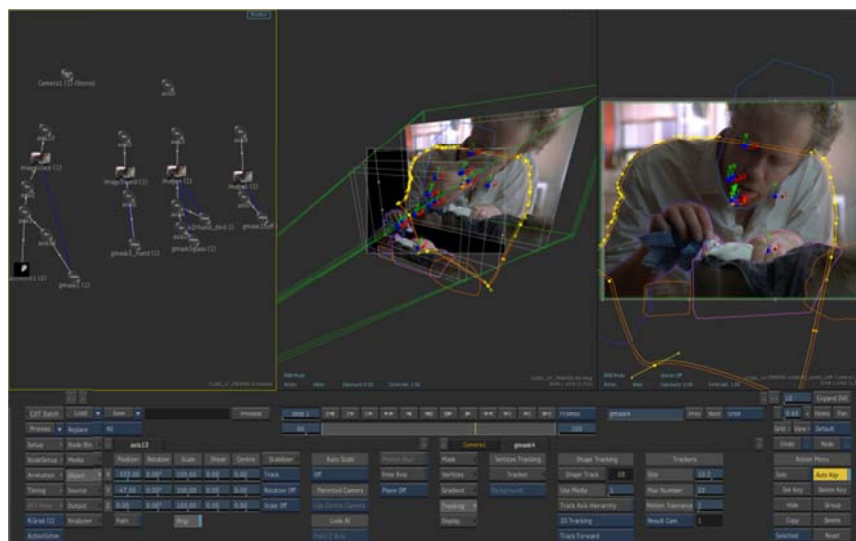


Figure 6. Here, we see the scene construction in 3D space. Using a variety of techniques, the artist is able to generate a stereo effect on this shot in just a few minutes.

Match-Moved Geometry

In this final example, we examine a shot that benefits from having matching 3D geometry. In a back alley, a character walks up to the camera, bends down and examines a pigeon. As the character moves closer to the camera, the relative depth of the character changes. To achieve a convincing stereo effect for the character, the artist actually creates the character geometry and animation in Maya, then imports it for use in Flame or Flare.

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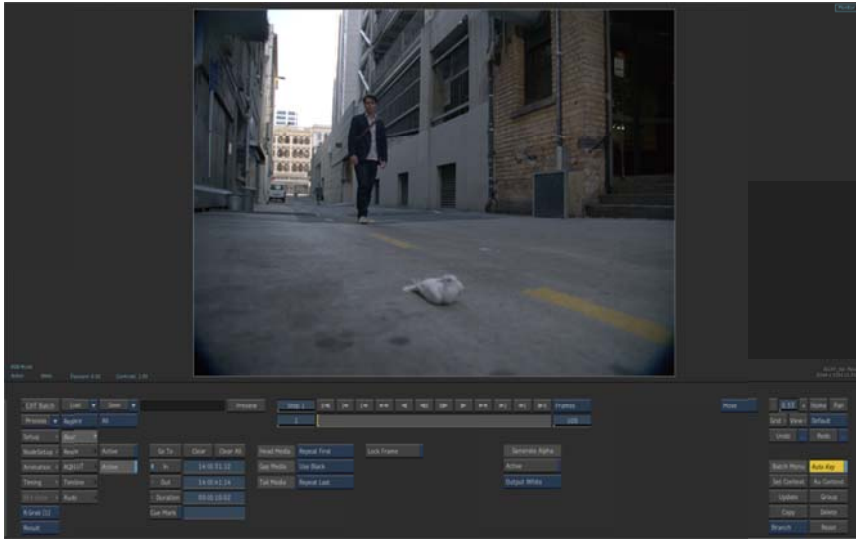


Figure 7. In this example, a character walks up to the camera, bends over and looks at the pigeon. To create a convincing stereo effect, the artist must generate the 3D geometry and match it to the scene.

To create the character in Maya, the artist can use a basic character rig and mesh. Using the HumanIK[®] Characterization Tool in Maya 2012, the artist can quickly rig a bio-mechanically correct bipedal character. A 3D animator can now animate the character and match it to the footage in Maya.

In terms of workflow, a key to efficiency is to be able to share data between the compositing application and 3D application with relative ease. Thanks to the Autodesk[®] FBX[®] data interchange format, the artist is able share data back and forth between Maya and Flame Premium/Flare easily. For example, once the artist has tracked the camera movements, the artist can export them to Maya to assist the animator in match-moving the character. Once the animator has animated the character, the resulting data can be brought back into the compositing environment easily with no manual data conversion required.

The artist can re-create the environment in 3D using planes, and project the footage onto the 3D geometry. Once again, by using the stereo camera rig in Flame/Flare, the artist is able to create the left and right eye offsets relatively easily.

Using the above-described method, the artist is able to generate a high quality stereo illusion. Although it is more labor intensive from the standpoint of requiring additional staff (for example, a 3D artist), the combination of Flame Premium/Flare and Maya removes a common complicating factor that is data interchange. Using the FBX data interchange format, the artist can tightly integrate the workflow between the compositing and 3D applications.

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We should, at this point, visit a crucial benefit in using Flame Premium (and hence Flare) technology in that it approaches compositing from a true 3D perspective. Action, its 3D compositing environment, uses the GPU and real-time shading technology to achieve high quality 3D composites in real-time. Artists are able to apply complex effects such as (re)lighting and camera projections on 3D geometry, with results rendered in real-time. Contrast this to certain other compositing applications that are primarily 2D image processors (with varying degrees of 3D integrated) and may require pre-rendering before viewing. Flame Premium and Flare represent a workflow advantage.

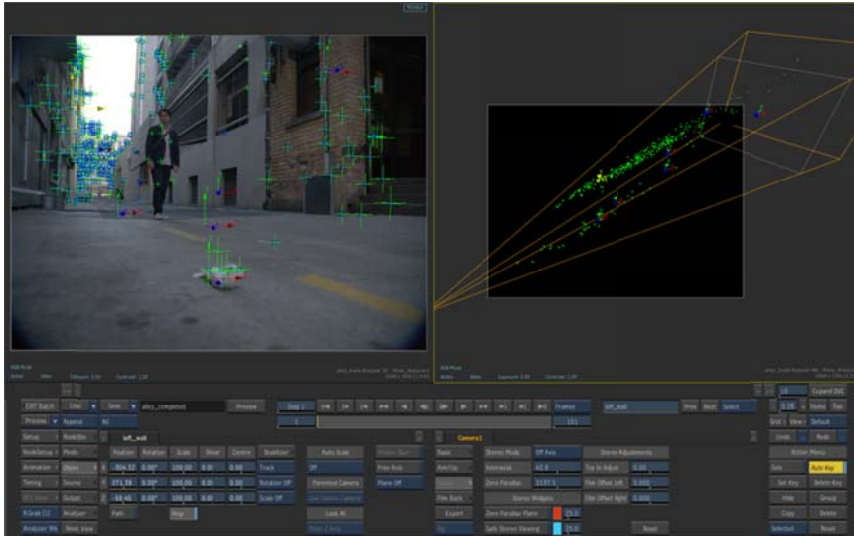


Figure 7. In this example, a character walks up to the camera, bends over and looks at the pigeon. To create a convincing stereo effect, the artist must generate the 3D geometry and match it to the scene.

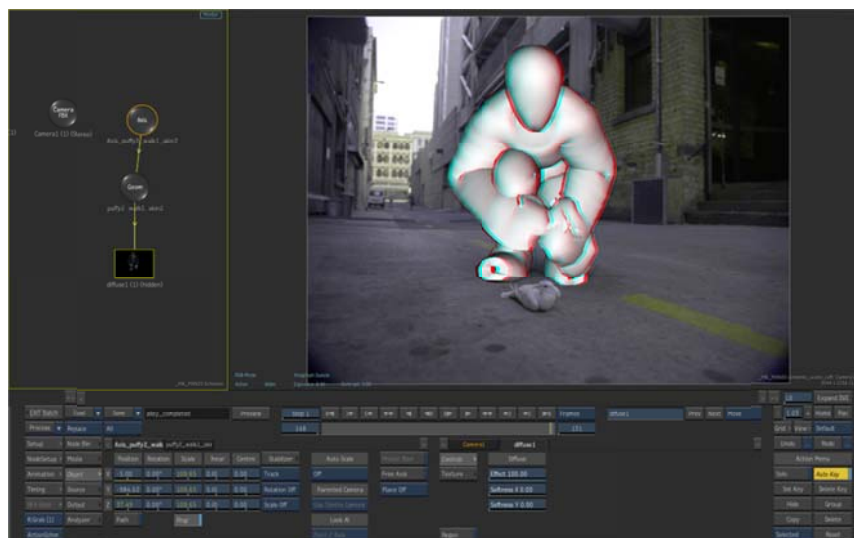


Figure 8. Using Autodesk Maya 2012 software features the artist can quickly create a basic 3D character mesh. Using the integrated HumanIK characterization tool, the artist can rig the character to have bio-mechanically correct movements. This enables an animator to match the movements of the 3D character to the footage with relative ease. Transferring data between Maya and Flame/Flare is straightforward with the FBX format.

How Flame Premium and Flare Address Common Stereo Conversion Issues

Stereo conversion is known to be generally labor intensive and non-trivial. This paper describes how some common stereo conversion issues are handled efficiently with Flame and Flare.

Simulating Eyes

At the most basic level, the artist has to simulate how human eyes work in a way that is conducive for artists to use in a compositing environment. Although one could write the scripts and presets for a stereo camera rig, in Flame 2012, a stereo camera rig is ready to use. The "FBX Camera" in Flame is a pre-rigged camera with many settings commonly required for high quality stereo work; for example, toe-in and inter-axial separation.



This stereo camera rig comes with some workflow enhancements:

1. The zero parallax plane and safe stereo views can be viewed and adjusted as semi-opaque overlays in the scene.
2. Changing the zero parallax position automatically re-converges the eyes with no scripts needed.
3. As layers are moved forwards or backwards from the camera, the rig auto-scales the layer so that it retains its perceived size.

Viewing Stereo

Another basic requirement is the need to view the stereo. Some applications require a separate viewer to see the stereo effect. Flame Premium, Flare, and Maya enable artists to use Dubois Anaglyph stereo on the primary UI monitor viewport, which doesn't require any special stereo monitor. This is a cost effective way to enable a stereo workflow for most artists in a studio. For aggregating content and monitoring the entire production, Flame Premium can output a full screen preview of the video image via HD-SDI, which can be viewed on a stereo monitor. Flare 2012 extension 1 can also show a full screen stereo preview on a second DVI monitor.

Cutouts and Rotoscoping

Possibly one of the most labor-intensive tasks of the stereo process is isolating individual elements in each frame. As described in the above examples, the masking and tracking tools in Flame Premium and Flare are well suited to isolating elements across multiple frames efficiently. Furthermore, with the Shape Tracker, the artist is able to more quickly generate usable masks across multiple frames, helping reduce the time spent doing rotoscoping.

There is also a workflow efficiency advantage in having these masking, tracking and rotoscoping tools integrated into both Flame and Flare. In other workflows, users may have to use multiple software packages to achieve a similar effect.

Using certain external packages can cause another issues in data interchange. For example, generating hard mattes with another software package can create another data set that needs to be managed. Multiply this over the course of all the production's shots and elements, and there's a logistical issue in managing large amounts of assets.

Mixing 2D and 3D Footage

Flame features a real-time 3D environment (Action) which enables artists to approach compositing from a true 3D perspective. Using real-time shading technology running on modern GPU's, the artist can use Flame to achieve high quality 3D composites in real-time. A flexible feature of Action is the ability to combine Stereoscopic 3D and mono footage. In a typical production, elements may come from a variety of sources that may or may not be in stereo. Flame is able to mix and match these elements, which enables artists to work with them in the Flame software's real-time Action environment.

Parallax Effects

A common issue with generating offsets for the left or right eyes is that they fundamentally look at objects from different viewpoints. In some cases, this means that there is missing image information as the second eye sees 'around' objects. Fixing this requires a certain amount of manual labor in painting in the missing information. With Flame, however, the artist can use the Pixel Spread tool in "contract" mode, to automatically generate the missing information. For up to about a

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30 pixel spread for HD and 2K work, the artist can generate adequate imagery without experiencing major distortion across multiple frames.

Characters and 3D Geometry

Characters and 3D objects (environments and objects) present a challenge because the shot requires collaboration with 3D artists. In addition to having to communicate between multiple artists, there is a workflow challenge in sharing data between the 3D application and the compositing application.

There are several advantages in using a Flame Premium/Flare and Maya workflow:

1. Tighter integration between the applications using FBX.
 - a. The same FBX Camera can be used in Flame, Flare and Maya packages
 - b. Camera tracking can be done in Flame or Flare, then exported to Maya for the animator to match-move a character
 - c. The resulting match-moved character can be exported into FBX and imported into Flame or Flare
2. Efficient character modeling, rigging and animation
 - a. Simple pre-made character geometry and rig available for use
 - b. HumanIK characterization tool can be used to create a bio-mechanically correct rig so that animators can more easily match-move the character
3. FBX stores a geometry cache for each frame in a single FBX file. Certain other solutions have either generated a geometry cache for each frame as separate files, or rendered a hard matte for each frame. Such approaches can present logistical challenges with passing data back and forth and present logistical issues.

Workflow and Data Interchange

A common challenge faced by productions is in getting data between people and between different software packages. For example, depending on the needs, artists on a production may end up using different software packages for 3D animation, tracking, rotoscoping, and compositing. Some challenges include:

1. Exporting and reading data. Can artists use the different packages to read the same formats? If not, are there development resources available to create the necessary importers/exporters?
2. Storing and managing data. At a basic level, artists can move data represented as images, or raw geometry. This can create a logistical issue as artists end up with a lot of data (per frame, per layer, different versions) that needs to be managed.

Autodesk Flame, Flare and Maya can read and write the FBX format. Therefore, passing 3D geometry data between the 3D and compositing applications can be achieved more easily without needing to render out hard mattes/image files. Furthermore, many tasks like tracking and rotoscoping can be achieved within Flame

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or Flare, enabling artists to focus on the shot without switching applications and fussing over data interchange.

Stereo Finishing

In a typical stereo conversion pipeline, most of the individual shots are processed by artists using individual compositing seats. The data then has to be aggregated, sequenced and finished. This can create a workflow issue if there are multiple, different finishing tools.

Autodesk Flame Premium is a proposition in helping solve this, as individual shots can be processed and converted to stereo by artists using Flare. The project can then be aggregated using Flame Premium, where shots are sequenced on a timeline and it can be depth and color-graded in real-time. Flare projects can be read by Flame Premium and vice versa. For example, if a change needs to be made when all the shots are aggregated, the Flame Premium workstation can open a Flare project and the changes can be made on the spot. This enables key decision makers to direct changes in a creative, interactive manner with immediate results.

Case Study: Nice Shoes Television Commercial Stereo Conversion

New York based studio Nice Shoes was tasked to convert a Friskies commercial "Adventureland" to S3D for release in cinemas. The conversion jobs were done in two phases. For the first phase in 2010, Nice Shoes wrote their own stereo camera rig with two parallel cameras (non-converging). When they approached the second phase in 2011, with a new version of Flame, they decided to try the built-in stereo camera rig and were pleasantly surprised to find that it did what they needed and more.

"We really wanted to try out the stereo features. They really worked better than what we had access to in the previous version of the software," says Russ Bigsby, VFX artist at Nice Shoes. "The benefit of the software is a converged camera setup. It would just line up the images. We were using parallel cameras before and this is much easier. The auto-scaling feature was really useful. Before, you had to do it with an expression. Now it's built in."

Summary

This white paper has presented how Autodesk digital entertainment creation tools Autodesk Flame Premium, Autodesk Flare and Autodesk Maya can be combined to provide an efficient solution for re-dimensionalizing 2D footage to 3D.

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In summary:

1. Flame Premium and Flare offer artists flexible approaches to stereo and can use a variety of techniques: image distortion, 3D cards and projection onto 3D geometry.
2. Using a true, 3D environment (Action), well suited to helping artists generate convincing stereo effects.
3. GPU acceleration and OpenGL shader-based effects enables real-time viewing by the artist in viewport, without having to pre-render.
4. Pre-made, feature-rich and ready-to-use stereo camera rig (FBX Camera) can be more quickly added by the artist to shots without scripting.
5. Stereo display in the viewport using Dubois Anaglyph. Artists can use Flame Premium seats to drive a separate, dedicated stereo monitor.
6. Using 2D displacements and distortion techniques, artists can convert simple scenes to stereo in a matter of minutes.
7. Rotoscoping tasks are accelerated by artists using the GMask and Automatic Shape Tracker tools.
8. Parallax issues can be resolved by artists in an automated fashion by using Pixel Spread.
9. Artists can share camera data (stereo information and animation) between Maya, Flame Premium and Flare using FBX.
10. 3D geometry and animation from Maya can be imported by artists using FBX. No need for artists to render out hard mattes or transfer large geometry caches per frame.
11. Characters can be more quickly created, rigged and animated by artists using Maya. The resulting data can be exported as an FBX file, which can be read with Flame Premium and Flare.
12. Shots can be aggregated, edited, color and depth graded by an artist using a Flame Premium seat.

For more information on Autodesk Flame Premium and Flare, visit www.autodesk.com/flamepremium and www.autodesk.com/flare. For more information on Autodesk Maya, visit www.autodesk.com/maya.

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