Innovations Project

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FIRE

Abstract

This report follows the steps and techniques used to develop and create two very different types of fire; the first being a smooth calm flame and the second being a gas fuelled turbulent flame. Both final products are to be implemented in to my major project animation, so there is a strong focus on visuals in the analysis.

Introduction

When a fuel present with an oxidant undergoes combustion, it produces heat and light in the form of either a glow or flames. There are various types of combustion, the most commonly known ones are fire and explosions. This report looks at a few different methods of re-creating two types of combustion in 3D and creating the lighting to add to the effect. The fire effects I will be producing are to be integrated into my major project and therefore along with exploring different means of creating the effects, I also need to keep in mind any techniques for how the effects could be incorporated into the scene. As the intention of this project is to create 3D effects for my major project, it will be very visually driven looking at the aesthetics of the fire rather than the physics behind it.

The two different types of combustion I will be creating in 3D are smooth flames and turbulent flames. By using the term 'smooth flames', I refer to the calmer and more hypnotic type of fire as seen in the image below.

The second type will be a fast paced, gas fuelled turbulent flame. This will give an almost explosive effect, but more controlled in its speed and direction. An example of this can be seen in the following image:

Research and Reference

Use of Calm Fire in 3D Animated Films

I have decided to look at the use of fire in 3D animated films as opposed to its use in live action films. This is because fire in real life is very hard to control whereas, in 3D, everything including the colour, size and intensity can be controlled easily. As a result, the director is able to create any type and style of fire that is suitable for the particular shot. This will therefore make it easier to study the fire without the presence of non-intentional effects such as wind and will also give a better indication as to the style of fire suitable for my major project.

"*Madagascar*" [1]

"*The Incredibles*" [2]

Although the fire in the screenshots of both films above are fuelled by wood, the effect is still very different from each other. In *The Incredibles*, the fire is a lot more compact and collected than it is in *Madagascar* which may be to do with the angle in which the wood is being held. In *Madagascar*, the wood is broad and being held horizontally giving the flames a bigger surface area to burn, spreading them out. However, in *The Incredibles*, the wood is being held vertically as it is being used as a fire torch. As flames always travel in an upward direction, they merge together creating a more solid looking flame.

Another possible reason could simply be for aesthetic purposes. The giraffe character shown in the *Madagascar* screenshots was previously seen trying to make fire by rubbing the two pieces of wood together and after finally succeeding, he begins to wave the wood around. The choice to have messier and less controlled fire in this shot gives the impression that the character has no experience of making fire and also presents it with a more dangerous look as he later realises that the burning wood is strapped to his legs. *The Incredibles* on the other hand, uses a lot calmer fire so it doesn't distract the eye so much. This is because the fire in this shot isn't as important to be seen or as integral to the story as it is in *Madagascar*.

Use of Turbulent Fire

I'm choosing to observe turbulent fire from both real life references such as photos and videos as well as from 3D games. My reasons are because gas and liquid fuelled fire jets can be controlled a great deal more easily than the type of fire as shown previously, in addition to there being a lack of relevant sources in 3D films.

A great example of the style of turbulent flame I am aiming to produce is not unlike that of a hot air balloon. "The burner unit gasifies liquid propane, mixes it with air, ignites the mixture, and directs the flame and exhaust into the mouth of the envelope." http://en.wikipedia.org/wiki/Hot_air_balloon [3]. This ejects a high speed and thin flame which can be seen in the images below.

I chose to use this style of fire primarily because of the speed it can turn on and off which is integral to my particularly short animation. I also really like the appearance of the flames and think that the almost cartoony look of the fire jet would fit in well with the style of my animation.

Although the three images all appear to be similar, they do have distinct differences in terms of colour and texture. This could easily have been the result of different camera settings when the photos were taken or any colour correction carried out afterwards. However, all three do seem to have a noticeable outline a shade darker than the rest of the flames which I think is a very important characteristic to be included in my 3D fire.

[video – hab1.flv] *[video – hab2.flv]*

To observe the movement of the flames, I watched each video through frame by frame. The most obvious similarity between the two videos was how the flame moved whilst it was at full velocity. Both videos showed a random pattern of the fire's shape which changed in every frame whilst still remaining at roughly the same size. The difference in the videos that I noticed was the way in which the flame subsided when the fuel supply was turned off. In the first video, the flame gets shorter and then disappears, while in the second video, it fades away instantly. A simple reason for this difference could be that in the first video, the fuel supply is slowly deceased before it is turned off whereas in the other video, it is turned off immediately leaving the flames to burn only the gas that is still remaining in the air.

Rarely does a video game not include fire or explosions, and *Team Fortress 2*, a first-person shooter game by Valve, is no exception. The screenshot above shows three jets of fire from a flamethrower of the character, Pyro. These flames, appearing also to be fuelled by gas, bear a fair resemblance to the flames of a hot air balloon. They have the noticeable darker outline and a reasonably similar shape remembering that the flames are being directed horizontally rather than vertically. These flames would also be a good point of reference to work from when creating my own fire as the stylised design of the game would fit in well with my animation.

Smooth Flames

For the first type of fire I will be creating, I will look into both fluid systems and compositing to achieve my desired look. My reasons for not using particle systems is because particles seem to be more appropriate for larger fires such as a campfire or explosive fires, and the recognisable lines in the flame can be more easily achieved using fluids. I also chose not to use shaders as it would require to model out and animate the shape of the flames which would be extremely difficult and time consuming.

This type of fire will appear in the first scene and is burning from torches attached to each pillar. It will be burning from a bowl shaped holder which will allow for broader flames and will also serve as a cover to avoid problems with the base of the fire. The following video is the first scene taken from my block test where, although the character animation is rough, the camera movements are as good as final.

[video – blocktes01t.flv]

After experimenting with and getting familiar with Maya's fluid system, I discovered some fluid presets available of various different types of fire. After importing TurbulentFlame.ma into a new scene, I rendered 100 frames to see how it looked.

[video – flamePreset.flv]

Already, the flames look very close to how I would like them, especially the movement and colour of the fire. However, fluid systems can be computationally expensive to render, especially as I will be including multiple fires in the scene. Also, the subtle differences I would make to these flames could be altered in compositing, or could even be more quickly and easily changed if the fluid flame render was used as an animated texture. This would help eliminate need for extra compositing work by carrying out any image editing early in the project allowing the new fire texture to be rendered along with the rest of the environment.

To start off with the basics, I simply applied the flame animation to a polygon plane and positioned these where the fire would be situated around the scene. Although I could safely assume that this method wouldn't work, I still found it useful as a good starting point to observe the bad points from the playblast and then set about fixing them.

[video – singleplane.flv]

The planes, as expected, are very noticeable as the camera rotates around the scene. As the camera moves quite a large distance, it would also rule out the possibility of rotating the planes so that they roughly face the camera. However, a way to ensure that the planes constantly face the camera throughout the whole camera move can be achieved by using sprites. "More often *sprite* now refers to a partially transparent two dimensional animation that is mapped onto a special plane in a 3D scene. Unlike a texture map, the sprite plane is always perpendicular to the axis emanating from the camera. The image can be scaled to simulate perspective, rotated two dimensionally, overlapped with other objects, and be occluded, but it can only be viewed from the same angle. This rendering method is also referred to as billboarding."
http://en.wikipedia.org/wiki/Sprite_(computer_graphics) [4]

[video – sprite.flv]

Using sprites to display the flame texture definitely looks better than using a single plane, however it's still missing something, aside from the lack of light and colour from the playblast. I think that the main reason why the sprites look worse than the fluids is because the sprites don't look solid enough and I feel that it is obvious that the animation is just a 2D texture. One way to overcome this problem would be to use a technique that is commonly used to model trees in computer games. By going back to the scene with the single planes, they can be duplicated and rotated by 90° in the y-axis so that there are now two identical planes that cross over each other. As there are now two layers of this texture, the flames are significantly brightened up and at the same time this method also solves the problem of looking through a rotating camera. The following video shows the double plane method in the scene.

[video - doubleplane.flv]

Screenshots showing the use of sprites and double planes where the increased brightness is remarkably clear. Both scenes were playblasted in identical scenes with Mayas default lighting.

There is a small problem with using two planes which occurs when they are viewed at a certain angle giving the flames a symmetrical look as the two planes have identical textures applied to them. This can easily be avoided by simply rotating the planes round so that they cannot be seen at the 'wrong' angle.

Turbulent Flames

For the second style of fire I have decided to experiment with particle systems to gain my chosen effect. "Particle systems were first used in computer graphics by Reeves (1983) to model a wall of fire for the movie *Star Trek II: The Wrath of Khan*. Since particle systems are a volumetric modeling technique, they are most commonly used to represent volumetric natural phenomena such as fire, water, clouds, snow, and rain (Reeves 1983)" Texturing & Modeling by David S. Ebert, F. Kenton Musgrave, Darwyn Peachey, Ken Perlin, Steven Worley [5].

These flames will appear later on in my major project animation in a more fast-paced shot than the smooth flames. The shot itself is very short being only 40 frames long, so therefore it is important that the flames can get to full speed quick enough. The flames in the block test for the moment have been substituted with a flame-shaped plane which rises from the bottom.

[video – blocktest2.flv]

Although the substitute flame is rising from the pit that the character is swinging over, it is more likely in the final render to be originating from the side walls as this then leaves the pit to remain dark and mysterious throughout the duration of the shot.

The first step I took to create the fire was to decide the shape and path that the particles would travel. If the fuel is being ejected horizontally at a high velocity, the particles would shoot forward and then begin to gradually curve upwards. To achieve this effect, I created a CV curve mimicking this shape and assigned a 'Curve Flow' to it. This creates an emitter at the first control point and releases particles along the shape of the curve. It also creates multiple control circles along the curve which allows the user to control the spread of the particles. After altering some attributes of the curve flow, I then changed the 'Particle Render Type' from 'Particles' to 'Cloud' and to it, assigned Maya's fire shader found on the default particle fire available.

[video – turb01.flv]

The flame already shows a few of the characteristics of the hot air balloon flames as examined previously, such as the rough edges and a clearly darker outline. The biggest flaw with this animation is the speed which is nowhere near as fast as it needs to be to fit into the shot. Taking this into account, I then proceeded to change some attributes in the particle settings.

[video – turb02.flv]

Although still not as fast as desired, the flames are still faster than in the previous video, however the edges appear a lot more random and there is a lot of unwanted noise in the texture of the flame and around the edges. So to achieve the ideal flame, I need to take the better points from each video and attempt to create another flame incorporating these aspects.

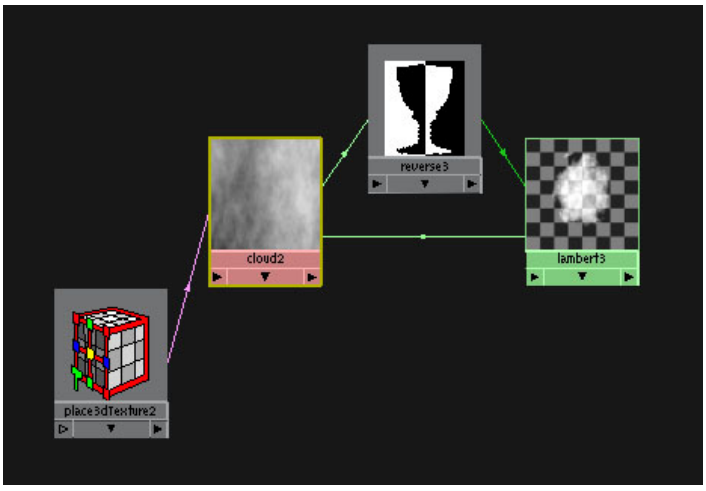
[video – turb03.flv] *[video – turb04.flv]*

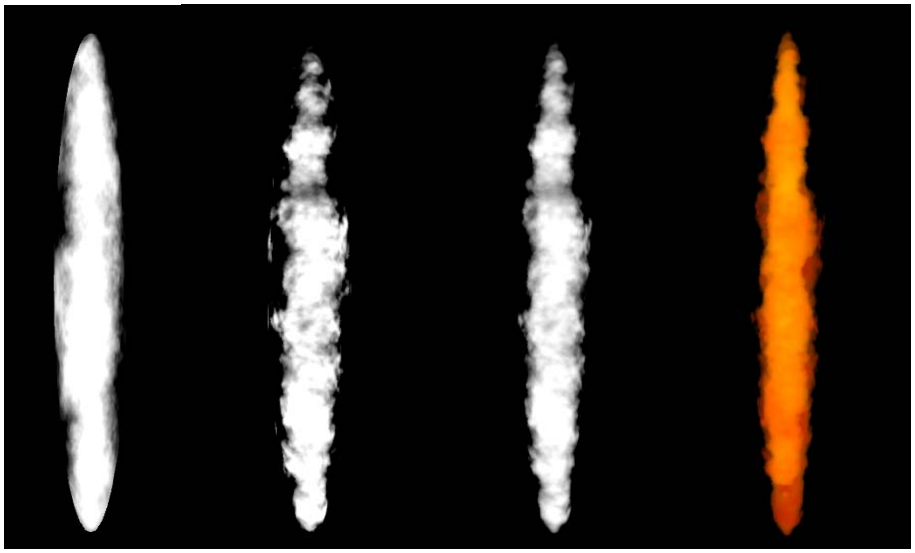
In this version, the lifespan of the particles was reduced to a very low number as the speed is dependant on this when using curve flows. The second video- the shortened version- shows that the increase in speed would be adequate enough for a short burst of

fire in my animation. However, shortening a particle's life span means that the fire will become a lot thinner as the particles die sooner. To counter this, I increased the 'emission rate' attribute up to a number a lot higher than before to thicken the fire out again and give it a more solid colour. However, I think that there is still a lot missing from this flame when comparing it to the original hot air balloon images and footage. The key feature that I feel is missing from these fire renders are the edges of the flame themselves. Looking again at the hot air balloon images, the edges of the flames don't stray too much and therefore the fire has a more solid shape. This would be very hard to control using particle systems and therefore requires investigation into another suitable method.

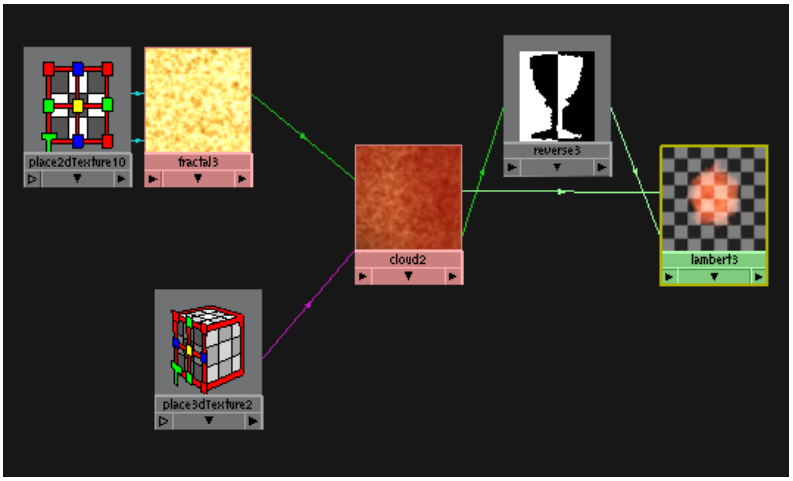
After browsing the internet for inspiration, I decided to explore the use of shaders and materials. I think that using shaders could be a strong possibility as modelling and animating the shape of the flame will be fairly simple. I soon found a shader available for download designed for use with fire and after opening the scene in Maya, I roughly studied how it was formed and went about creating my own version as the downloaded shader wasn't quite what I required.

To begin with, I stretched out a polygon sphere in the y-axis to roughly resemble a flame so I could test the shader during the process. As the shape of the flame was the biggest problem with using particle systems, I decided to first concentrate on getting it right with the shader. After creating a new lambert material, I also created a 3D cloud texture. This will help not only with the texture of the flame, but as it is a 3-dimensional texture, it can allow the user to edit the appearance of just the centre of the object by connecting the 'out color' of the cloud to the 'incandescence' of the lambert material. Therefore, to create the uneven flame edges, the same 'out color' of the cloud can be inverted and again put into the lambert material, but this time it is plugged into the 'transparacy' input.

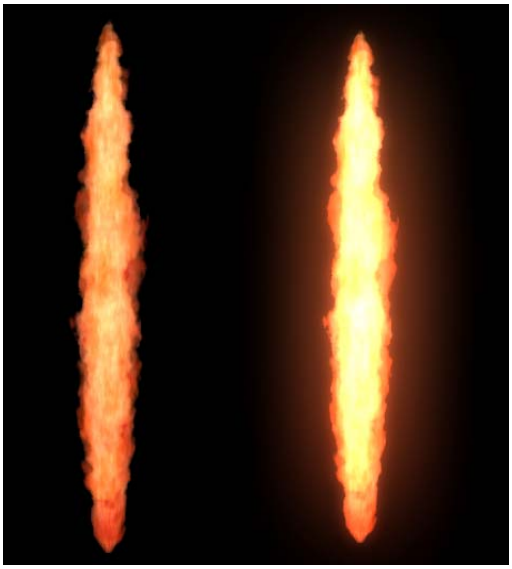




These four images show the progress during the tweaking of attributes in the 3D cloud node and finally editing the colour inputs. The most useful attributes to achieve this effect were 'Amplitude' and 'Transp Range'.



I then proceeded to add a 2D fractal texture and connected it with the colour input of the cloud node. As seen in the images below, this was done to add both colour and texture to the surface of the flame, giving it a more realistic appearance. Flames and extremely hot objects appear whiter in the middle due to the laws of black body radiation [Meyer-Arendt, 1983] [6] and so to increase the brightness of the centre of the flame will cause that area to appear hotter. Finally, I added a glow to the lambert material thus brightening the centre of the flame furthermore and giving the object the illusion that it is a light source.



Since looking into using shaders for the turbulent fire, I have decided to change the position of the flames in the scene from emitting horizontally off the side walls to emitting vertically from the pit below the character. This was purely a design choice and was chosen so to mimic the flames seen in a hot air balloon.

To animate the flames, I used an identical sphere to the ones used in the testing and applied a non-linear flare deformer. I then key framed the sphere moving upwards giving the impression that it is expanding.

[video – turbshader01.flv]

However, the edges in the video above don't animate and remain stationary as soon as the object ceases movement. The main attribute which controls the contours of the edge is called 'Ripple' which has three inputs that determine the texture's waviness in the X, Y, and Z directions. By manually keying the X and Y values, I was able to give the appearance that the flame was actually burning in an upwards direction. To add to the effect and include a little more movement within the flame, I also keyed the rotation of the mesh which, in turn, rotates the 2-dimensional fractal texture.

[video – turbshader02.flv]

The next video shows an approximate example of the proposed position and movement of the fire in the scene. It is not final, as it is clear by comparing it with the previous video that if the flames are scaled, the effects become out of proportion. To defeat this problem, I will use a render of the smaller version above to composite into the scene separately from the environment.

[video – blockwithfire2.flv]

Final Outcome

These two videos show the two final products from the innovations project.

[video – testrender.flv]

[video – turbshader02.flv]

Smooth Flames

This final video also includes the lighting to be used in the final scene. The smooth flames were a lot less challenging than the turbulent flames, but this meant I that could experiment with them more and consequently ended up using a technique which I wouldn't have thought would be suitable for my animation. Although the fire at close inspection probably wouldn't look good, the imperfections caused from using textured planes are eliminated in the final scene due to the camera being reasonably far away. This is a huge advantage to my project as it means a more computationally cheaper method can be used whilst still looking as good as using fluids. It also helps lessen the amount of compositing work needed towards the end of the project a great deal.

Turbulent Flames

These flames were a huge challenge for me as I have never dealt with either particles or shaders before. It was interesting to study such an unusual and uncommon type of fire and then try to recreate it in 3D graphics and overall, I am very pleased with the result. As mentioned previously, the flames pose a problem when scaled up to fit the environment but this can easily be solved in compositing, especially as the camera is static throughout the duration of the shot.

Conclusion

Overall, I am very pleased with the project. I have managed to create two very different types of fire whilst making sure they will both suit the style of my animation. I came across numerous problems throughout, but always managed to overcome them by one way or another ending up with two useable fires I am proud of. This project has been very innovative for me as I have never used particles or dealt directly with shader nodes before. I have learnt a great deal from experimenting with features of Maya I had previously avoided and feel I would be a lot more confident to use them again in the future.

However, if I were to do this project again, I would definitely dedicate the whole of my time looking into fluids as I have realised how powerful and diverse fluids can be. I have discovered this from a combination of Maya's fluid presets, various internet tutorials and from an ACM Siggraph paper on Animating Suspending Particle Explosions[7] which looks at the use of both particles and fluids for explosions. I would also have liked to learn about using expressions, especially if I had ended up using a particle system for the final fire animation. If I was to improve on this project, I would probably spend more time on the turbulent fire to try and get it to look closer to the fire in hot air balloons. I think this because I feel that now I am more confident with the Hypershade in Maya, I could experiment further into the area and perhaps emerge with more complicated and sophisticated effects.

Although I really enjoyed creating the turbulent fire, I did find it very time consuming to have to keep rendering the shot every time I changed something and was curious to see the difference. When creating the shader it wasn't so bad as the progress during the initial setup could be monitored by just rendering still frames. However, when I was animating the flames and the particle effects, it soon became very troublesome.

Bibliography

[1] - *Madagascar*, 2005. Film. Directed by Eric Darnell, Tom McGrath. USA: DreamWorks SKG.

[2] - *The Incredibles*, 2004. Film. Directed by Brad Bird. USA: Walt Disney Pictures, Pixar Animation Studios.

[3] - Hot air balloon - http://en.wikipedia.org/wiki/Hot_air_balloon, Last Updated: 11/03/2009.

[4] - Sprite (computer graphics) - http://en.wikipedia.org/wiki/Sprite_(computer_graphics), Last Updated: 09/03/2009.

[5] - Ebert, D.S., Musgrave, F.K., Peachey, D., Perlin, K., Worley, S., 2003, Texturing & Modeling: A Procedural Approach. 3rd ed. San Francisco: Morgan Kaufmann

[6] - Meyer-Arendt, J.R., 1994. Introduction to Classical and Modern Optics. 4th ed. USA: Benjamin Cummings

[7] – Feldman, B.E., O'Brien, J.F., Arikan, O., 2003. Animating Suspended Particle Explosions. *Computer Graphics Proceedings, Annual Conference Serie.* Siggraph, 2003. San Diego.

Miscellaneous Images (in order of appearance)

Background image- http://www.loupiote.com/photos_m/1112235738-torch-fire.jpg, Last Updated: 2009, Accessed 26/01/2009.

Introduction page:

Yellow torch flame - http://www.loupiote.com/photos_m/1112235738-torch-fire.jpg, Last Updated: 2009, Accessed 26/01/2009.

Turbulent flame – http://public.ca.sandia.gov/crf/images/TNFflamesLabeled.jpg, Last Updated: 2006, Accessed 01/03/2009.

Research and Reference page:

Three hot air balloon images (from left to right):

Leftmost image - http://blog.wanamakerphotography.com/wp-content/uploads/2008/07/3s8z5691.jpg, Last Updated: 12/02/2009, Accessed 28/02/2009.

Central image - http://ottosballoonflights.com/images/flames.jpg, Last Updated: 15/03/2008, Accessed 28/02/2009.

Rightmost image - http://pro.corbis.com/images/NL005189.jpg?size=67&uid={90768B55-B831-473A-9E5A-FC0C0BE56CD9}, Last Updated 2009, Accessed 28/02/2009.

Videos

Research and Reference page:

Hot air balloon videos (from left to right):

YouTube. How to Fly a HOT AIR BALLOON. http://www.youtube.com/watch?v=GlqLoGq_FSc. Downloaded 03/03/2009

YouTube. Remote Control Hot Air Balloons. http://www.youtube.com/watch?v=2MWCMPzU1cY. Downloaded 03/03/2009