

# **The Cel Shading Technique**

## **Dissertation**

November 2012 – December 2012

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December 2012

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# **1. Introduction**

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This Dissertation is planned to help me with my Final Project, an Animated Short Film called 'Purple Eyes'.

With the research and analysis of Cel Shading history, evolution, performance and technical use, I plan to acquire the necessary knowledge to decide and execute the most appropriate technique and visual style for my Final Project.

Extracting my own conclusions about Cel Shading, and analysing why the technique is used and which are the strengths and weaknesses, I want to achieve a proper conclusion of how it has to be employed the technique.

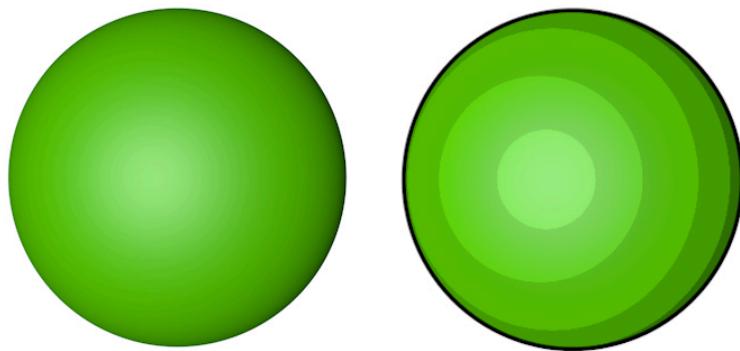
With direct testing and practical experimentation, I want to arrive to a proper conclusion on which type and variation of cel shading is the best for my project, both on technical and artistic aspects.

## **1.1. What is Cel Shading?**

Cel Shading, also called toon shading or cel/toon shader, is a 3D technique based on a specific shading method, which consists in recreate the look of traditional 2D animation cels with the use of flat colours for shading 3D objects in a unrealistic way.

But it's not only referred to a shading method, nowadays Cel Shading is known also and more generally as a artistic style/method of making 3D graphics seem cartoonish with the use of specifically colored textures, and also using outlines to simulate drawing lines. So the research will include also those 3D graphics with realistic shading, which look like cartoons using Cel shading elements.

In this Dissertation "Cel Shading" will be treated as a whole artistic style rather than a specific technique. I can explain the style more in detail but a picture is worth a thousand words, here is an example I have made. Realistic shading on the left, Cel Shading on the right:



**Figure 1: Shading comparison.**

With this technique, and depending on which artistic style is going to be achieved, it is possible to create 3D elements with looks really like 2D animation.

## 2. History and evolution

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Although this technique is used in so many fields, it is widely and frequently used in Video Games. Is in this field where the technique has been more used and exploded, and its evolution is linked to it. It hasn't a specific creator.

The commercial use of the Cel Shading technique starts with Video Games. Even before there was a standard and known definition of the technique, a video game called *Fear Effect (1999)* used a very similar style for representing game characters.



Figure 2: *Fear Effect (1999)* In game capture.

But it wasn't proper real "Cel Shading". Due to limitations of the PlayStation system itself, it has no real-time shading, so shadows and colors were simple pre-rendered flat textures. Also it has no black outlines due to the lack of real-time shading rendering.

The first commercial use of real Cel Shading was done in the game *Jet Set Radio (2000)*. This game had real-time Cel Shading, with the use of black thick outlines and flat colors with real-time shadows, giving the game a very successful cartoon appearance for the time.



Figure 3: *Jet Set Radio (2000)* In game capture.

Jet Set Radio (**2000**) popularized the Cel Shading technique into the general public. After that, so many games used and perfected this technique, and also Cel Shading was used in other fields in a lesser extent.

## 2.1. Video Games

Let's do a review over the most significant Video Games using Cel Shading. In this field the technique has evolved considerably over the years.

*The Legend of Zelda: The Wind Waker* (**2002**) is one of the most famous cel shaded games in the history. With big and very expressive toon styled characters, bold colors, and a great artistic design, this game was well known about bringing to the Cel Shading a great smoothness in front of past cel shaded models which were stiffer than usual 3D shading and 2D traditional animation. At the beginning the graphics were poorly accepted, some people dislike the toon aspect, which was uncommon in Zelda series and more childish than the other games of the saga.



Figure 4: *The Legend of Zelda: The Wind Waker* (2002) In game cutscene capture.

*Okami* (**2006**) shows how versatile the Cel Shading technique can be, recreating a *Sumi-e* style, which is a Japanese Ink painting method. The game really looks like brush painting. Its style is not based on Cel Shading lighting, but is based on outlines and flat colors in combination of painted textures so it should be included under Cel Shading artistic technique.



Figure 5: Okami (2006) In game capture of the HD remake version.

*Dragon Ball Z: Budokai Tenkaichi 3 (2007)* is a clear example of how this technique can recreate the style of traditional 2D series, such as Dragon Ball, with the use of 3D graphics. Preserving all the characteristics that represent the original 2D hand drawn animation series.



Figure 6: *Dragon Ball Z: Budokai Tenkaichi 3* (2007) In game capture.

Since the popularization of Cel Shading, almost every Video Game based in Japanese “anime and manga” series, use Cel Shading technique to resemble the original works.

*MadWorld (2009)* uses a type of Cel Shading that represents the look of a classic black & white comic book, the graphic style is inspired by Frank Miller’s *Sin City (1991)*. The game uses nearly only 4 colors, black and white/sepia for characters and world, yellow for graphics, and red for blood.

This game demonstrates that Cel Shading can also be used for adult and dark stories, and not only for colorful cartoon style.



Figure 7: *MadWorld* (2009) In game capture.

The forms of the game are difficult to understand with static images due to the great amount of elements on the screen and the simple color palette.

With the arrival of the High Definition and the “Next Generation” Video Game systems, graphics improved significantly. And there are some Cel Shading titles that perfect the technique reaching some surprising results.

Different games demonstrated that Cel Shading is a very adaptable graphic style, within different game genres using it in a right way and with the beauty of the High Definition.

*Prince of Persia (2008)* is an action-adventure platformer, *Eternal Sonata (2007)* is a Japanese RPG (Role Playing Game) and *Borderlands 2 (2012)* is a first-person shooter game. These games are an example of the variety that can be achieved.



Figure 8: *Prince of Persia (2008)* In game cutscene capture.



Figure 9: *Eternal Sonata (2007)* In game capture.

Although *Borderlands 2 (2012)* use realistic shading instead of Cel Shading, is widely encompassed under Cel Shading artistic technique. This is because it uses real time black outlines for in game elements. It also uses penciled textures, giving the game a cartoonish look.



Figure 10: *Borderlands 2 (2012)* In game capture.

One of the greatest uses of Cel Shading in the actual Video Game generation is *Naruto Shippuden: Ultimate Storm Generations* (2012). This fighting game is based on animated 2D series.



Figure 11: *Naruto Shippuden: Ultimate Ninja Storm Generations* (2012) In game capture.

In this game the technique just got really perfected, the quality of the animations and the graphic style surpasses the one of the original 2D hand drawn animation series, conserving all of the characteristics of the original 2D characters.



Figure 12: *Naruto Shippuden: Ultimate Ninja Storm Generations* (2012) In game capture.

The animations look really smooth and soft, with the typical flat shaded characters and plenty of visual effects, like fire, smoke, light, etc. It really looks like 2D is being drawn in real time. And the combination of all the elements results in a very harmonic blend, which looks absolutely perfect. It is one of the best uses of Cel Shading nowadays.

## 2.2. Movies & Other

Cel Shading in other media is not as popular as it is in Video Games, there are a very few works compared to the large amount of Cel Shading Video Games.

In Movies, TV series and other media, Cel shading is used for complementing another types of animation, rather than being the center and a full production technique.

One of the most frequent uses of Cel shading is in 2D animated movies/series, for animate things that otherwise would be harder to do with hand drawn animation.

In 2D series like *The Simpsons* (1989 – present), *Futurama* (1999-2003), or *Family Guy* (1999-2002), we can see that some elements are in cel shaded 3D. Normally is used for cars, machines, and non-organic objects. This combination was frequently used in 2D hand drawn productions, like Disney modern movies such as *Tarzan* (1999).



Figure 13: *Futurama* (1999-2003) Opening capture.

*Futurama's* (1999-2003) opening sequence is fully done with cel shaded 3D.

The Movie *The Iron Giant* (1999) uses a combination of traditional animation and cel shaded computer animation through the entire Movie. The Giant Robot is computer animated, and the rest is done by traditional hand drawn animation.

In the process of integrating the two types of animation, they created a specific technique in order to make 3D lines look irregular. With this random imperfection in lines they achieved a 2D hand drawn animation look. (**Scott Johnston Talks Iron Giant 10th Anniversary, 2009**)

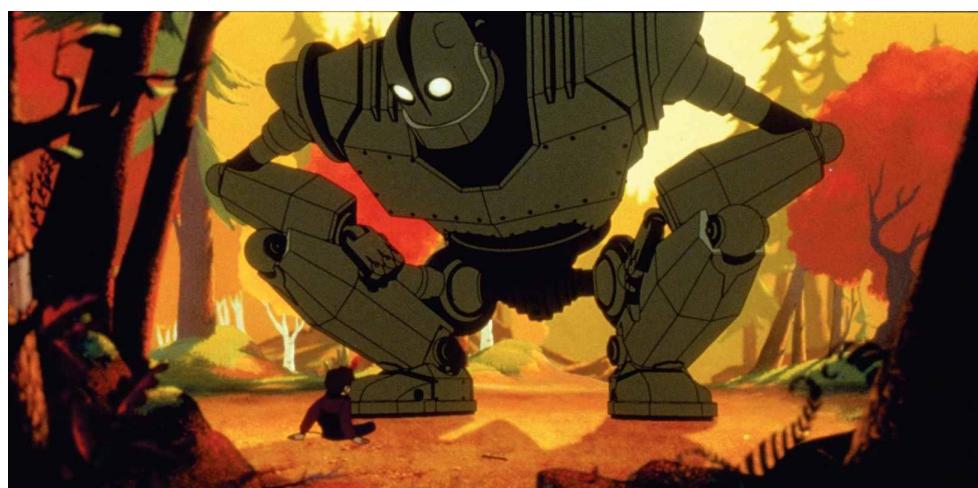


Figure 14: *The Iron Giant* (1999) Movie capture.

We can see Cel Shading implemented in short films and advertisements, is a technique that looks jazzy and eye-catching, and it's more usual to see. But it's not common to see Movies with full implementation of the technique, is very hard to find them.

One of the most known full cel shaded movies is *Appleseed (2004)* based on the work of Masamune Shirow. The look of this movie is similar to cel shaded Anime based Videogames, but it doesn't look like 2D animation, it's more like 3D with flat shaders, resulting in a strange blend.

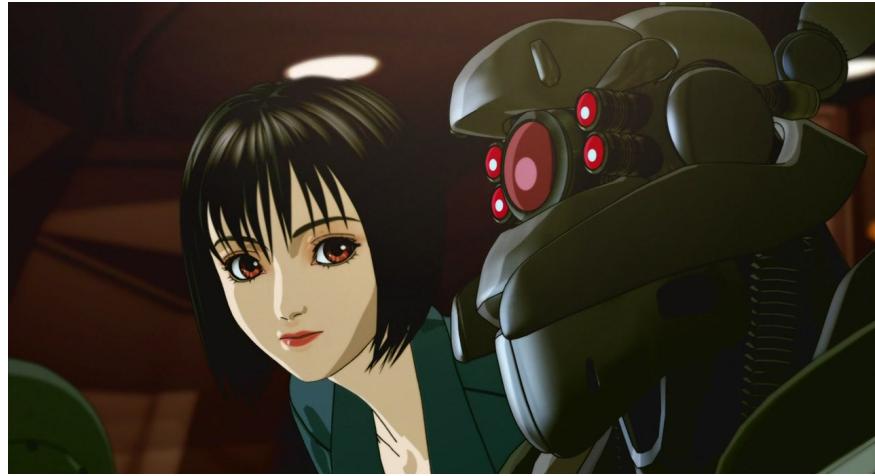


Figure 15: *Appleseed (2004)* Movie capture.

The sequel, *AppleSeed Ex Machina (2007)*, moves away from the conventional Cel Shading, getting a more realistic style, but still cel shaded. It tries to achieve its own artistic style through cel shading rather than imitate other techniques.



Figure 16: *Appleseed Ex Machina (2007)* Movie capture.

Sometimes Rotoscoping is confused with Cel Shading, although the results may look similar, it's not the same. This is the case of the Movie *A Scanner Darkly* (2006), which most people think it is Cel Shaded. The rotoscoping process is based on redrawing live action film. It's not a 3D technique.



Figure 17: *A Scanner Darkly* (2006) Rotoscoping process.

Studio Ghibli is a very well known Japanese studio that produces only 2D movies. But their latest films include some 3D elements hidden as cel shaded elements.

Sometimes is really hard to identify them because they are really highly integrated and implemented. Normally the cel shaded elements are backgrounds, buildings and non-organic elements.

On *Howl's Moving Castle* (2004) some parts of the castle are done using cel shaded 3D.



Figure 18: *Howl's Moving Castle* (2004) Movie Capture.

### **3. Cel Shading nowadays**

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Cel Shading is getting popular, but not in all fields. Here I am going to describe the present situation exposing some conclusions about Cel Shading based on observation of the different productions through history and evolution of the technique.

#### **3.1. Current Panorama**

As we can see, Cel Shading is being used widely in the Video Game Industry. It works as a great technique used for full productions in very different artistic ways. It is also used for representing full short films and advertisements, although is not a very popular technique, is employed to achieve specific visual styles.

But we can't say the same about the Movie Industry. In this field the technique is used more like a secondary technique.

In 2D productions, is used to help in parts where the 2D hand drawn animation would be difficult and a waste of time, with the consequent loss of money. In the past the use of 3D was really expensive for producers, but nowadays is not that expensive, using Cel Shading they save time and money.

In 3D productions is a very minor technique. Normally 3D productions use realistic render, recreating reality rather than searching for a 2D cartoonish visual style.

We can also see the technique used in some TV Shows punctually, for representing a contrasting 3D that departs from reality.

There is a marked difference between the different fields.

#### **3.2. Why is there this difference in the current use of Cel Shading?**

I observed that the reason of this difference is due to the technique itself and the way the companies implement the technique in their productions to fulfill their needs.

##### **3.2.1. Different Uses & Objectives**

With the arrival of the 3D era in Video Games, Cel Shading was really appreciated. In videogames, if companies want to represent the look of an animated 2D series, movies or "anime" Japanese style, the most appropriate technique is Cel Shading.

With the continued use of the technique, they improved the uses and arrive to great quality levels. They can do 3D games with all the advantages of 3D environment and gameplay, but with the look of 2D hand drawn animation in real time. In Video Game Industry this technique sometimes is a necessity to simulate specific graphic styles in a 3D environment.

But what happens with Cinema and Movies? Realistic shading is used on almost every 3D production, *Disney*, *DreamWorks*, *Pixar*, and quite a lot of others.

In the Movie Industry there seems to be no necessities of emulate 2D hand drawn animation with 3D. When they want to do a classic animation with the old hand drawn style, they do it. Like Disney did with *The Princess and the Frog* (2009).

Cel Shading is a complicated technique, when simulating 2D on characters they may look stiff compared to 2D hand drawn animation.

When a classical hand drawn animator makes a rotating view of a Character, it redistributes the mass on each frame, the Character will always look good in front of the camera because each draw is created separately.

But in cel shaded 3D, when rotating a Character view the 3D model will be always the same, it won't adapt to each frame. The 3D model is perfect and doesn't vary its from one frame to another, so it's very difficult to make the model look great from each view without modifying it.

That provides a stiff look, making the model look lifeless. Inevitably when we see this effect, we see that is stiffer than hand drawn animation, and lifeless compared to 3D realistic shading.

That's why normally Cel Shading is used to represent inorganic, lifeless or technological things.

Unlike 2D, 3D is perfect, it has no imperfections and lines and perspectives are just like there are in real life. Shadows look very fluid and they adapt shapes describing the exact 3D form of the models in a perfect way. It isn't the proper behavior of 2D animation, and that's why 3D is used with realistic render rather than other techniques.

Also, with this realistic render and aspect, nowadays animation films are well seen by adult audiences. In the past, 2D animation films were almost always cataloged as child's movies, and now, with this realistic shading and render, animation films are more addressed for all audiences rather than specifically for childhood.

That's another reason why this technique is not exploded in the Movie industry.

### **3.2.2. A potential technique**

But this technique is not so limited, thanks to Video Games we've seen that the technique is really useful and can achieve amazing and very different artistic results.

In Video Games the technique has been perfected: imitating 2D animation with stunning accuracy, creating new graphic styles, giving life to different painting techniques like sumi-e or comic book style, and a great many others. And all with excellent results, creating gorgeous characters full of life, and magic environments.

In east, specially Japan, 2D animation and "anime" cartoon are very popular and we can see how Industry intend to improve and create 3D products based on Cel Shading in an appropriate way.

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## **4. Good Cel Shading Employment**

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Normally Cel Shading is described and used just as a shading method. But it's more than that; in terms of production Cel Shading is not a simple type of illumination. If a production is going to be done in Cel Shading the production should be done in a certain specific way. Depending on the artistic style based on Cel Shading you want to achieve one production will differ from another.

It's a mistake to think that Cel Shading is only a lighting method which is applied just at the end of the production, the production has to be done in a certain way depending on which Cel Shading is going to be applied.

When a production is done in a normal 3D way and then applies Cel Shading, is when models look stiffer and not well prepared. The decision of make a Cel Shaded cartoonish appearance includes a lot of aspects that should be done in a specific way, modeling, animating, rigging, shaping, and so on.

### **4.1. Aspects to consider when producing in Cel Shading**

With the analysis of both 3D and 2D animation, I have developed a guide with important aspects I thought are essential for simulating 2D toon style when using cel shaded 3D:

- With Cel Shading, volumes are almost nonexistent due to flat illumination, so you have to make sure that your model is going to look right in all angles, taking into account the black outline that defines the character.
- When using Cel Shading for creating static frames, the technique is really powerful and very difficult to distinguish from a 2D paint, so for creating individual image pieces the technique is literally perfect simulating 2D.
- When animating, avoid exaggerated 3D camera movements and use static and more traditional camera shots.
- When animating Cel Shading in a 2D simulation way, you have to think on the way 2D hand drawn animation is done. You have to change shaping of your models and redistribute the mass depending on what are they doing and in which angle they are being shown.
- Try to animate the most traditional way possible, using frame-by-frame, and less interpolations.
- If using black outlines, try to modify the volume of those on different parts, avoid same sized perfect outlines. Using thicker outlines will guide viewer through important parts.
- Render and export animation with classical hand drawn animation 12 frame per second pattern. Double frames to achieve the 24 frames per second cinema ratio. With a higher number of frames per second, animation will look smoother like reality instead of 2D classic animation.
- Don't use Motion Capture for character animation. It will ruin the classic animation look, giving to the animation inappropriate 3D realistic smooth movements.

- Make Simple characters, 2D designs are quite simple due to the difficulty of hand drawn animation. So a character full of details will look digital and 3D in contradistinction to 2D traditional animation.
- Take control of lights and spotlights. Shadows with constantly movement and adaptation through model shape will reveal the 3D.
- Sometimes flatter lighting is better, because with lot of gradient tones, the image will look more as real 3D with posterize effect rather than 2D animation.



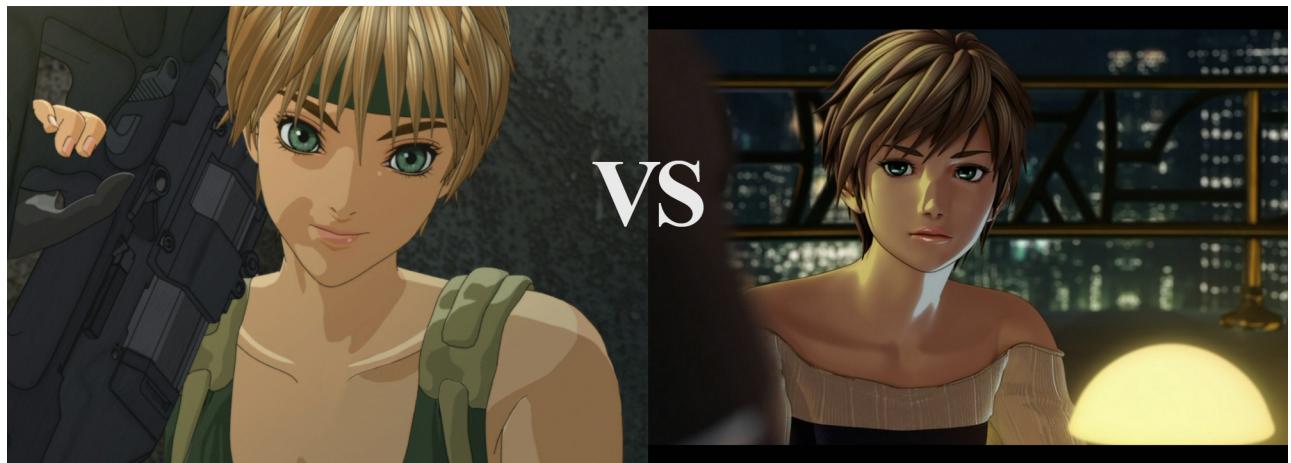
**Figure 19:** Posterized photography.

## 4.2. Cel Shading in its own way

Also, Cel Shading can be employed as a technique itself without the 2D simulation factor. Looking like 3D but in its own creative and artistic way. A clear example is the aforementioned *AppleSeed (2004)*, and its sequel *AppleSeed Ex Machina (2007)*.

The first movie uses "Cel Shading" in a 3D flat colored way. With a slightly stiff aspect and a lot of detailed digital effects, it doesn't achieve a 2D traditional look neither a 3D realistic style. Referring to human characters is not a proper use of Cel Shading. It contains some errors that I mentioned in previous section making characters look stiff and lifeless. The biggest obstacle of the movie is that combines 2D cartoonish-look with motion capture, two techniques somewhat incompatible.

But in the 2<sup>nd</sup> Movie Cel Shading is used in its own artistic way rather than trying to look like other techniques, achieving a really good looking Cel Shaded artistic style with the basis of the first film.



**Figure 20:** Appleseed Comparison.

Here is a comparison between the same Character in both movies. On the left an *Appleseed (2004)* capture, and on the right an *AppleSeed Ex Machina (2007)* capture. We can see that in the first movie the character looks stiffer and lifeless comparing to the sequel. Movement emphasizes this sensation.

## 5. How it works

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Cel Shading is not as technically complex as other techniques, in fact is not so complex. As I mentioned before, the difficulties of getting a good use of the technique entails some other aspects you have to include during the production. But here I will explain the technical behavior of the technique itself.

### 5.1. Shading

The effect is generated from object's normals. Each normal has its own angle, which is determined between its direction and the lighting point. It calculates the respective cosine and applies a specific tone to that faces/area. When both normal and light directions match, the tone will be brighter. When directions mismatch, the angle increases and the tone will be darker.

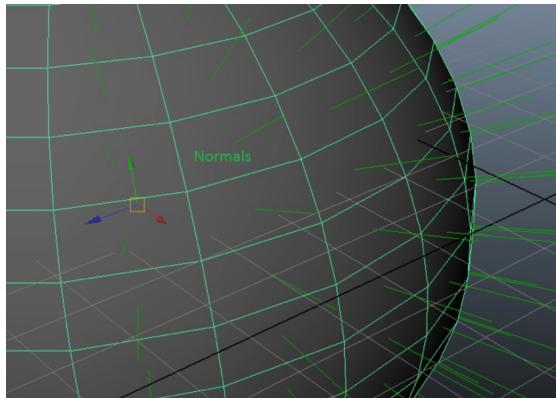


Figure 21: Normals of a 3D object.

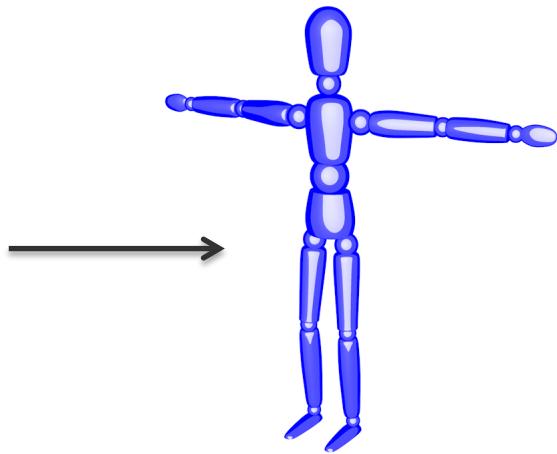


Figure 22: Cel shaded 3D Model.

The different tones are flat and change without gradients, simulating cell/acetate painting style. Depending on the style, the number of tones can be increased or decreased.

### 5.2. Outlines

To achieve cartoon look sometimes Cel Shading graphics include black outlines simulating drawing strokes, this outlines are generated by different techniques such as "Edge-detection" or "Back-face culling".

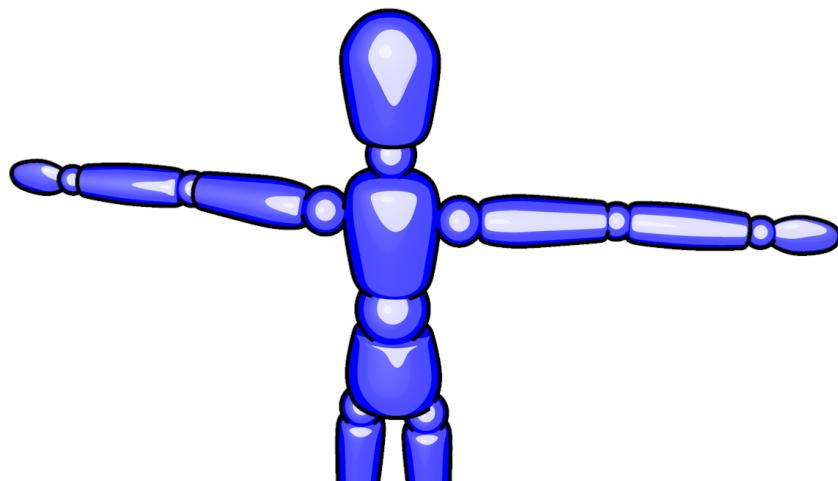


Figure 23: Cel Shaded & Outlined 3D Model.

"Edge-detection" or "Back-face culling" are two independent techniques, but due to the fact that they are used almost always in combination with Cel Shading, it's common to see those techniques encompassed under Cel Shading technique.

### 5.2.1. Edge-detection

Edge-detection is based on algorithms that detects changes of contrast, bright, and sharpness, determining where are the points that form object edges inside an image. The technique is a post process so is not limited to 3D. It's not the most used technique for outline 3D contents.



Figure 24: Outlined image by Edge-detection from Unreal Developer Network.



Figure 25: Outlines of an image by Edge-detection from Unreal Developer Network.

### 5.2.2. Back-face culling

This technique is used for hide back non-visible 3D elements, or part of them, in all kind of 3D programs. It hides the elements that are not visible from the point of view of the observer/camera. These hidden elements of the back don't appear in the final render.

For generating those outlines, the technique is inverted for showing to the observer/camera the hidden elements. Those elements are showed as colored vertices/faces. To make the lines thicker, the vertices/faces are reproduced and translated several times, producing a black outline through the entire object. Then the shaded object is reproduced in front of the black amount of vertices, calculating which are the faces that stay in front, achieving these black outline effect with the hidden back faces.

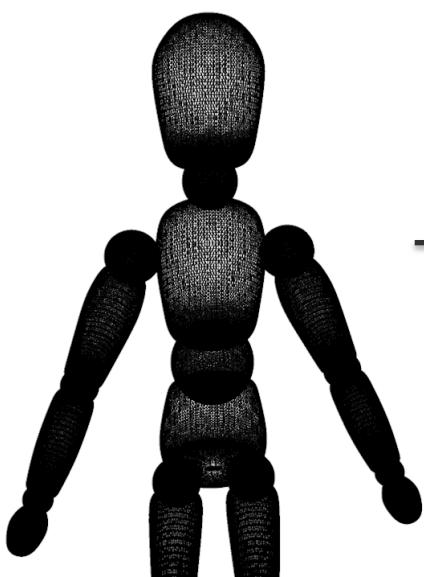


Figure 26: Back elements in Black.

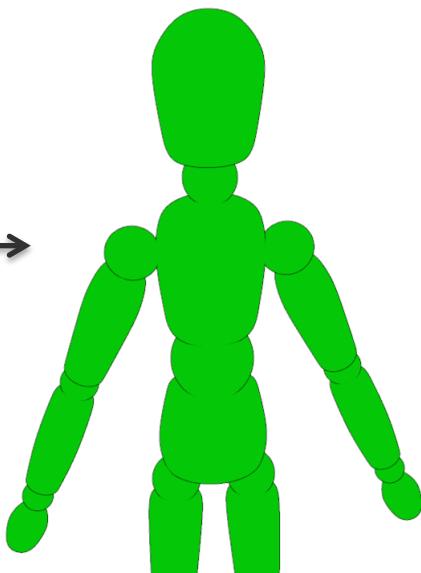


Figure 27: Back elements + Shading.

## 5.1. Texturing

Texturing to achieve cartoon or pictorial style is based on using textures specifically created with this purpose. Including black lines in textures or painting them in a traditional way with brushes and visible strokes. Programs incorporate specific shader functions to include your own artistic textures.

One example is the "Art Shader" of Cinema 4D, where you can import textures and use them as normal spherical materials. I've painted a texture on "ArtRage" for the example:

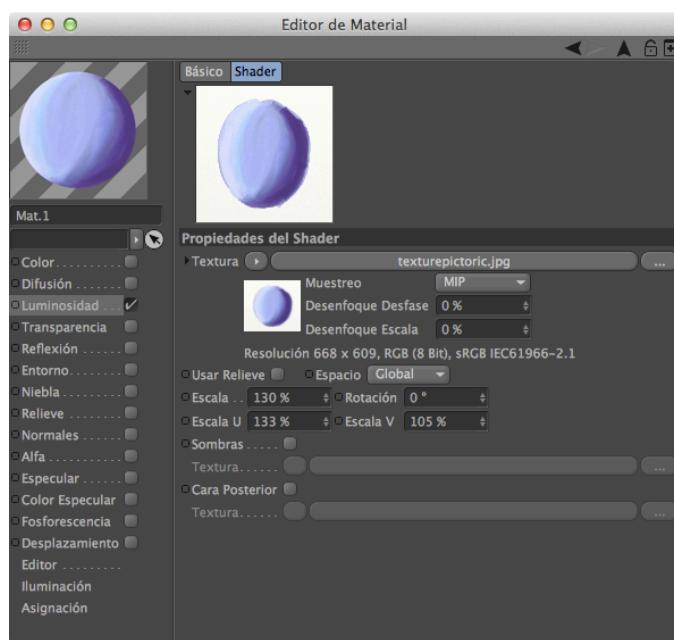


Figure 28: "Art Shader" on Cinema 4D.

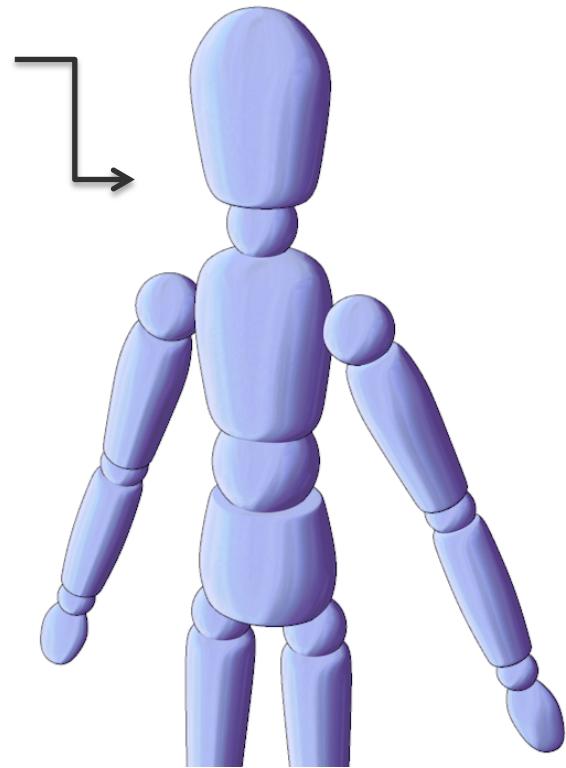


Figure 29: Artistic texture on 3D model.

## 6. Types of Cel Shading

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Based on the observation of different productions that employ Cel Shading, I will test and classify different types of Cel Shading applied to the same 3D elements for comparing them.

I have modeled a basic character and a scenario for testing the different typologies. I modeled the character with simple shapes in order to achieve a good Cel Shading performance. I have done all the tests with the use of "Sketch and Toon" Module of Cinema 4D, is a very powerful module with very advanced settings. I used different texturing methods in combination of the "Sketch and Toon" module for some of the renders.

**Realistic shading:**



Figure 30: Realistic Shading Scene.

This is a realistic render of the model and the scenario, with ambient occlusion, global illumination, recreating real lighting condition. The visual result is excellent but is too conventional.

**Flat two tones with outline:**

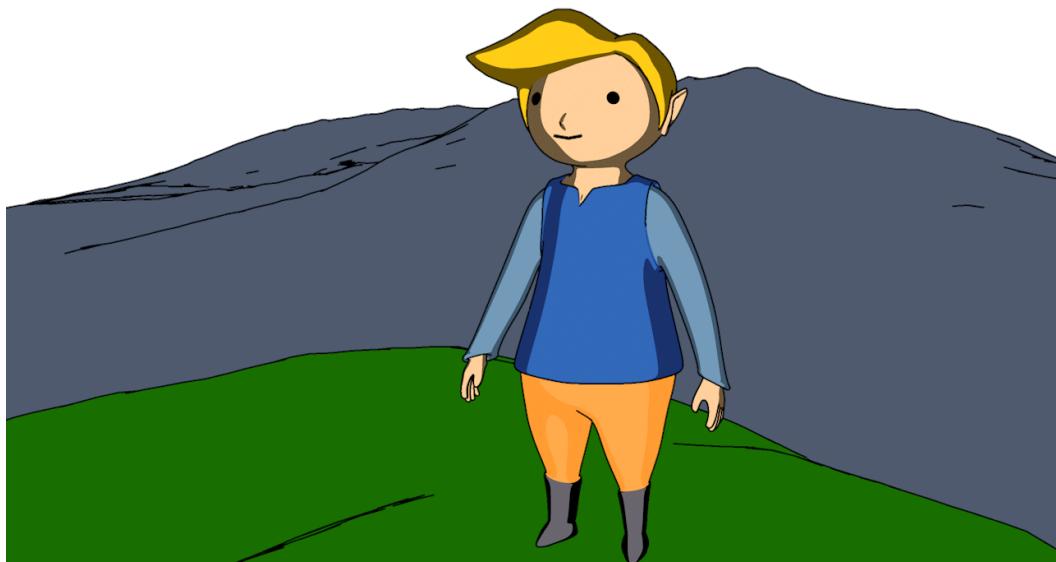
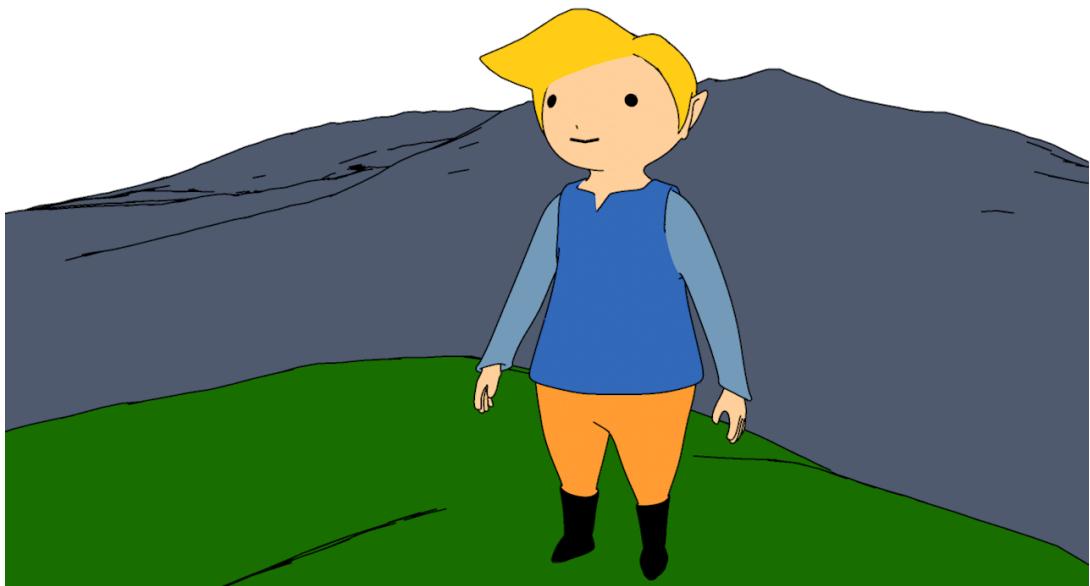


Figure 31: Two tones Cel Shading Scene.

Here I have applied a Cel Shading illumination, which consists in one color for the major base, and a second color for darkest shadow zones. Also I applied a black thin outline adapting to shapes and borders. This combination results in a figure quite understandable, with a 2D cartoonish look.

**Flat one tone with outline:**



**Figure 32: One tone Cel Shading Scene.**

Here I applied a one color flat based Cel Shading. In this combination, the force of shapes and borders is only defined by the black outline. This is the most 2D combination but it losses detail in model shapes and perspective.

**Pictorial style with artistic brush outline:**



**Figure 33: Artistic Render Scene.**

This is the most artistic combination. Is based on textures painted as ball materials in an external painting program, and applied in 3D detecting shadows and highlights. I applied an outline that mimics traditional ink lines, enhancing the painting style of the render.

This is a very good looking style, but it's not the most precise, sometimes misinterprets original forms representing the models with low accuracy. But it's perfect for representing irregular and traditional painting style.

**Flat multi tone:**

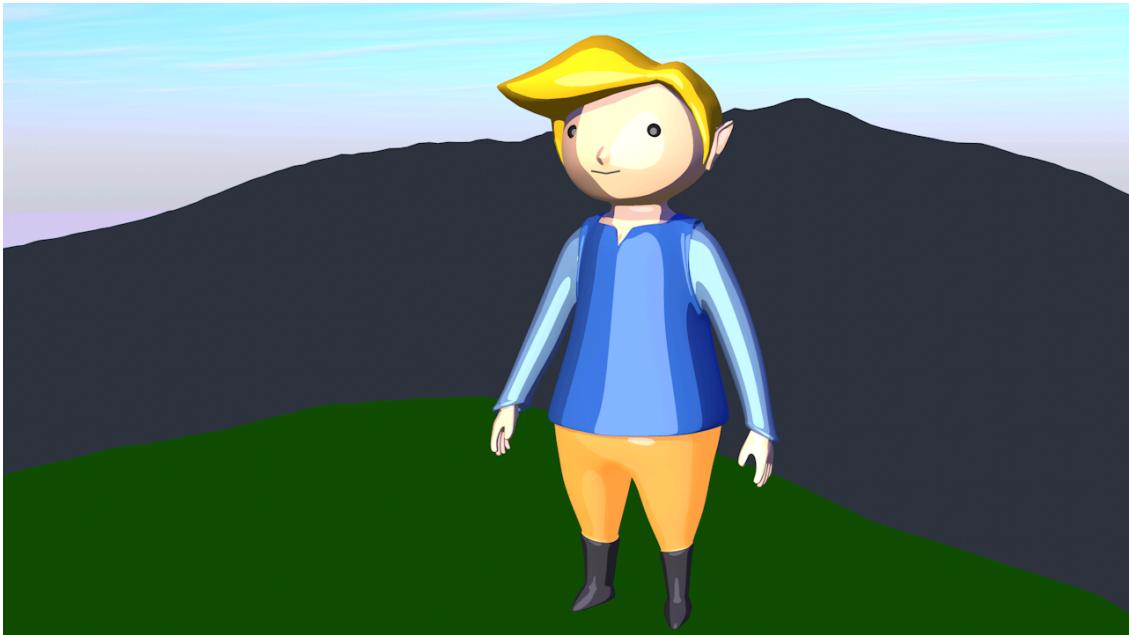


Figure 34: Multi tone Cel Shading Scene.

This combination provides a very good looking and sharp result. With the use of several tones, model shape is totally understandable, and no needs an outline for defining shapes. This combination is the one that looks more 3D due to the multiple amount of tones.

**Black & White Comic style:**



Figure 35: B&W Cel Shading Scene.

Here I have used thick outlines and few colors, it's based in shapes rather than defined figures, and it works better with more complex models. I use grey scales, black and white. I applied a dotted texture on the mountains, which defines better the topography. It can look completely 2D.

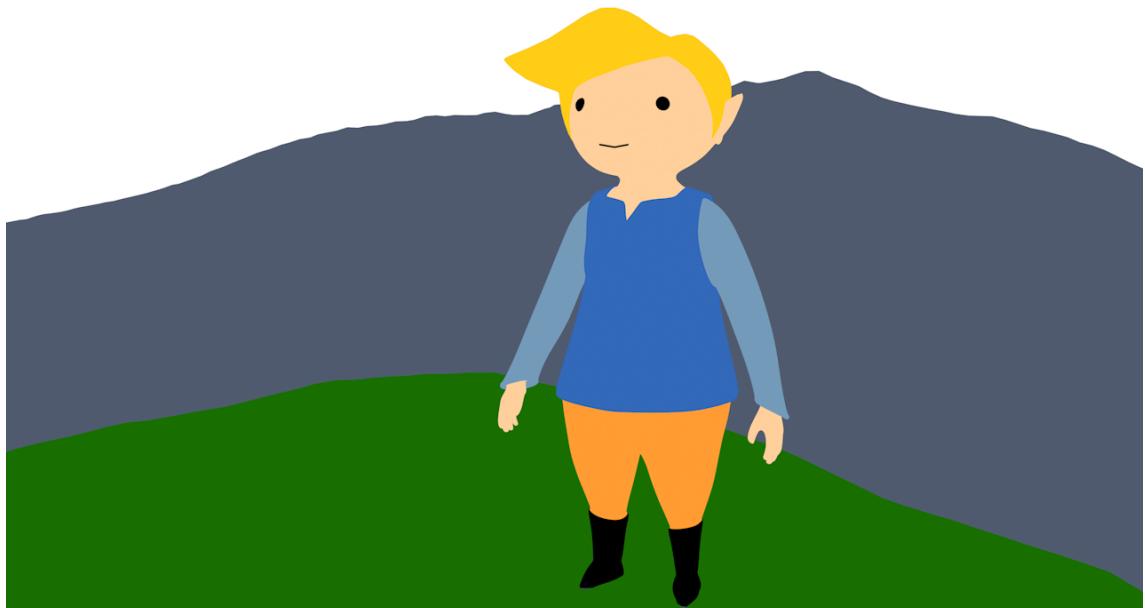
**Real Shading + Black outlines:**



**Figure 36: Real Shading Outlined Scene.**

This combination is commonly used and it can be combined also with cartoon textures to achieve a cartoon looks with the volume advantages of realistic lighting. It defines shapes perfectly and gives to the production a cartoonish style. It is treated like a post effect, which can be applied to any normal 3D production without losing properties.

**Flat tone:**



**Figure 37: Flat tone Cel Shading Scene.**

This is the most minimalistic combination and consists in simple color shapes. Is a one flat color Cel Shading without outline or shadows. It needs very distinctive colors and separate shapes for being understandable.

Different Outlines:



Figure 38: Rainbow Outline Scene.



Figure 39: Opacity Brush Outline Scene.

The possibilities with the outlines are almost endless; there are very many options and settings you can control to create your own perfect outline depending on the style you want to achieve. Also you can animate the outlines creating a live sketching style.

## 6.1. Materials

This is a basic cel shaded tri-tone material:

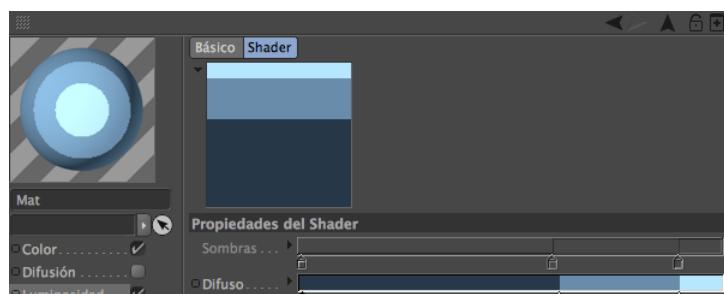


Figure 40: Cel shaded Material.

This is a Sketch Material, where outlines are modified:

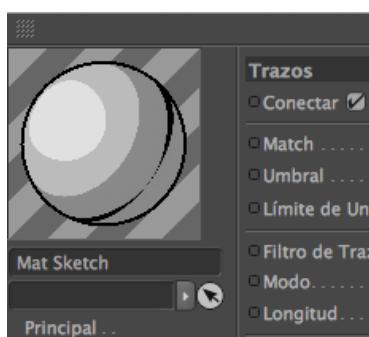


Figure 41: Sketch Material.

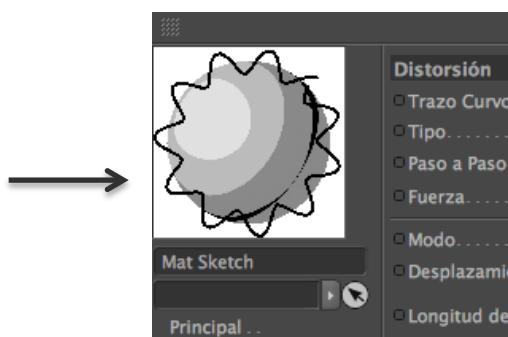


Figure 42: Wooble Sketch Material.

And these are some of the “Artistic Shader” materials, which I have painted in Artrage Studio:



Figure 43: Artistic Shader Materials; Shirt, Pants, Ground, Skin.

## 6.2 Other Tests

I also made other tests with some old elements I have modeled a year ago, to see how Cel Shading interacts with elements not modeled with the aim of apply Cel Shading.

This is a realistic shading render of the model I have made, as you can see is a very detailed and complex model.

**Figure 44:** Realistic Shading old model.



And here is the model with Cel Shading applied, as you can see Cel Shading is not working really well due to the high level of details. It creates a lot of unwished artifacts through all the mesh with quite noisy shadows; it's not a clean result.



**Figure 45:** Cel Shading Renders of the old model.

## 7. Conclusions

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After all the research and investigation, I've noticed that Cel Shading is a very complicated technique, much more than I thought.

This dissertation has helped me to understand how this technique really is. Before doing this dissertation I thought I knew the technique fairly well, but in fact I was losing so many things.

After doing all the tests and analyze the technique, I realized how hard is it to control and achieve good results. Doing tests has helped me to understand by myself what I have been researching, the hardness of the technique.

Analyzing which are the differences between 3D Cel Shading and 2D animation, I realized which are the strengths and weaknesses points of Cel Shading (chapters 3<sup>rd</sup> and 4<sup>th</sup>).

Cel Shading requires a very specific production if want to look as 2D cartoon. It's not just a filter you can apply at the end of the production, you have to consider the style through all the aspects of the production, for achieve a good-looking Cel Shading.

Investigate and compare the different uses of Cel Shading has made me see and understand why there are wrong Cel Shading uses and good Cel Shading uses, like I analyzed in the 4<sup>th</sup> chapter.

Like I proved in chapter 6.2, Cel Shading works great with simple Characters, but with detailed Characters the results are imprecise and dirty.

Unlike in other techniques as Realistic Shading, in Cel Shading is very hard to achieve good-looking results. With Realistic Shading the results are very good with less effort.

Cel Shading is not a widely appreciated technique, some people see Cel Shading as an under-technique compared to Realistic Shading. Some audiences do not understand the technique and think that is simple and childish.

As I have observed throughout the entire dissertation, Cel shading is a technique that it still has to go a long way and has not yet been fully exploited. But some Video Game studios have achieved an amazing use of the technique with amazing results, now I appreciate much more those Video Games that use Cel Shading so flawlessly.

One objective of the dissertation was to get a proper conclusion about which artistic style I will use in my Final project animated short, now that I have a good knowledge about the technique, I think I will use a combination of Aristic Shader and Realistic Shading; with the adding of artistic outlines.

I think that Realistic shading and lighting can make my characters look so much better without losing detail. The Artistic Shader for objects and scenarios in combination with the artistic outlines will give to the production a traditional artistic style, unconventional, fanciful and gorgeous. I will test all this combinations with the definitive characters in order to make a final decision.

I feel that this dissertation has been very useful and I have gained much knowledge about Cel Shading. This have allowed me to control and know how to manage the technique in order to determinate which is the best way to employ Cel Shading to fulfill my preferences.

Now I understand Cel Shading in depth and I know what I can achieve with the use of this thrilling technique. I think I fulfilled my goals, and my idea has changed; now I know that Cel Shading is a hard and powerful technique, which I respect more than ever.

# APPENDICES

## **Shader Definition:**

*"In the field of computer graphics, a shader is a computer program that runs on the graphics processing unit and is used to do shading - the production of appropriate levels of light and darkness within an image - or, in the modern era, also to produce special effects or do postprocessing.*

*Shaders calculate rendering effects on graphics hardware with a high degree of flexibility. Shading languages are used to program the graphics processing unit (GPU) programmable rendering pipeline, which has mostly superseded the fixed-function pipeline that allowed only common geometry transformation and pixel-shading functions; with shaders, customized effects can be used. The position, hue, saturation, brightness, and contrast of all pixels, vertices, or textures used to construct a final image can be altered on the fly, using algorithms defined in the shader, and can be modified by external variables or textures introduced by the program calling the shader."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** <http://en.wikipedia.org/wiki/Shader/> Internet source produced by Wikimedia Foundation, Inc

## **Posterization Definition:**

*"Posterization of an image entails conversion of a continuous gradation of tone to several regions of fewer tones, with abrupt changes from one tone to another. This was originally done with photographic processes to create posters. It can now be done photographically or with digital image processing, and may be deliberate or may be an unintended artifact of color quantization."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** <http://en.wikipedia.org/wiki/Posterization/> Internet source produced by Wikimedia Foundation, Inc

## **Rotoscoping Definition:**

*"Rotoscoping is an animation technique in which animators trace over footage, frame by frame, for use in live-action and animated films. Originally, recorded live-action film images were projected onto a frosted glass panel and redrawn by an animator. This projection equipment is called a rotoscope, although this device has been replaced by computers in recent years. In the visual effects industry, the term rotoscoping refers to the technique of manually creating a matte for an element on a live-action plate so it may be composited over another background."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** <http://en.wikipedia.org/wiki/Rotoscoping/> Internet source produced by Wikimedia Foundation, Inc

## **Motion Capture Definition:**

*"Motion capture or mocap is the process of recording the movement of objects or people. It is used in military, entertainment, sports, and medical applications, and for validation of computer vision and robotics. In filmmaking and video game development, it refers to recording actions of human actors, and using that information to animate digital character models in 2D or 3D computer animation. When it includes face and fingers or captures subtle expressions, it is often referred to as performance capture. In many fields, motion capture is sometimes called motion tracking, but in filmmaking and games, motion tracking more usually refers to match moving."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** [http://en.wikipedia.org/wiki/Motion\\_capture/](http://en.wikipedia.org/wiki/Motion_capture/) Internet source produced by Wikimedia Foundation, Inc

## **Normal Definition:**

*"In the three-dimensional case a surface normal, or simply normal, to a surface at a point P is a vector that is perpendicular to the tangent plane to that surface at P. The word "normal" is also used as an adjective: a line normal to a plane, the normal component of a force, the normal vector, etc. The concept of normality generalizes to orthogonality. (...)*

*The normal is often used in computer graphics to determine a surface's orientation toward a light source for flat shading, or the orientation of each of the corners (vertices) to mimic a curved surface with Phong shading."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** [http://en.wikipedia.org/wiki/Normal\\_\(geometry\)/](http://en.wikipedia.org/wiki/Normal_(geometry)/) Internet source produced by Wikimedia Foundation, Inc.

### **Edge Detection [Extended] Definition:**

*"Edge detection is a fundamental tool in image processing, machine vision and computer vision, particularly in the areas of feature detection and feature extraction, which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The same problem of finding discontinuities in 1D signals is known as step detection."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** [http://en.wikipedia.org/wiki/Edge\\_detection/](http://en.wikipedia.org/wiki/Edge_detection/) Internet source produced by Wikimedia Foundation, Inc

### **Back-face culling [Extended] Definition:**

*"In computer graphics, back-face culling determines whether a polygon of a graphical object is visible. It is a step in the graphical pipeline that tests whether the points in the polygon appear in clockwise or counter-clockwise order when projected onto the screen. If the user has specified that front-facing polygons have a clockwise winding, if the polygon projected on the screen has a counter-clockwise winding it has been rotated to face away from the camera and will not be drawn."*

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** [http://en.wikipedia.org/wiki/Back-face\\_culling/](http://en.wikipedia.org/wiki/Back-face_culling/) Internet source produced by Wikimedia Foundation, Inc

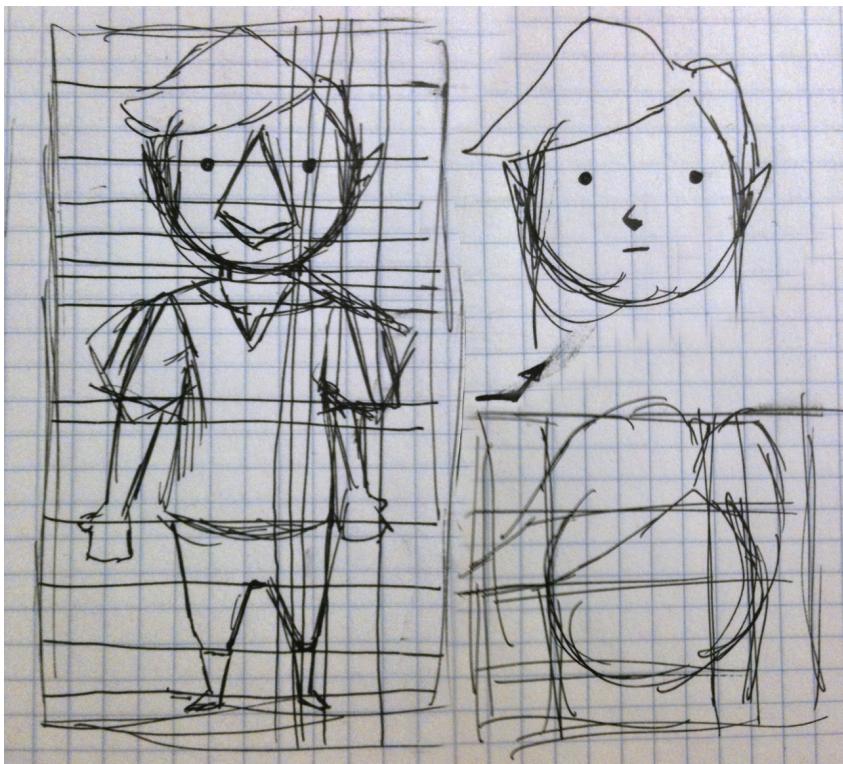
### **List of cel-shaded Video Games:**

Wikimedia Foundation, Inc. (2001-2012) **Wikipedia** [http://en.wikipedia.org/wiki/List\\_of\\_cel-shaded\\_video\\_games/](http://en.wikipedia.org/wiki/List_of_cel-shaded_video_games/) Internet source produced by Wikimedia Foundation, Inc

### **Final Project's Blog:**

This is my Project blog, where you can find storyboard, animatic, designs and the complete storyline of the project.  
Raul Reyes (2012) **Wordpress** <http://raulreyesfinalproject.wordpress.com/> Internet source produced by Raul Reyes.

### **3D "Testing Character" design sketches:**



Some sketches I have made for creating the character I used in the Cel Shading tests. Raul Reyes (2012)

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Kronos Digital Entertainment. (Developer) (1999) **Fear Effect [PlayStation, Videogame]**. England, Eidos Interactive.

**Reference 2 : *Jet Set Radio***

Smilebit. (Developer) (2000) **Jet Set Radio [Dreamcast, Videogame]**. Japan, Sega.

**Reference 3 : *The Legend of Zelda: The Wind Waker***

Nintendo EAD. (Developer) (2002) **The Legend of Zelda: The Wind Waker [Nintendo GameCube, Videogame]**. Japan, Nintendo.

**Reference 4 : *Ōkami***

Clover Studio. (Developer) (2006) **Ōkami [PlayStation 2, Videogame]**. Japan, Capcom.

**Reference 5 : *Dragon Ball Z: Budokai Tenkaichi 3***

Spike. (Developer) (2007) **Dragon Ball Z: Budokai Tenkaichi 3 [PlayStation 2 & Nintendo Wii, Videogame]**. Japan, Namco Bandai Games.

**Reference 6 : *MadWorld***

Platinum Games. (Developer) (2009) **MadWorld [Nintendo Wii, Videogame]**. Japan, Sega/Spike.

**Reference 7 : *Sin City***

Frank Miller. (Creator) (1991) **Sin City [Comic Book]**. USA, Dark Horse Comics.

**Reference 8 : *Prince of Persia***

Ubisoft Montreal. (Developer) (2008) **Prince of Persia [Multiplatform, Videogame]**. France, Ubisoft.

**Reference 9 : *Eternal Sonata***

Tri-Crescendo. (Developer) (2007-2008) **Eternal Sonata [Xbox 360 & PlayStation 3, Videogame]**. Japan, Namco Bandai Games.

**Reference 10 : *Borderlands 2***

Gearbox Software. (Developer) (2012) **Borderlands [Multiplatform, Videogame]**. USA, 2K Games.

**Reference 11 : *Naruto Shippuden: Ultimate Ninja Storm Generations***

CyberConnect2 (Developer) (2012) **Naruto Shippuden: Ultimate Ninja Storm Generations [Xbox 360 & PlayStation 3, Videogame]**. Japan, Namco Bandai Games.

**Reference 12 : *The Simpsons***

Matt Groening (Creator) (1989 – present) **The Simpsons [TV, Animated Sitcom]**. USA, 20<sup>th</sup> Century Fox Television.

**Reference 13 : *Futurama***

Matt Groening (Creator) (1999 – 2003) **Futurama [TV, Animated Sitcom]**. USA, 20<sup>th</sup> Century Fox Television.

**Reference 13 : *Family Guy***

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**Reference 14 : *Tarzan***

Chris Buck & Kevin Lima (Directors) (1999) **Tarzan [Cinema, Movie]**. USA, Walt Disney Pictures.

**Reference 15 : *The Iron Giant***

Brad Bird (Director) (1999) **The Iron Giant [Cinema, Movie]**. USA, Warner Bros.

**Reference 16 : Scott Johnston Talks Iron Giant 10th Anniversary**

Bill Desowitz. (2009) **Animation World Network <http://www.awn.com/articles/2d/scott-johnston-talks-iron-giant-10th-anniversary/>**. Internet source produced by Journalist Bill Desowitz. [Electronically accessed 07<sup>th</sup> November 2012.]

**Reference 17 : *Appleseed***

Shinji Aramaki (Director) (2004) **Appleseed [Cinema, Movie]**. Japan, Toho.

**Reference 18 : *Appleseed Ex Machina***

Shinji Aramaki (Director) (2007) **Appleseed Ex Machina [Cinema, Movie]**. Japan, Toei Company.

**Reference 19 : *A Scanner Darkly***

Richard Linklater (Director) (2006) *A Scanner Darkly* [Cinema, Movie]. USA, Warner Independent Movies.

**Reference 20 : *Howl's Moving Castle***

Hayao Miyazaki (Director) (2004) *Howl's Moving Castle* [Cinema, Movie]. Japan, Studio Ghibli.

**Reference 21 : *The Princess and the Frog***

Ron Clements & John Musker (Directors) (2009) *The Princess and the Frog* [Cinema, Movie]. USA, Walt Disney Pictures.

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Epic Games, Inc. (2011-2012) **Unreal Developer Network**

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Sami Halawa. (2011) **Visual Key** <http://www.youtube.com/watch?v=FbCipLPdBd4/> Internet source produced by Sami Halawa. [Electronically accessed 03<sup>rd</sup> November 2012.]

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