CREATIVE CHARACTER DESIGN BASED ON COMBINATION OF 2D AND 3D CHARACTERISTICS

A Thesis

by

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ABSTRACT

This research combines the need for innovation in character design with the idea of combining 2D and 3D characteristics to create an original and appealing character style. The goal has been to benefit from the capabilities of 3D animation while implementing the simplicity of 2D designs. I studied character design and analyzed examples of existing animated characters followed by experiments with different approaches to combining 2D and 3D character elements. Based on the results of these experiments, I designed a set of characters that combine both 2D and 3D components. These characters have been rigged, animated and rendered to demonstrate their functionality.

DEDICATION

To my mother, my father and Armin.

ACKNOWLEDGEMENTS

I would like to express my most sincere thanks to my committee chair, Frederic Parke, for his constant support, guidance, patience and enthusiasm for my work. I would also like to thank my committee members, Richard Davison and Stephen Caffey, for the feedback and encouragement they have provided. I am truly grateful to visualization department head and staff, for their being considerate and coping with all the personal problems I went through in the past year. I would like to express my appreciation to Armin Banaei for all the support and encouragement he provided me. I definitely could not have done this without his support. Finally I would like to thank my parents for their unconditional love which means everything to me.

NOMENCLATURE

2D	Two-dimensional
3D	Three-dimensional
CG	Computer generated
CGI	Computer-generated images
IK	Inverse Kinematics

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE Page

1. INTRODUCTION AND BACKGROUND

1.1 Introduction

In recent years most animation is done using computer-based systems. User friendly software has made it easier to produce animation. A studio or professional equipment is not necessarily needed to be able to create animations. Producing animated movies is becoming widely accessible and a variety of programs are available offering tools which support powerful technical approaches. But these technical achievements are not enough to guarantee successful results. What are the keys to producing unique and successful animation? One is to provide *creativity* and *innovation* in parallel with the technical aspects. The characters of an animation are the story heroes, they deserve significant attention to appear *appealing* and *original*. So creativity and innovation in designing the characters is one of the basic rules for a successful result.

The transition from 2D hand-drawn animation to 3D digital animation has happened in only about 30 years. It has been a rapid transition. As a part of a generation whose childhood favorite animations and hero characters were in 2D, having them all vanish so fast to be replaced by a world of 3D characters, gives me a nostalgic feeling. While the 3D animation environment and its growing capabilities are tempting, I miss the simplicity I grew up with. The allure of older style animation and the nostalgic feeling toward it is not limited to me but belongs to my generation. So, I believe that bringing 2D characteristics into todays 3D animation might be a good way to fulfill that nostalgic feeling.

A benefit of 2D animation is its limitless capabilities. A 3D animated character is a rigged 3D model. The model and the rig both have limits. If the animator wants

to push the character to some extreme poses, the model and rig need to support such poses. For 2D animation, there are no such limits. The animator can draw the character in any extreme pose with no restriction, as in Fig. 1.1.

Figure 1.1: Examples of extreme poses

All the reasons mentioned above, made me decide to create an innovative character style that combines the benefits of both 2D and 3D character design.

1.2 Research Approach

The continuing need for innovation in animation character design and the widespread appreciation of old style animation encourages me to research the creation of a character style which combines 2D and 3D characteristics. To do this I experimented with possible combinations of 2D and 3D characteristics and then selected an appealing combination. Based on the experiment results, I designed and implemented a small cast of animation characters that combine 2D and 3D characteristics.

2. RELATED WORK

The 2012 Oscar winning short animated film *Paperman* [1], produced by Disney Animation, owes its uniqueness to the creative blending of traditional animation and computer animation. Director John Kahrs appreciation for 2D traditional drawings drew his attention to a creative way of bringing 2D brush strokes into 3D animation, see Fig. 2.1. "For many artistic purposes hand-painted imagery can produce a warmth and range of styles that is difficult to achieve with 3D computer rendering" [2]. Director John Kahrs further states:

> "When I came to Disney, one of my first impressions about being here was that, there was drawing everywhere. There is a deep legacy of it being in the final product right up there on the screen there goes back to the very beginning. You know, there is something about that hand of the artist that I really admired so much. It was so expressive and it can tell such a great emotion with such simplicity. When I saw all the preproduction drawings for any show but particularly for Paperman, there were such phenomenal drawings being done of all the characters and it seemed like why do we have to leave these drawings behind, isn't there a way that we can get these drawings to move on top of the CG, can we get the CG to carry those drawings along with them? I mean I feel that we are definitely in a golden age of CG right now, this is explosion of content, beautiful color and appeal, characters are so expressive and alive but as good as, there is part of me that believes that kind of stylized for realism it isn't the only way that computer animation can look, this got to be other ways that animation can look and I feel like bringing the drawing back to it has a great potential." [3]

One early example of combining 2D and 3D elements is one scene in Disneys *Beauty and the beast* [4], Fig. 2.2. This feature animation was one of the earliest traditional animations that employed computer-generated imagery. The animation system used was called *CAPS* [5]. "CAPS was a sophisticated digital platform

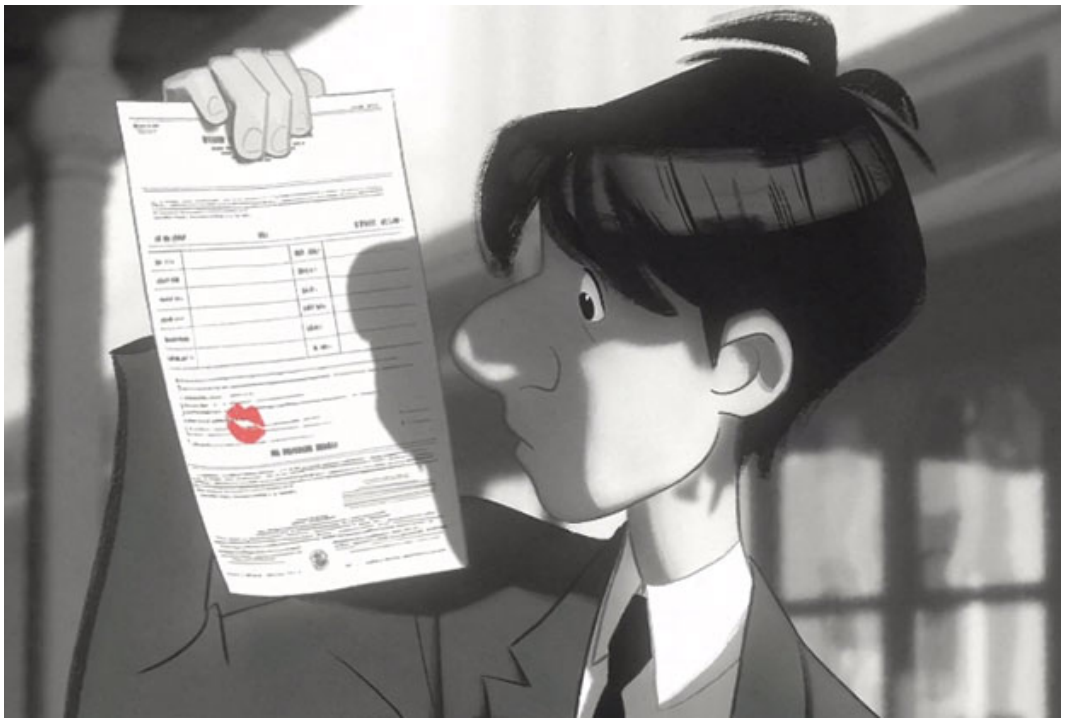

Figure 2.1: 2D brush strokes on top of 3D renders from "Paperman"

developed for Disney by a then little-known company called Pixar, and dedicated to the task of managing and enhancing animation material. It was not used to generate animation: characters and effects were still drawn by hand, frame by frame" [6, p. 271]. CGI plays its role in the ballroom scene, where Belle and the Beast dance through an enchanted 3D environment. The Belle and Beast characters are both traditionally created; they are 2D hand-drawn. "They dance through a computer-generated ballroom as the camera dollies around them in simulated 3D space. The filmmakers had originally decided against the use of computers in favor of traditional animation, but later, when the technology had improved, decided it could be used for the one scene in the ballroom. The success of the ballroom sequence helped convince studio executives to further invest in computer animation" [7, p. 203].

In some cases, combination of techniques is not a matter of creativity, but it is

Figure 2.2: 2D characters in a 3D generated palace from "Beauty and the beast"

used to decrease the cost of production. In such examples, the effort is to blend the two styles so that the end result appears seamless to the audience. "In Dreamworks *Spirit Stallion of the Cimarron* [8], one may not notice that the main horse is sometimes 2D, sometimes 3D. The same goes for many foreground and background characters in the film" [9, p. 94]. In several long and complicated shots of this animation, both 2D and 3D techniques are used within the same shot simultaneously to decrease the production costs, rather than animating the entire shot traditionally [10].

The interest to combine and manipulate environments to create new and more visually interesting environments is not something new. Artists have always been keen to such creativities. *The Cabinet of Dr. Caligari* [11] is a 1920 German silent horror film which was very innovative in its era. The unique characteristic of this movie is the stylized set design with abstract, jagged buildings painted on canvas

backdrops and flats [12]. *The Cabinet of Dr. Caligari* is a live action movie, it is not an animation. But, because of its interesting set design, the environment paintings, and shades of grey makes a nice illusion of 2D design. The contrast between the 2D looking backgrounds and the 3D actors creates an innovative combination, see Fig. 2.3.

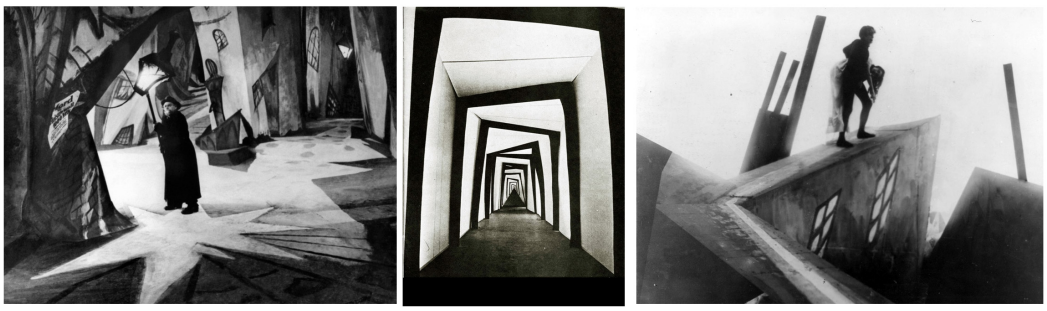

Figure 2.3: Stylized paintings for set design from "The cabinet of Dr. Caligary"

Combining different techniques in one animation, especially the combination of traditional animation and CG animation can create innovative visuals. This approach has the potential to attract a wide range of audience. If carried out successfully, it can incorporate the best of both styles. Major animation studios are paying increasing attention to this and try to outdo each other by producing animations with such novel combinations. For instance, Blue Sky Animation Studio is producing an animation called *Peanuts* [13]. *Peanuts*, to be released in 2015, is inspired by a famous comic strip and TV cartoon under the same name, which ran from October 2, 1950, to February 13, 2000 [14]. So far, only a teaser trailer has been released for this animation. From the teaser screen shots shown in Fig. 2.4, one can detect some key techniques used to imitate the 2D feeling in this 3D animation. One prominent

technique is the use of two layers, with one layer containing Snoopys body and head, and the other containing his features. Another technique is the use of lines to mimic the hand drawn lines used in cartoon strip panels to demonstrate motions [15].

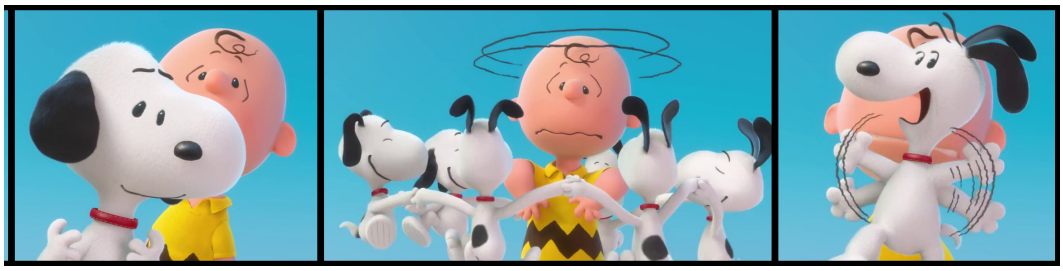

Figure 2.4: Combination of 2D and 3D from "Peanuts"

Another company that is utilizing 2D features in a 3D animation is DreamWorks Animation. The movie is called *Me and My Shadow* [16] and it is to be released in 2016. It is the story of a man and his shadow, where Stan, the shadow, yearns for a more exciting life than being attached to Stanley, a timid human. The film will have a blend of CGI and hand-drawn animation to emphasize the stark difference between the worlds of Stan and Stanley [17]. Fig. 2.5, shows a poster of this movie.

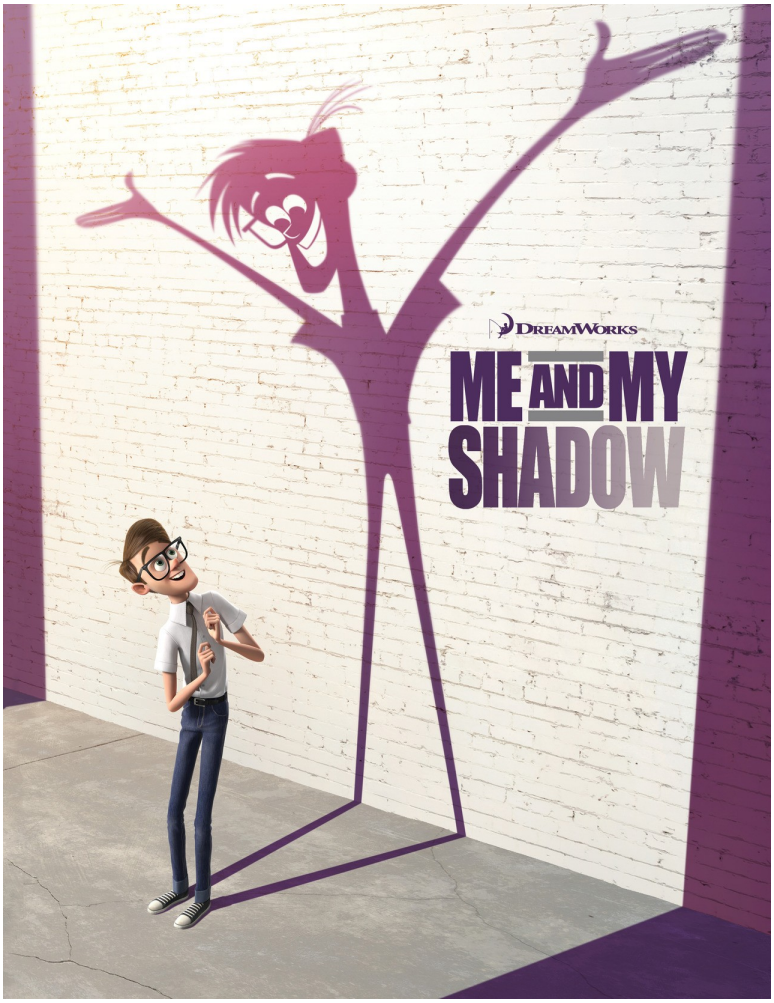

Figure 2.5: Combination of 2D and 3D from “Me and my Shadow”

3. GOALS AND OBJECTIVES

3.1 Goal

Each animated character has a number of body parts such as *head*, *torso*, *arms*, and *legs*. For most animated characters the entire character is created as a 2D character or as a 3D character. The goal of this research is to explore character design styles that combine both 3D and 2D components. For this project I will create a small cast of characters that combine both 3D and 2D parts. The challenge will be developing consistency in design, aesthetics and functionality while integrating 2D and 3D character components.

3.2 Objectives

- To study aspects of animated character visual design
- To analyze the characteristics of a number of animated characters drawn from a variety of animation studios
- To research prior animation character designs combining 2D and 3D components
- To do a number of 2D/3D character design experiments
- To design and create a family of characters informed by my research analysis and experiments
- To create a short animated piece demonstrating the originality, appeal and functionality of this family of characters

4. CHARACTER DESIGN

4.1 Character Design Overview

Creating appealing characters is the specialty of the character designer, although this is often done as a collaborative effort with the animators who will eventually bring the characters to life. You might have seen movies that have been beautifully animated, yet have characters that are ugly or simply uninteresting. In the same way that good acting can't save a bad movie, good animation can't turn an unappealing character into an appealing one. Even villains must have a certain sinister appeal [18, p. 18].

The history of character design dates back to the beginning of storytelling. Each story had one or more characters. However, they weren't initially displayed in a visual form such as an illustration. Each character had its own characteristics and usually a brief description of its appearance. As the audience heard the stories, they got to know the characters. This enabled them to use their imaginations to visualize the characters. Years later, when man started writing down the stories on paper forming books, they began including a few simple illustrations for the reader to see in a general sense what the characters looked like. However, many details were left to the reader's imagination. For instance, the story's main character might be a prince presented in an illustration as a charming man in his royal attire, standing by the window looking outside. Then the story might present the prince in a different situation, for instance sick in bed dressed in pajamas. This would lead the reader to imagine the same prince in a different body posture, with a different facial expression in a different environment. This imaginary view would be entirely based on the way the prince was presented in the first illustration, mixed with the

creativity and imagination of the reader.

When movies became available, the art of storytelling changed and it required a major change in character design. As any story progresses the characteristics of each character are further displayed. The character is presented from different angles, distances and facial expressions, and one can even hear the character's voice. We develop an understanding of the character in different situations. We, the audience, develop a more intimate relationship with the character. With movies presenting so much detail, the role of our imagination becomes less involved. Instead, we replace imaginative skills with our analytical skills, judging whether the characters play their roles up to our expectations.

If the character designer is successful, the character will be believable to the viewer as the designer intended. However the human mind is very sharp, trying to find even the smallest flaw that could cause failure of the character and the designer. Reasons for this failure could be:

- An unappealing design
- Inconsistency of the character's appearance in different shots
- Inconsistency of the character's personality and behavior during the story

Normally, an artist has favorite combinations of sizes, shapes and proportions, which she or he will probably use during their working life, unconsciously or not. A character designer has no such comfortable career. He or she must deliberately and consciously seek variety in character designing, ignoring personal feelings [19, pp. 71-72]. "Character design is no more and no less than creating someone or something that, taken in the context of its environment, will elicit a belief, reaction, or expectation from the audience about the physical make up, disposition and personality of the creation" [20].

Designing a character really refers to the whole process of constructing a visual representation of the character. That process often involves many steps, with the end result being something with which an audience can relate visually. This product can be as mundane as a character on a flyer left on a doorstep advertising the services a handyman, or it can be as complex as the development of the visual designs for a full length animated movie [21]. There are many resources for studying character design. Some focus more on the visuals and the art of drawing. Some discuss more in depth both the visuals and personality of the character and how it should fit in the context of the story. In this research, I will focus primarily on the visual aspects of designing characters with both 2D and 3D aspects.

4.2 Extracting Characteristics from Existing 2D Animated Characters

For this research, I intend to develop a character style in which characters will be modeled in a 3D program while I will integrate characteristics of 2D animated characters. To do this, some of the body components will be created as 3D volumetric geometries and the rest as planes, like pieces of paper which are capable of being folded in 3D space. While these paper-like pieces are literally 3D objects, they don't have volume. They can have the characteristics of a 2D element. Another approach to apply characteristics of 2D designs into 3D, is to have some hand-drawn components added as a layer on top of 3D rendered parts of the body.

Before designing my characters, I studied a number of existing traditional animated characters to extract some of their characteristics. I selected the characters designed by three different animation studios:

- Walt Disney Animation Studio
- Warner Bros. Animation Studio
- UPA Animation Studio

From each studio, I studied a number of characters and found their common features. Basically these features are the extract of their 2D characteristics. Then I used these features as guidelines for designing my hybrid characters.

4.2.1 Walt Disney Animation Studio

Figure 4.1: Examples of characters designed by Walt Disney Animation Studio

Walt Disney animation has always been very popular. Each story's characters, from the earliest features in the 1940's to the most recent ones, no matter the most brutal villains or the loveliest princess heroin, have always been appealing and memorable. The pictures above (Fig. 4.1) show characters from four movies: *Pinocchio* [22], *Alice in Wonderland* [23], *Sleeping Beauty* [24] and *101 Dalmatians* [25] which were produced respectively in 1940, 1951, 1959 and 1996. Prominent characteristics in the creation of these 2D animated characters include:

- In *Pinocchio* and *Alice in Wonderland*, the colors are vibrant and clear, while in *1*01 Dalmatians and *Sleeping Beauty* colors are muted and toned down. They

all share a lack of texture and shadows. Character bodies are all painted with solid color, which makes for easier animating.

- All of the characters have outlines. The color of the outline is usually darker than the fill paint. In a few cases it is lighter.
- With the help of outline and solid colors, characters do not blend into the backgrounds.
- The character's bodies are stylized, but still follow correct and semi-realistic anatomy.

4.2.2 Warner Bros. Animation Studio

Warner Bros. Animation Studio (WBA) is one of the leading producers of animation in the entertainment industry, with an innovative and talent-rich roster boasting some of the most accomplished writers, producers, and artists working today. The studio is on the cutting edge of animation technology, and has both CG and traditionally animated projects [26]. I have selected this work for its simplicity of design. The characters were designed to save time and effort of redrawing them for each frame, see Fig. 4.2. I used the characteristics of this approach to give the old style and nostalgic feeling to my designs.

The outstanding characteristics of this category include:

- There is no texture or shadow on the moving characters. They are painted only with solid colors. The only use of textures and shadows is in the backgrounds or still objects.
- All the characters bodies have a border line which is usually black except for the black body parts, which are outlined with a lighter color.
- Most of the characters are animals.
- There are many exaggerated poses.

- Most of the characters have unrealistic and exaggerated anatomy. For instance, very big oval eyes are a common feature in these characters.

Figure 4.2: Examples of characters designed by Warner Bros. Animation Studio

4.2.3 UPA Animation Studios

United Productions of America, better known as UPA, was an American animation studio active from the 1940s through the 1970s. UPA had a significant impact on animation style, content, and technique. Its innovations were recognized and adopted by the other major animation studios and independent filmmakers all over the world. UPA pioneered the technique of *limited animation*[1]. From this work, I

[1]Limited animation is a process of making animated cartoons that does not redraw entire frames but variably reuses common parts between frames. Its major characteristics is stylized design in all

studied and extracted the features of a character called *Gerald McBoing-Boing* [28]. Gerald McBoing-Boing is an academy award winning short film produced in 1950.

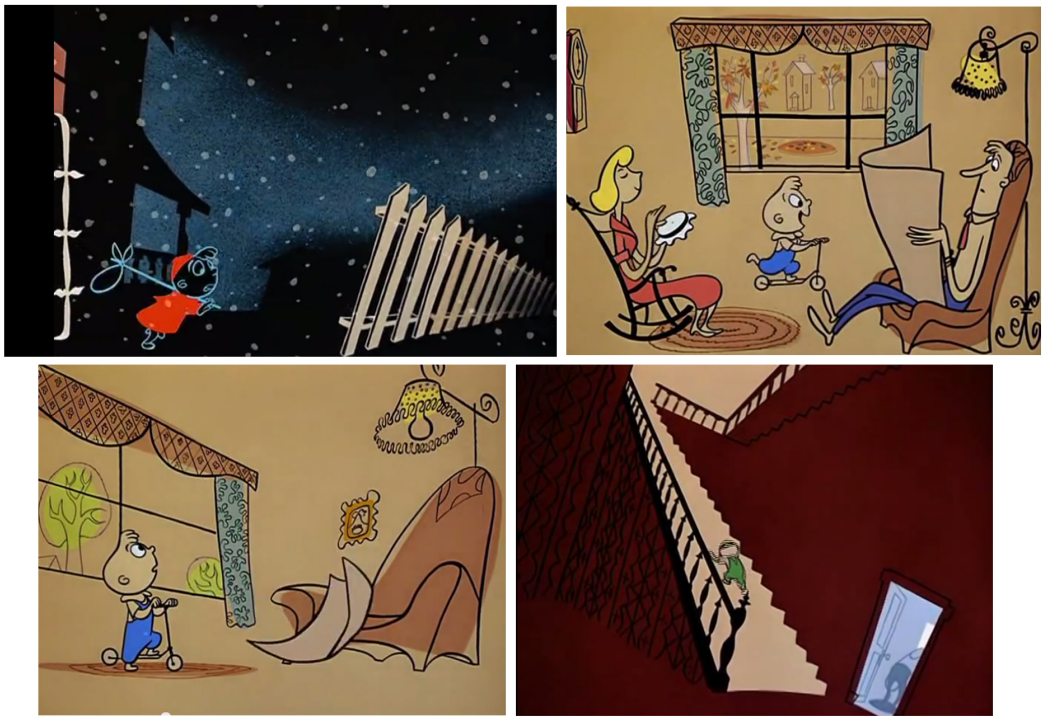

Figure 4.3: "Gerald McBoing-Boing" designed by UPA studio

The most prominent features of this 2D traditional animation, as seen in Fig. 4.3, include:

- The design of characters, environments and also the compositions are all very stylized.
- Outstanding usage of curves is another eye-catching feature in this animation.

forms and shapes [27]

- In most cases, both background and foreground is painted in solid colors. Only rarely is there textures in the still backgrounds.
- The most unique and interesting feature in this short animation is the very prominent border lines for the characters and props. These border lines are not aligned with the inside colors, and create interesting gaps in-between.

5. CHARACTER DESIGN EXPERIMENTS: 2D AND 3D COMPONENT COMBINATIONS

Each character is comprised of several different components. For non-realistic and stylized characters, these components would be simply listed as head, torso, arms, hands, legs, feet and facial features. In this research, the character style I developed is based on the idea of combining both 2D and 3D body parts in the same character. This offers the opportunity for a large variety of possible mixtures. After doing research on a number of existing 2D animated characters and studying their characteristics, a series of experiments was conducted. To achieve the most appealing and practical result, I conducted the following series of experiments.

5.1 Definitions of 2D for This Research

In this research, there are two different definitions of 2D used.

* First definition of 2D refers to the parts which are created in a 2D program. To combine these components with the 3D parts, a compositing program is required.

* Second definition of 2D is assigned to planar surfaces that are created in a 3D environment but because they do not have volume, they are considered 2D. These planes are capable of being folded, bent or twisted; and depending on their placement in relation to the camera, they would have varying visibility.

5.2 Experiment 1 – 3D Head, 2D Body

Having the head as a 3D geometry helps to keep it visible and expressive in all angles. The planar body resembles the simplicity of 2D traditional characters and gives the opportunity to project a texture onto it. From some angles, the planar

components are invisible and the head is the only visible part. Normally, the 2D limbs or torso would bend or twist, which improves their visibility. (Fig. 5.1)

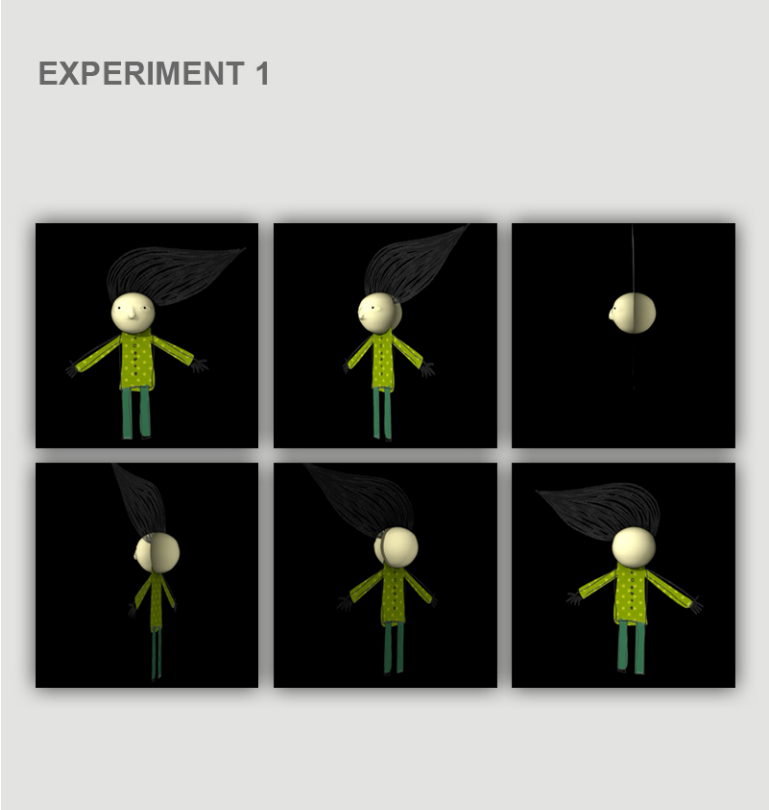

Figure 5.1: Experiment 1

5.3 Experiment 2 – Gradual Transition

Transition of 3D components into 2D might be gradual or sharp. For instance, in this experiment legs and feet are not two discrete objects. The 3D feet transition into planar legs. Similar treatment happens for the arms and also the neck. (Fig. 5.2)

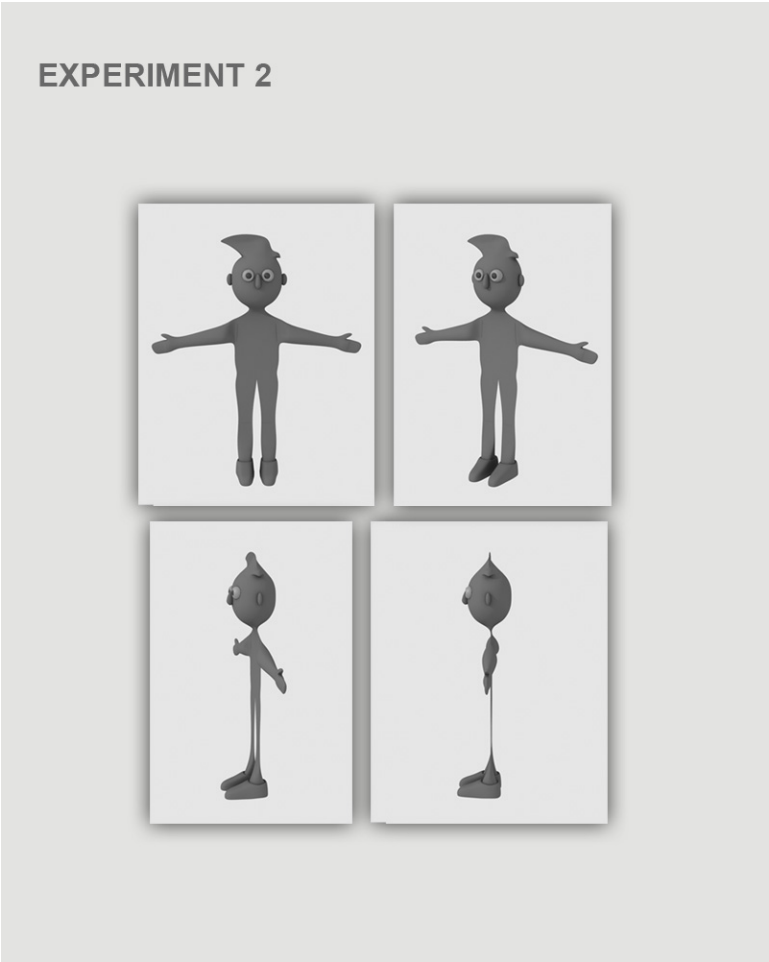

Figure 5.2: Experiment 2

5.4 Experiment 3 – 3D Head and Torso, 2D Limbs

In this experiment the character's head and torso are 3D while the limbs are 2D. The 2D components might have less visibility in some angles. However, they provide the opportunity to be expressive via their shadows. (Fig. 5.3)

5.5 Experiment 4 – 3D Arms, 3D Facial Features, 2D Head, Torso and Legs

In this experiment, the character's head is 2D. 3D facial features lie on a 2D face. 3D arms come out of the 2D torso. (Fig. 5.4)

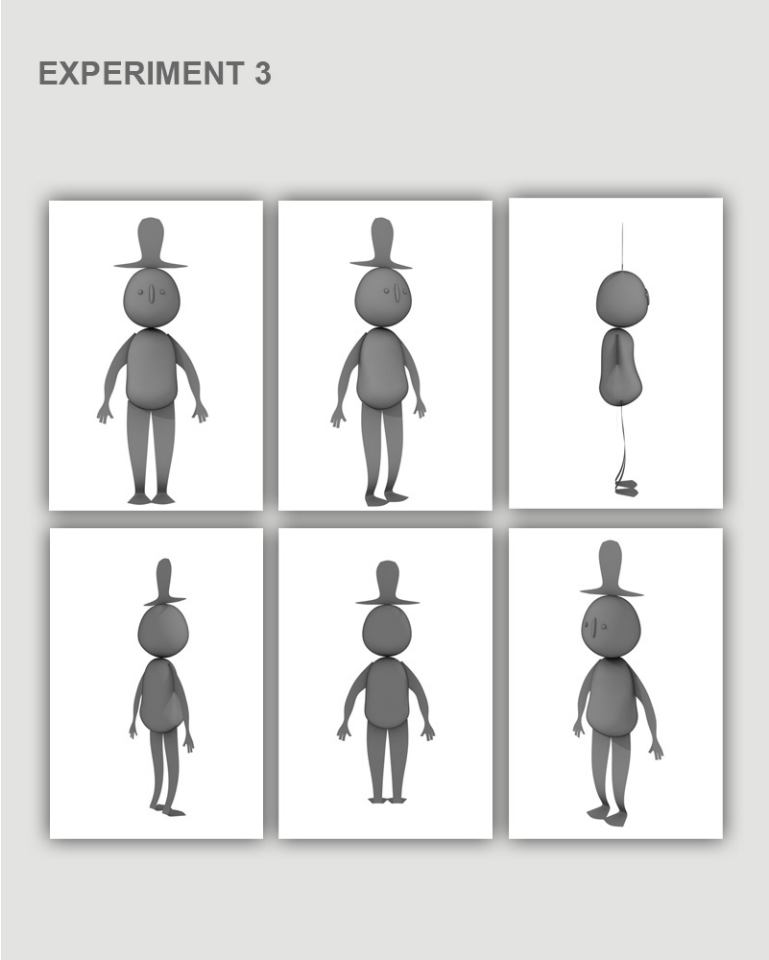

Figure 5.3: Experiment 3

5.6 Experiment 5 – Asymmetry

This experiment was to explore asymmetry in body components. One of the arms is 2D and the other is 3D. Similar asymmetry is applied to the legs as well. (Fig. 5.5)

5.7 Experiment 6 – Outlines

One common characteristic of 2D character design is the use of outlines around each body part. To translate and implement this property into the characters, I

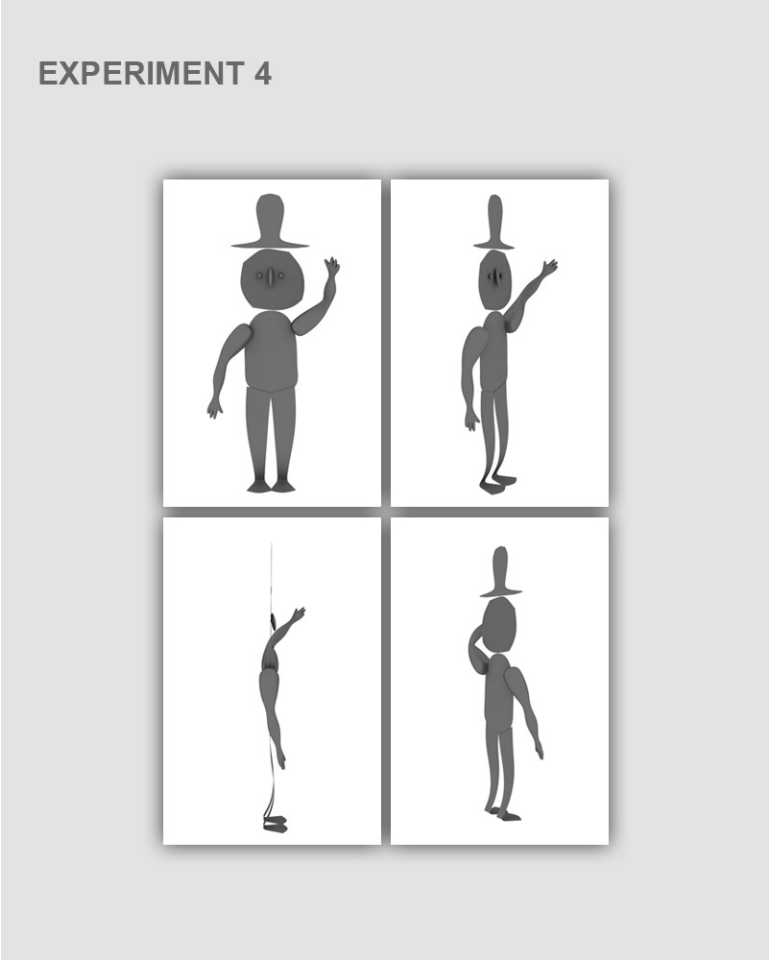

Figure 5.4: Experiment 4

modeled the outlines in Maya [30]. These outlines are flat geometries surrounding the 2D planar components. I modeled them in two different ways, but the results appeared similar. One approach was to model them as tubes (cylinders) around the planar body component, an then flatten the tube. The other approach was to model the outlines with surface planes and shape them as desired. (Fig. 5.6)

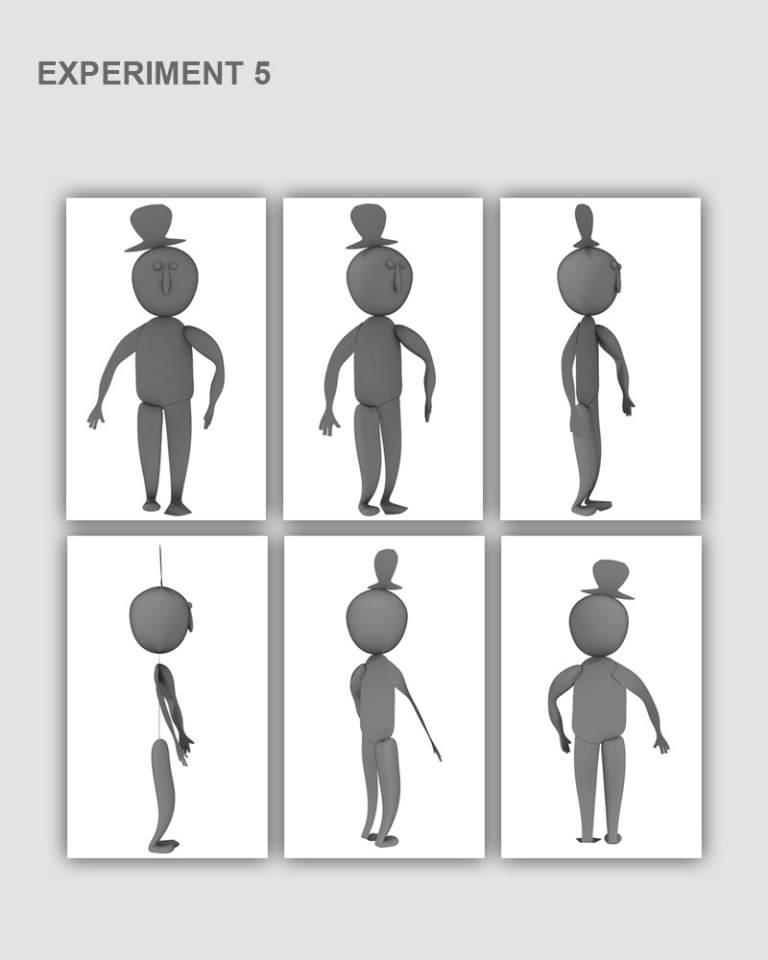

Figure 5.5: Experiment 5

5.8 Experiment 7 – 3D Head, Texture Mapped 2D Facial Features

The purpose of this experiment was exploring the expressiveness of a 3D head with 2D facial features. To do that, some floating planes were placed in front of the head. Then hand-drawn facial features as textures are mapped to each plane. In this experiment the textures were static images, but the planes are capable of having animated textures, if desired. (Fig. 5.7)

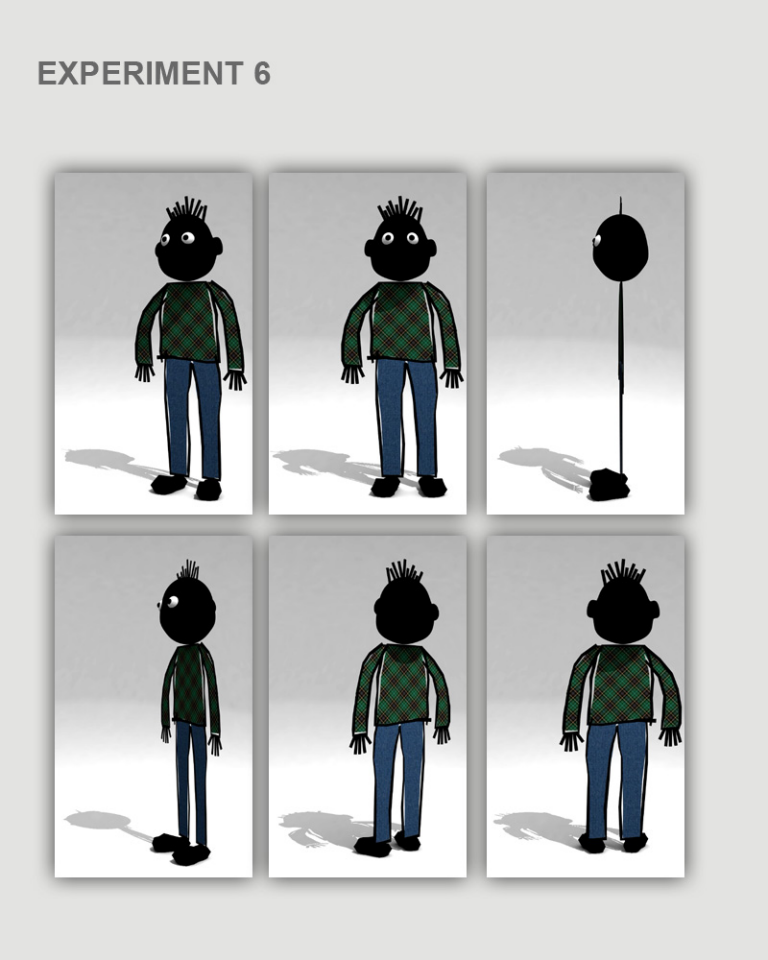

Figure 5.6: Experiment 6

5.9 Experiment 8 – 3D Head, 2D Facial Features with Blend-Shapes

This experiment, again, explores the capabilities of 2D facial features over a 3D head. However, the nose was modeled in 3D along with the head, to make the placement of other facial features easier. Because the 2D features (eyes and mouth) would not be fully visible from all angles, having the 3D nose helps the face read better. In this experiment, blend shapes [1] are used to shape the eyes and mouth.

[1] A method of warping an object to its deformed version.

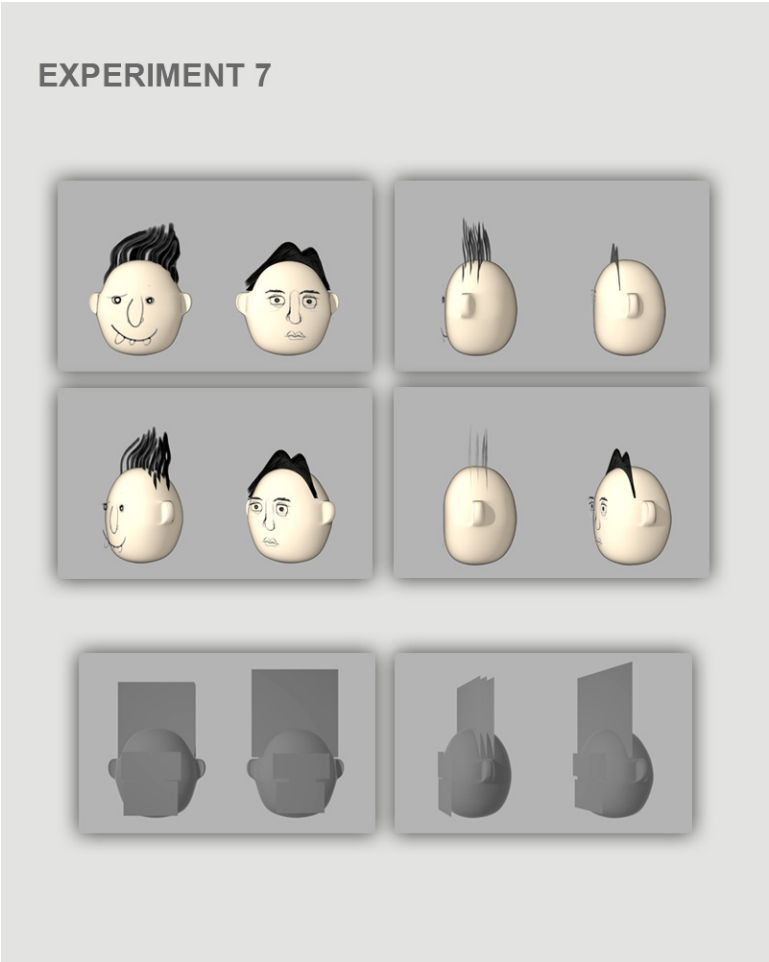

Figure 5.7: Experiment 7

(Fig. 5.8)

5.10 Experiment 9 – 3D Head, 2D Texture Mapped Facial Features with Blend-Shapes

This experiment is a combination of the two previous experiments. The character's head is 3D and facial features, excluding the nose, are 2D floating planes. Static textures are mapped on the eyes and mouth planes. The same planes also have blend-shapes. The textures on the eyes and the mouth follow the geometry

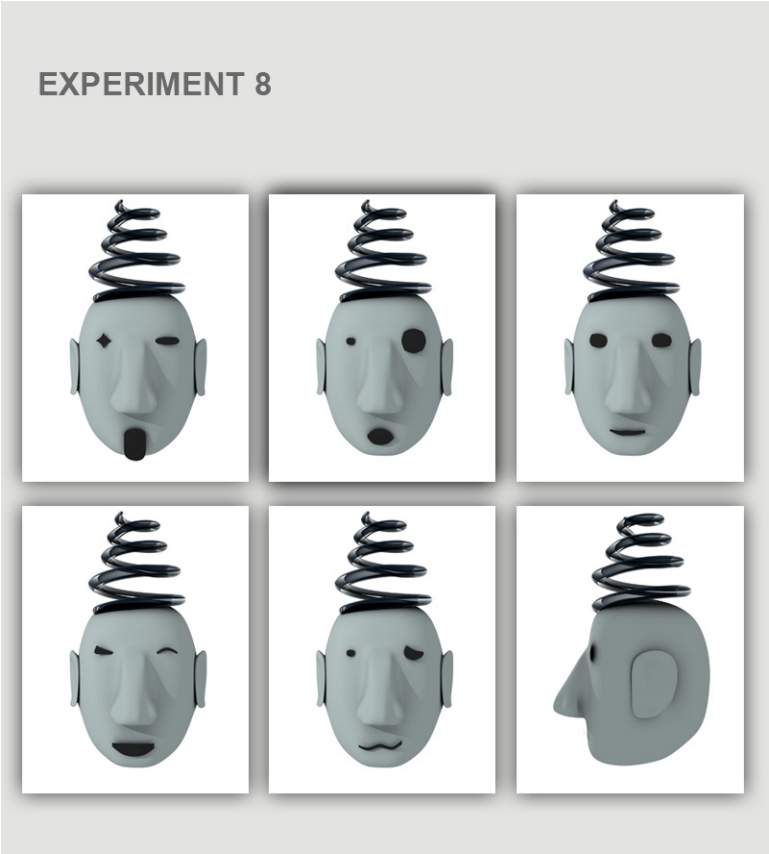

Figure 5.8: Experiment 8

changes when animated with blend-shapes. (Fig. 5.9)

5.11 Experiment 10 – 3D Head and Arms, 2D Body Created in Adobe Flash

In this experiment, 2D and 3D components are each created in different programs and brought together using a third program. In previous experiments, 2D parts were planar surfaces in a 3D environment, in this experiment 2D parts were drawn and animated in *Adobe Flash* [29], and were added to the 3D rendered parts as an overlay layer. (Fig. 5.10)

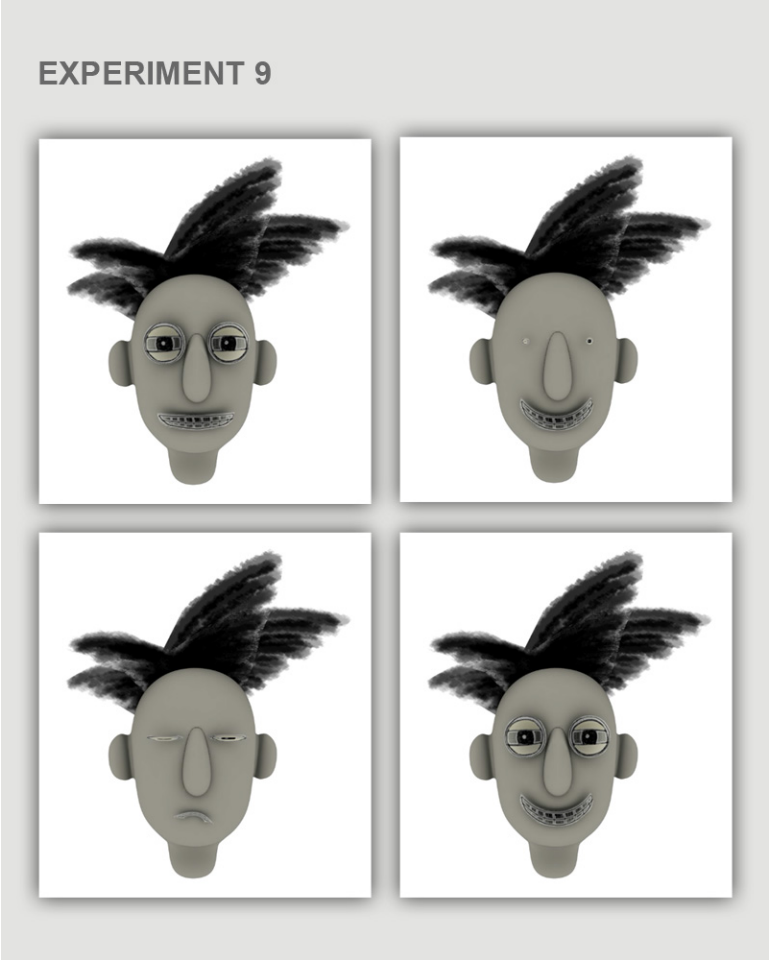

Figure 5.9: Experiment 9

5.12 Experiment 11 – 3D Head and Arms, 2D Body Created in Adobe Flash

This is a similar experiment to the previous one except for the 2D animating technique. In this experiment, 2D body parts were drawn independently for each frame. In the previous experiment, the body parts were drawn once and were key-framed after translating them to a new position or after changing their shapes with motion tween technique. [2] The benefit of this technique is the freedom to draw the

[2] A motion tween is an animation that is created by specifying different values for an object property in different frames

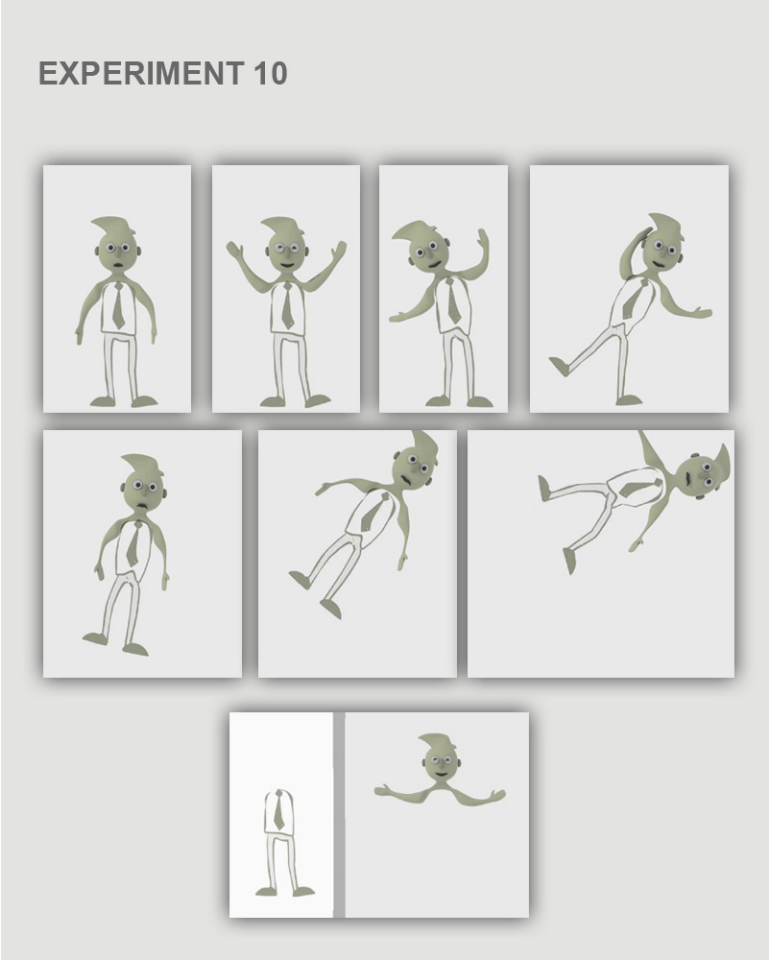

Figure 5.10: Experiment 10

extreme poses. There is no limit in creating forms or gestures when the artist is drawing each frame individually by hand. (Fig. 5.11) As Michael Eisner observed "In animation, there is no limit in what you can do, because it's all about drawing. Your imagination can go unchecked, except as to your discipline on story." [7, p. 203]

Figure 5.11: Experiment 11

5.13 Experiment 12 – Adding Details to a 2D Body Using Parallel Planes

In the previous experiments, the 2D body parts where surfaces with texture mapped details. In this experiment, I developed a way to add more details to the 2D planar parts. For this, I added desired details using additional planar surfaces parallel to the main 2D planar component. This provided the opportunity to add more details as overlays on the body surface. (Fig. 5.12)

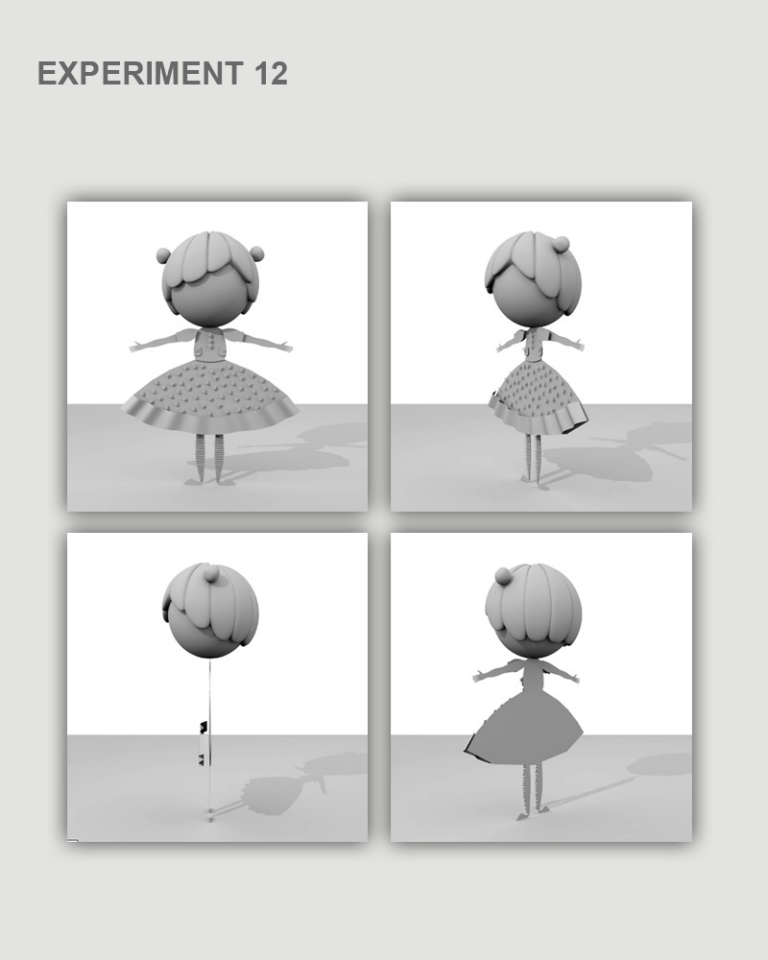

Figure 5.12: Experiment 12

5.14 Experiment 13 – Adding Details to the 2D Body Using Non-Parallel Planes

This experiment was similar to the previous experiment. The only difference is that for this experiment, the added planes are not parallel with the body surface. They are created in various angles which makes a better visibility for the model from different view angles. (Fig. 5.13)

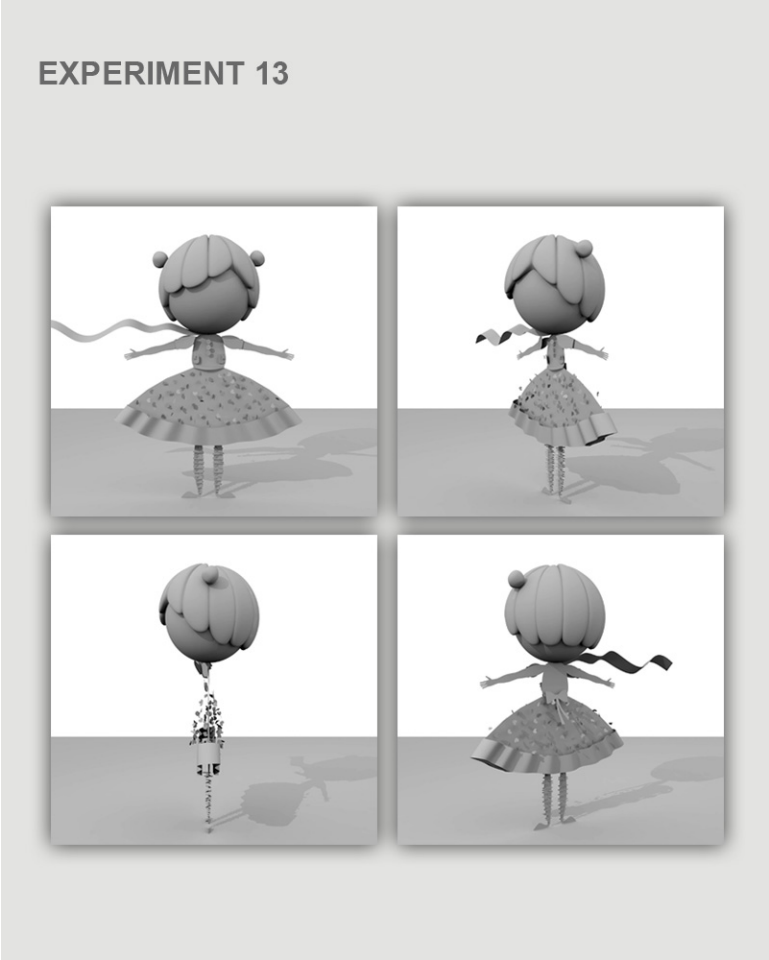

Figure 5.13: Experiment 13

5.15 Experiment 14 – All 2D Planar Body Components

This experiment is demonstrating characters which are entirely made of 2D planar surfaces. Head, torso and limbs, including all details, are 2D. The only 3D aspect in this experiment is the environment. These paper-like characters don't have volume but their existence in the 3D environment enables them to have characteristics that they would not have in a purely 2D environment. (Fig. 5.14)

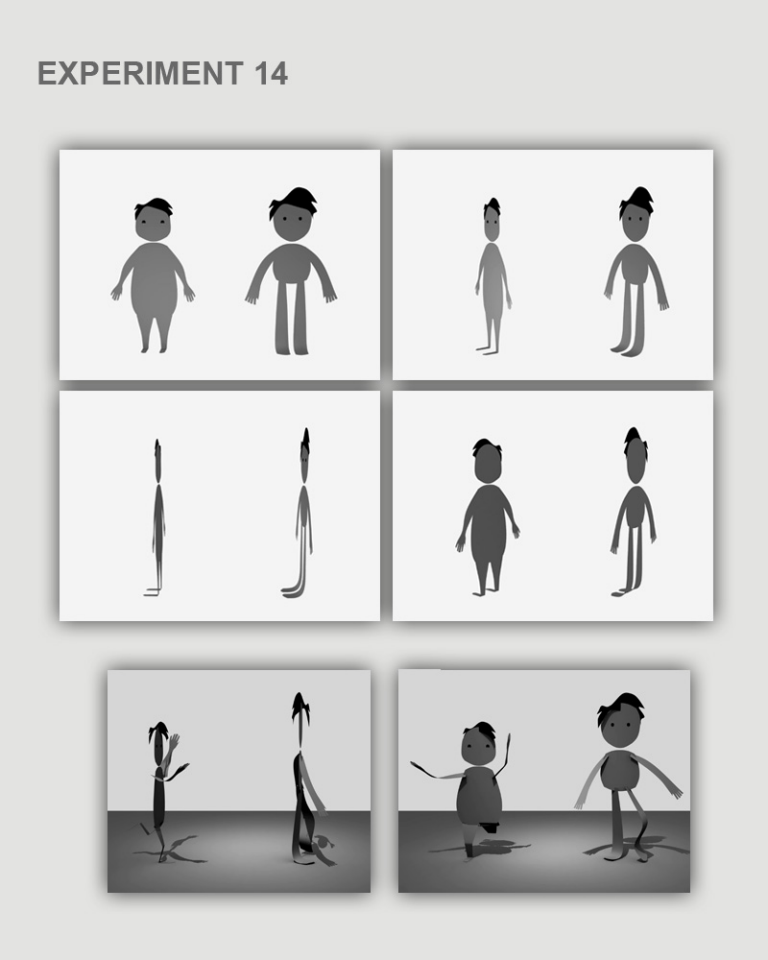

Figure 5.14: Experiment 14

5.16 Experiment 15 – Animating Hand-Drawn Facial Features on Top of 3D Rendered Character with Motion-Tween Technique

This experiment is implemented using 2D facial features created in *Adobe Flash*. The 3D character is modeled, rigged and animated. The rendered 3D animation is used as the reference animation to animate 2D facial features in *Adobe Flash*. 2D facial animation is created with motion-tween technique; meaning the translation of the objects without changing their shapes. (Fig. 5.15)

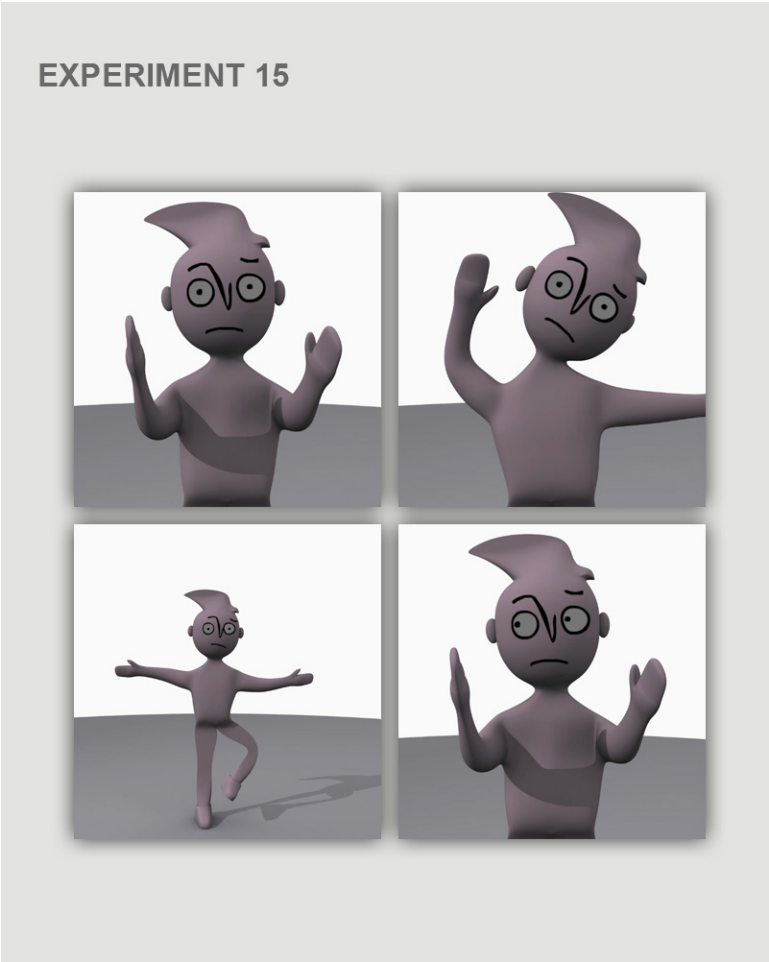

Figure 5.15: Experiment 15

5.17 Experiment 16 – Animating Hand-Drawn Facial Features on Top of 3D Rendered Character with Shape Tween Technique

Very similar to the previous experiment, 2D facial features were created in *Adobe Flash* and were added as an overlay on the 3D body. The difference is the technique of animating the 2D facial features. In this experiment, shape-tween technique is used, which means the 2D objects can change both their positions and shapes. This approach was implemented to emphasis 2D characteristics of facial features. (Fig.

5.16)

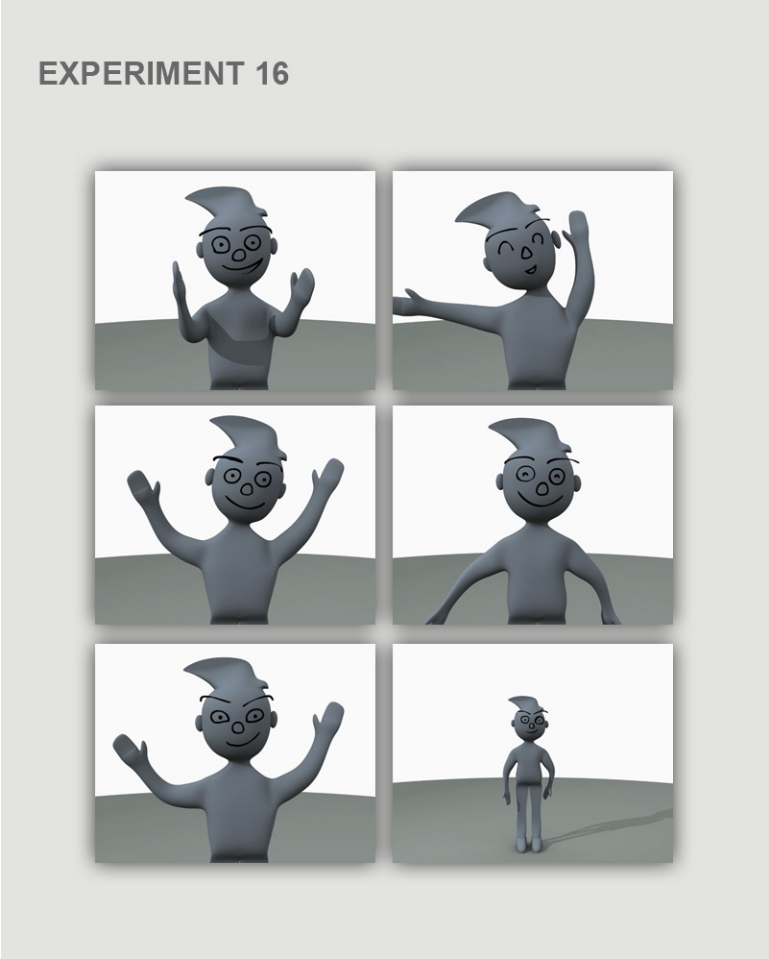

Figure 5.16: Experiment 16

6. IMPLEMENTATION

Based on what was learned from the character design experiments discussed above, an implementation was done to visualize a specific 2D/3D character style and explore its functionality. For this implementation I designed a cast of four different characters partially in *Autodesk Maya* [30] and partially in *Adobe Flash*. I placed them in an environment which I modeled in 3D. Two independent, but synchronized animations were created for the *Flash* parts and the *Maya* parts. In post production, these two animations were composited to create a short film.

6.1 Six Characteristic Used in the Final Character Designs

After doing a research on a number of existing 2D animated characters, and studying their characteristics, a series of experiments were conducted, as stated in the previous section. In each experiment those characteristics were individually applied and tested to check the practicality and appeal of each characteristic. These experiments informed the final character designs.

In the following discussion the final selected combination is presented.

* **3D Head:** The head as a body part that includes the face is usually the most expressive part of the body and needs close attention while designing a character. In this implementation, the character's head is designed 3D to preserve visibility and expressiveness from all angles.

* **2D planar body:** Character bodies are designed as planar surfaces with no volume in a 3D environment. They are capable of being folded or twisted arbitrarily. These planar parts are reminiscent of the simple traditional designs. For example, the feel of traditional cut-out animated characters can be

reproduced in a CG environment.

* **2D facial features:** The facial features are implemented using the first definition of 2D (cf. Section 5.1). The facial features were created in a 2D program, *Adobe Flash*. The 2D facial components are independent of the body parts created in a 3D environment. All the components created in the 3D program are rendered out and together with the 2D facial features imported in a compositing program. Due to the transparency of the facial features layer, they can be overlaid on top the rendered body layer. The key challenge in this design is to synchronize the 2D facial animation with the 3D rendered body animation. With successful timing and proper design, the final character look is consistent.

* **Outlines:** In traditional 2D character design, each body part is usually made with a border line around the shape and a filling color. Because outline is a common characteristic of 2D traditional design. It is implemented in the final designs. Inspired by some traditional 2D animations, the outline used in these designs does not have a constant width. To convey the feel of freehand design, the outline changes in width. Also the outline is not completely aligned with the shape. In some areas the outline follows the shape and in some other areas there are gaps or overlaps between the outline and filling.

* **Parallel planes for adding details:** A 2D body made of a planar surface is not capable of many design details. For example an oval plane as torso and four rectangles as limbs can be reminiscent of a basic body. Changing the shapes and refining the edges of each component might improve the design. Mapping a texture with painted details is the most we can add to make it look like a body. But is this enough? From angles where visibility of the 2D body is partially lost, the details on the texture will also be lost. In this research, the

solution offered is to add planes to the body. These planes would be created with different shapes and sizes parallel to the body plane, floating in front of, or behind the body at a small distance. For example, if the texture on the character's body is like a shirt, the pockets on the shirt can be two small planes shaped like pockets, floating in front of the character's chest. This not only gives the opportunity to add details, but gives the character a fresh and unique look. Another benefit to this approach is that since these parallel planes positions are slightly different, while the visibility of the body decreases from some angles, these floating planes will help improve the clarity of the design.

* **3D feet or shoes:** Because the designed characters have 3D heads and 2D planar bodies, when the 2D components are perpendicular to the camera view, their visibility and clarity is reduced. From these angles the head is a volumetric 3D object while the body could look as thin as a line. To visually balance the weight of the head, the solution offered in this research is to add another visually heavy component on the other end of the body. So, the feet or shoes of the character are designed in 3D. This approach helps to maintain the balance of design. It also improves the clarity to the characters position where the 2D legs are less visible.

6.2 Designing a Set of Four Characters

After making the decision about an appealing and practical combination of 2D and 3D components and how to implement all the extracted characteristics of 2D traditional animated characters (cf. Section 4.2), it is time to design the characters. For this research it will not suffice to design only one character. To demonstrate the capabilities of this innovative style and show how it is possible to design different characters (in terms of sex, age, bipedalism or quadrupedalism) while maintaining

consistency of style I designed a set of four characters as a family.

6.3 Concept Art

For this project I designed a set of four characters as a family, including a father, twin daughters and a pet donkey. Respectively they are named Mr. Crisp, Lisa, Melanie and Hank. I started by doing sketches. Each set of sketches had different stylized characteristics. I tried to keep the characters stylized with limited details so they would match the style of 2D characters, see Fig 6.1. From all the sketches I chose one for each character and painted concept art using *Adobe Photoshop* [31], as shown in Fig. 6.2.

Figure 6.1: Initial sketches for the concept art

6.4 Modeling

Modeling my characters was a relatively easy and quick part of the process. The 2D components do not have complicated geometry. Normal 3D modeling needs sketches of three views of the character (front view, side view and top view). The 2D parts that I modeled in Maya were planar surfaces only visible in front view. For the side and top views, the 2D components were not visible. So, I needed to create planes and refine their shapes only in the front view. Modeling the 3D components

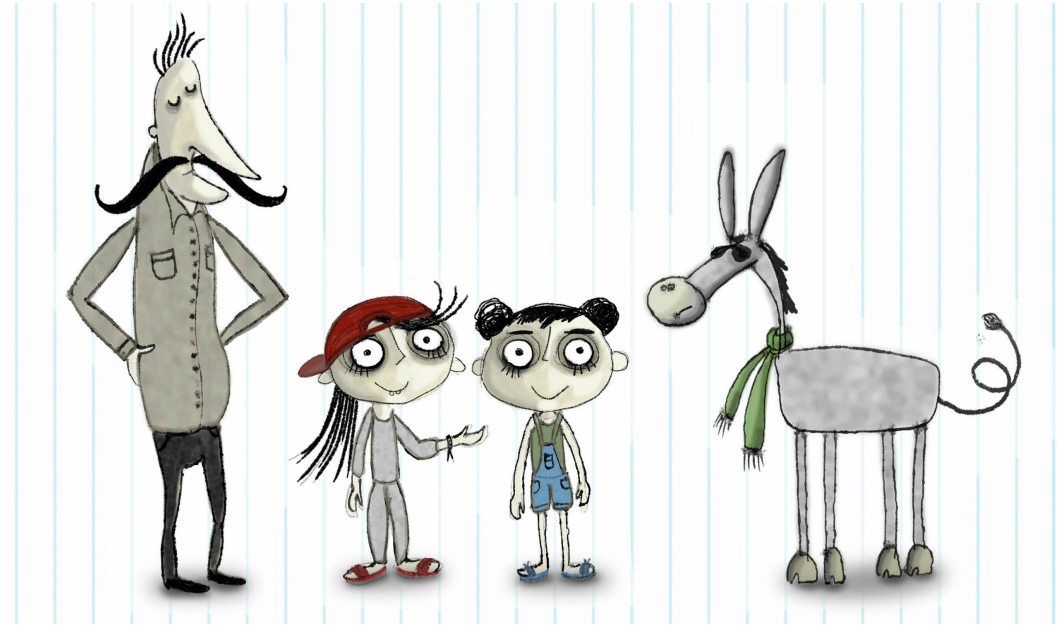

Figure 6.2: The final concept art for "The Crisp Family"

was similar to normal 3D modeling.

The only modeling challenge I encountered was in creating the outlines. Outlines were meant to resemble freehand drawings, so they needed to have varying width. Also they needed to not follow the border of each plane shape perfectly. They were to create random gaps and overlaps to look more hand-drawn. The issue that I faced was a flickering effect that occurred in renders of the overlapping parts. Where the two surfaces with different textures were overlapping each other, as shown in Fig. 6.3, the rendered area would appear to flicker. To fix this issue, I decided to leave the gaps in between the outline and inside part as before, but remove the overlapping parts. So the finals outlines are either a short distance from the inside planes, or are tangent with them.

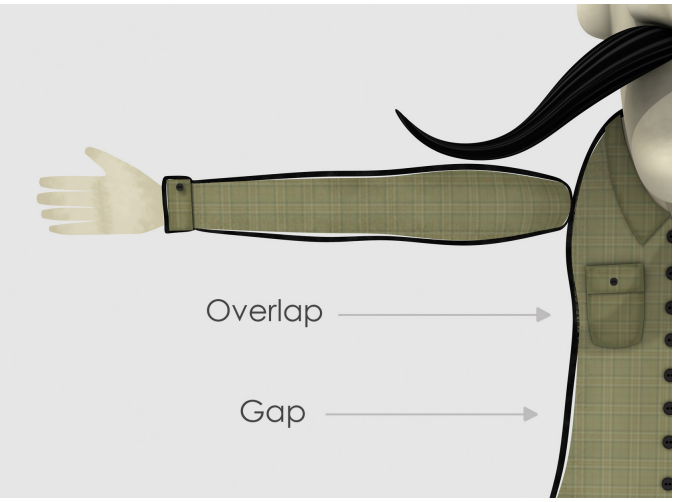

Figure 6.3: A modeling issue: flicker on the overlaps of outlines and the planar surfaces

6.5 Facial Features

Various 2D facial features were drawn and tested on the rendered characters, as shown in Fig. 6.4. Some of the designs are more detailed and with the help of shadows look 3D, some are more simple and stylized. Because in this research I was trying to demonstrate the different characteristics of 2D and 3D, I decided that the most stylized facial features, which are only black lines, would look the most 2D and will present a better contrast with the 3D heads. (Fig. 6.4)

6.6 Texturing

To texture and shade a model, the first step is to unwrap the UV coordinates. UV unwrapping is one of the least popular parts of the process. Fortunately in this project, due to the use of 2D planar surfaces, UV unwrapping was simpler compared to unwrapping fully 3D models.

The only challenge that I faced during the texturing process was the fact that textures mapped on a 2D plane were displayed on both sides of the surface. To

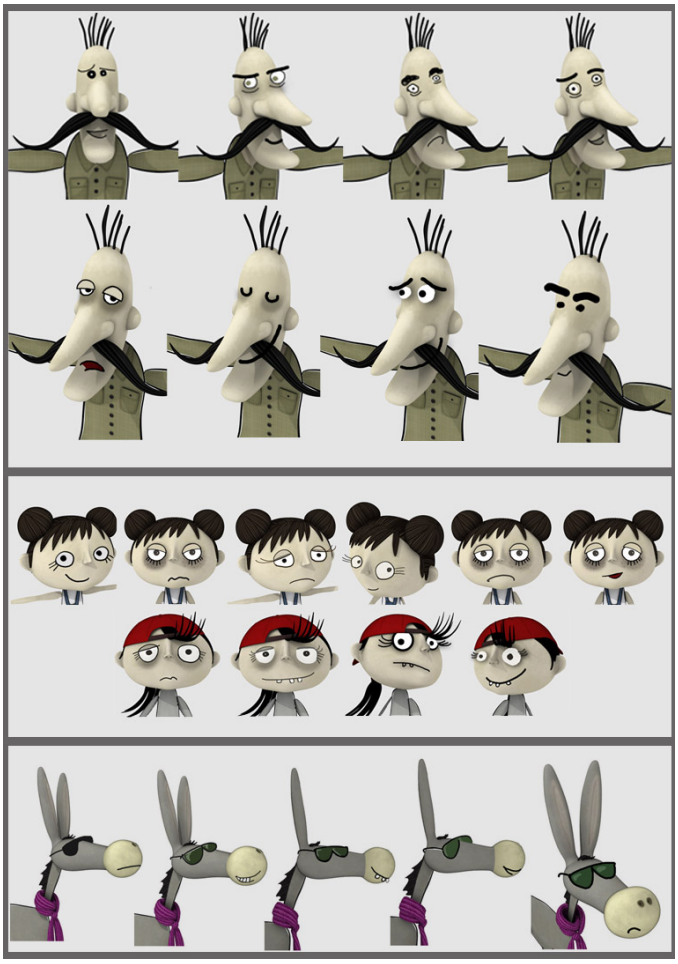

Figure 6.4: Experimenting different 2D facial features on each character

overcome this issue I tried two different approaches. The first was avoiding painting specific textures that had text or signs because these would reveal the issue easily. Instead, I used general textures that looked normal from both sides. The second approach was using parallel planes spaced at a very close distance. This provided two surfaces that could each hold a texture.

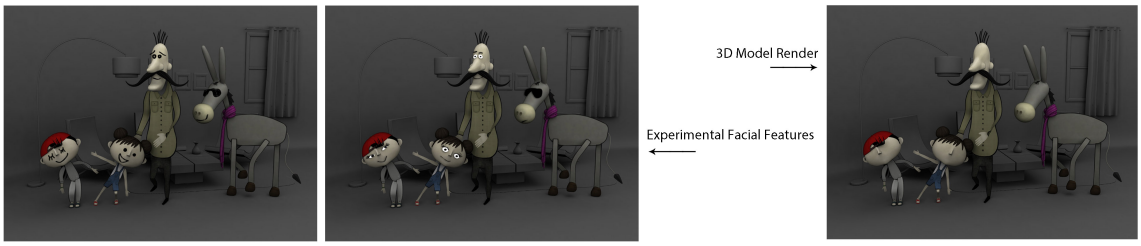

Figure 6.5: Right: A render of all 3D characters Left: Experimenting 2D facial features on 3D rendered characters

6.7 Rigging

All four characters I created for this project were rigged by Sean Low. He indicated some unique challenges encountered while rigging these characters due to the combination of 2D and 3D features:

1. The arms are flat from the top view and the legs are flat from the side view. Normally he would place the joint inside 3D the meshes but in this case, he needed to place the elbow and knee joints outside of the meshes, so that they will form a slight angle for the benefit of IK construction[1].

2. The body parts are not attached to each other. The rig needs to be flexible enough to let each body component move apart from the others, to assist the animator manipulating the character pose. Again, this was different from the rigging he normally does.

3. The costume accessories (pockets) need to be deformed according to the body movement. But at the same time, occasionally they need to be offset from the body for better visualization. Therefore, the nature of this relationship creates

[1]IK or Inverse Kinematics is a rigging method which allows to position the last bone in a bone chain and the other bones are positioned automatically and simplifies the animation process

a counter effect or double transformation. To solve this, he wrote a simple script for the animator to execute whenever they need to offset the accessories parts.

6.8 Animating

After designing, modeling and rigging the characters, the next step was to animate them and explore their capabilities. For this project, I made a short animation with all four characters taking part in a story. Each character with poses, movement and facial expression was contributing in the animation while being tested for functionality. To create the short animation I started by animating the 3D parts in Maya. The process was completely similar to usual 3D character animating. Then I rendered out the animation and imported it to Adobe Flash as a movie file.

Adobe Flash is a multimedia platform used for producing 2D vector graphics and animations. I used the movie file as the reference layer for synchronizing the 2D facial components with the 3D animated characters. To animate the 2D facial features I tried two different approaches and explored which one was a better fit to my character's style. The first approach was designing keyframe facial features and employing the 2D program to create in-between frames. This led to a smooth 2D animation with facial features smoothly following the 3D animated head. The second approach is more similar to traditional animation where each frame is separately hand-drawn. For this I used an option called *Onion Skin*[2] in Adobe Flash, which allows a process similar to cell animation. Each frame is drawn in a transparent page where the previous frame is visible. Hand-drawing each frame individually leads to a less smooth animation which resembles old style animations or flipbooks.

I tried the two different approaches and compared the results. The second ap-

[2]Onion Skin is a technique used in creating animated cartoons which allows the animator to see several frames at once.

proach, which resulted in a slightly jumpy animation similar to stop motion style, had an interesting contrast with the underlying smooth 3D animation. Also, this approach emphasized the hand-drawn characteristics of the facial features, which I desired. After finishing the facial animation, I rendered it out as a separate layer. 2D animation and 3D animation were separately ready to be composited for the final animation.

6.9 Compositing

2D facial animation and 3D animation were created separately. I used the *Adobe AfterEffects* [32] program to import both animations and composite them together, and added the audio. Compositing did not involve any special challenges related to these specific characters and the process was similar to the usual compositings in which layers are added to each other.

7. RESULTS AND EVALUATION

7.1 Results

The primary goal of this research was to create a hybrid character design style bringing 2D and 3D characteristics together; creating characters with a fresh and new look which are functional and animatable. Based on studying existing successful animated characters and their characteristics, I developed some guidelines to create such a fusion. Considering both aesthetics and practicality, I decided which body components would benefit from the 2D and which parts from 3D characteristics. I believe the result was close to the established goal and fulfilled the expectations.

Having some flat components, made the characters appear different in various angles. Hand-drawn face features makes the characters seem more akin to traditional animated characters. Intentionally, I designed the facial features not to follow physical and perspective rules; exaggerating the facial expressions, breaking perspective rules, such as seeing both eyes in the side view of the face, and breaking physical rules, such as having the facial features floating out of the face area, as shown in Fig. 7.1. These actions can be named among the benefits of this approach. The combination of these characteristics has given a unique and interesting look to the characters and makes them different from the most characters we see in animations.

To animate the facial features, I experimented with two different approaches to explore which one fits the style of my characters better. The first method, as Adobe Flash names it, is *motion tweening*. There I designed the facial features and with the help of the program, keyframed them. The in-between frames were generated by the program, and thereby made a smooth animation such that 2D facial features smoothly followed the 3D under-laying animation. The other approach was more

Figure 7.1: 2D facial features are breaking physical rules: Both eyes can be in the same side of the face, eyes and eyebrows can float around the face

similar to traditional animation in which each frame is individually hand drawn. This method takes longer to create and if each frame is not perfectly drawn based on the previous frame, the result is more like economic old TV animations. The motions look a bit jumpy. I tried both approaches and studied them. Finally I chose the second method with less smooth motions, because of the vivid contrast it creates between the smooth 3D animation and jittery 2D animation. The emphasis on the hand-drawn characteristics of the 2D animation is what I accomplished with this method.

7.2 Evaluation

Although the result of this project was satisfying, still there are some points that I would do a bit differently if I were to redo the project. The first thing is the outlines, which played a major role in making the characters look traditional. If I were to improve the project I would take more advantage of the outlines. I would do

more variation on the width of the outlines and exaggerate the random gaps between the outlines and inside color. The gaps create an appealing trait where viewer could sometimes see through the parts of the character's body. In their current size, it is not very noticeable. So creating a more prominent outline with bigger gaps where the outlines are not aligned with the fill color is the first thing I would try to improve the characters.

The 2D animation style that I chose for the faces was a time-and-labor-intensive method. It took a long time to create the animation frame by frame. But, compared to the more automated method, the result was more satisfying for my project's specific style. If I were to do a similar project again, I would do more experiments to find another approach for the 2D facial animation with similar result but less work.

8. CONCLUSIONS AND FUTURE WORK

My research has focused on bringing the characteristics of 2D character design into 3D animation. I have proposed a number of ways to create characters that bridge between the 2D and 3D realms.

An area that deserves exploration is the utilization of a similar approach for combining 2D animation with live action video. The characters of a movie (the actors), both human and animals, could have an innovative and creative look if combined with 2D animation. The idea is to replace the character's facial features with 2D drawings, similar to an approach described earlier in this paper. The live action video, where characters play their role, is the backdrop. The drawn 2D facial features are then animated over the video. Such a combination could not only give a new look to the piece, but also provides the opportunity for creative facial animation. Hand-drawn facial features do not need to follow the physical limitations of a real face. The animators can do exaggeration and use facial expressions that are not possible in live action, see for example Figs. 8.1 and 8.2.

Figure 8.1: 2D facial features on live action movie characters

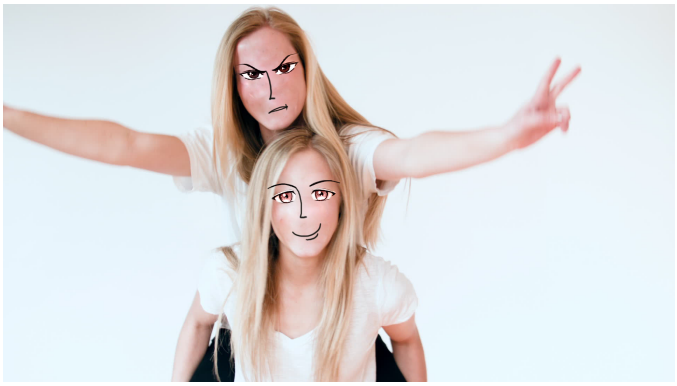

Figure 8.2: 2D facial features on live action movie characters

Another idea is to overlay 2D hand-drawn apparel animation on top of a 3D character's body. Fig. 8.3 below is an example. Flatness of 2D apparel will create an appealing contrast with the 3D body.

Figure 8.3: 2D apparel on top of 3D character

Another idea that could be applied to live action actors is using brush strokes, similar to the technique, used in Disney's *Paperman*. This approach was briefly discussed earlier in this paper. Brush strokes can have characteristics of 2D design.

If added appropriately over live action video, this creates a unique contrast and may result in an interesting look. See Figs. 8.4 and 8.5 for examples.

Figure 8.4: Freehand brush strokes around live action characters

Figure 8.5: Freehand brush strokes around live action characters

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