Smearframes in Video Games

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MASTERARBEIT

eingereicht am
Fachhochschul-Masterstudiengang

Digital Arts

in Hagenberg

im September 2018

Declaration

I hereby declare and confirm that this thesis is entirely the result of my own original work. Where other sources of information have been used, they have been indicated as such and properly acknowledged. I further declare that this or similar work has not been submitted for credit elsewhere.

Hagenberg, September 20, 2018

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Contents

Abstract

This thesis is about an animation technique called smearframes and how it is used in computer games. The term describes an abstracted type of motion blur that originated in the early days of 2D cartoons. Since smearframes have not yet been scientifically described, the text starts off covering their history and the state of the art to show what they are and how they are used. Also, this text explores why smearframes work by looking at how the eye perceives the illusion of film. This knowledge is key to understanding how to craft a smearframe. The text continues with a definition and the classification of different smearframe types. After the basics are laid out, the text analyzes the use of smearframes in the game *Overwatch* (2016, Blizzard Entertainment). The game has a very stylized aesthetic and often makes use of smearframes. Furthermore, the creators of the game expanded the lore with different mediums including 2D, 3D, and stop-motion animation. This makes it ideal to compare the use of smearframes in different mediums.

Kurzfassung

Diese Arbeit befasst sich mit einer Animationstechnik namens Smearframe und wie diese in Computerspielen verwendet wird. Die Bezeichnung beschreibt eine abstrahierte Art von Bewegungsunschärfe, die in den Anfängen der 2D Animation entwickelt wurde. Nachdem diese noch nicht wissenschaftlich beschrieben wurde, fängt der Text, an die Geschichte und die aktuelle Verwendung zu beschreiben. Außerdem wird behandelt, wie ein Smearframe erstellt wird, und worauf geachtet werden muss. Die Grundlage dafür bildet die menschliche Wahrnehmung. Weiters wird der Begriff Smearframe definiert und in verschiedene Kategorien unterteilt. Nachdem das geschehen ist, wird die Verwendung von Smearframes im Videospiel Overwatch (2016, Blizzard Entertainment) analysiert. Dieses Spiel eignet sich besonders dafür, weil es neben dem Spiel selbst die Geschichte mit verschiedenen Animationen erweitert.

Chapter 1

A Brief History

Smearframes are essentially a type of motion blur in animation. A proper definition and what differentiates a smearframe from motion blur is described in chapter 4. The technique of smearframes was not invented with animation. It took some time for this unique visual style to develop. The following pages should give a basic understanding of where smearframes originated from.

1.1 Film

It started with the recreation of motion blur on cels by creating a lot of streaks along the path of movement. An example for this can be found in the 1935 Disney short, *The Tortoise and the Hare* [43], as seen in figure 1.1 (a). It tried to mimic the motion blur as seen in film cameras. This was done by using a dry brush to distribute the fresh ink along the path of motion. The downside to this technique was that is was very costly. As a result, the much tighter budgets at *Warner Bros* called for a new way of doing things. So the elongated inbetween was invented. This meant that for a frame or two, the character would be stretched from the starting pose into the target pose. The first movie with this abstraction of a motion blur was called *The Dover Boys at Pimento University* [38] seen in figure 1.1 (b).

This technique made animation a lot cheaper for two reasons. First is of course that this type of motion blur did not require an extra artist creating the blur effect. The not so obvious reason is, that the animator has to draw less frames to come from one pose to the other. Traditional Disney animation would create multiple inbetween poses to create very fluid motion which is also very labour intensive and thus costly. With the elongated inbetween, the animator only has to draw about 3 frames to get to the next pose which can be held still afterward. Due to this drastic saving in work hours it was considered lazy animation at first [51]. But as time went on it was discovered as a tool to create a certain style of animation.

Some time after the creation of the first elongated inbetween, another technique was invented called multiples. In this type of smearframe a shape or a part of it is duplicated multiple times. Unfortunately no specific date can be given for its invention. However it is the *Looney Tunes* characters that are mostly associated with multiples. So multiples must have come shortly after elongated inbetween. The difference between elongated

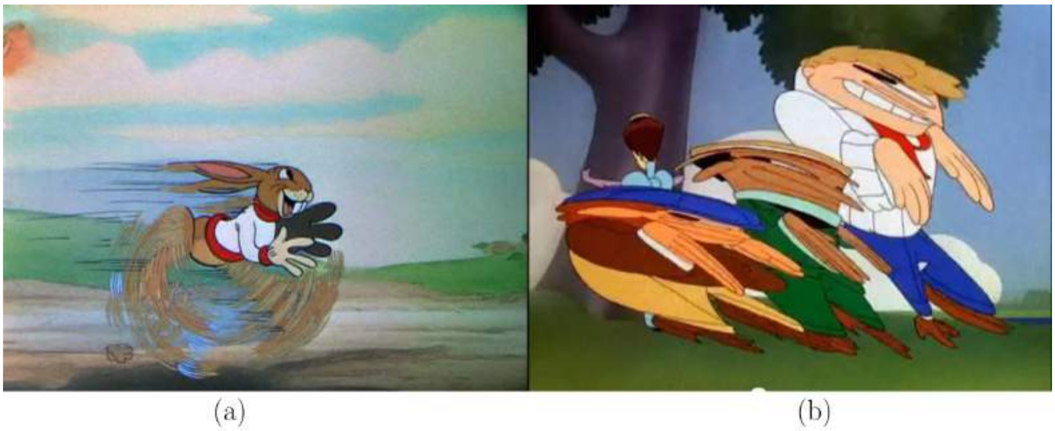

Figure 1.1: On the left is a frame from Disney's *The Tortoise and the Hare*[43] (a). The process of creating this type of motion blur was very expensive and time consuming. Image (b) shows a frame from a Chuck Jones short, *The Dover Boys at Pimento University* [38]. Note the difference in abstraction of the motion blur. The Dover Boys at Pimento University marks the first use of an abstracted motion blur that can be considered a smearframe. Images from [50].

inbetweens and multiples is that multiples do not necessarily blur the image. As the name suggests, it rather multiplies the object or a part of it. This is particularly helpful in staccato movements, where an object or character is vibrating violently. However it can also be used more as an elongated inbetween like in *ParaNorman* [30] which can be seen in figure 2.7.

Until the dawn of the CG era, there has not been another breakthrough in smearframes. Even though it was refined in TV shows like *Looney Tunes*, the concept stayed pretty much the same. But even after *Toy Story* started the CG era, it took a lot longer until smearframes in CG became reality. The problem with this technique is that it requires sophisticated underlying rigs in order to deform the geometry in the necessary way to convey a smear. In the starting days, the software and processing power just was not up to the task. The first film that embraced the power of smearframes is *The Incredibles* [40]. However the style of smears is very different in CG animation, again due to technical reasons. Usually technically less sophisticated approach to smearframes is used, where the geometry is slightly elongated or shortened to give the impression of a smear. Furthermore, there is usually a lot of motion blur that is realistically calculated. So the need for smearframes is somewhat reduced.

1.2 Games

For games it is very hard to track down a history on smearframes. Games have only been around since the 1960s and due to processing power had very strict limitations. Only in the last two decades computers got strong enough to handle proper graphics that would allow for detailed animation and thus smearing. Looking at a list of the 50 most significant games by *GamesRadar* [56], there are only a handful that use smearframes. Most of them as motion trails, which will be discussed further in chapter 5. Even now

Figure 1.2: An example for a smearframe in the game *Jak and Daxter* [20]. It is typical for games that the geometry is wildly distorted. This has technical reasons as the geometry is deformed by a rig that limits the possible range of motion. For example an arm might only be able to be lengthened in one direction due to these limitations. Images were taken from Youtube [35].

that the processing power is there, there is hardly any smear animation happening. That is due to the fact that not every genre of game can have smears. Smearframes tend to be more stylized so the standard realistic first person shooter has no use for it. Also smears need to be targeted at the camera, which is very hard to do with a camera that is controlled by the user. it is mostly 2D games with a camera that is locked to one side that managed to do smears.

A very early example for a smearframe in a game is the 1991 classic *Sonic the Hedgehog* [33]. It is a 2D sidescroller with sprite animations. The smearing is very minimal and only appears on the feet of the main character when he is running. Due to the fast speed and the low frame rate the feet need to be blurred into a circular shape in order to convey the fast running motion. Fighting games provide another example where games made use of smearframes early on. Due to the fact that fighting games rely heavily on animation to sell the strength of a character one would assume that smearframes became standard very quickly. However it was not until 1999 that *Street Fighter III: 3rd Strike* [36] came out. It was the first game in the series that featured noteworthy smearframes on attack animations.

Advancing into the 3D era the first notable example for a smearframe is *Crash Bandicoot* [15]. It used multiples as well as motion trails when the character is spinning very quickly. Although the camera is not locked off, the motion that includes the smear is confined to a very limited space in the center of the screen. The camera always rotates around the the character, leaving the smear always in the center of the screen. The same studio that made *Crash Bandicoot* created *Jak and Daxter* [20] in 2001. It has similar gameplay elements like *Crash Bandicoot*, but in a more open world. The game is famous for its very snappy cartoony animation style which can be seen in figure 1.2. However it uses mostly a type of smear where the character is squashed and stretched. Unlike *Crash Bandicoot* it does not utilize multiples. The ability to properly squash and stretch a character within a game opens new possibilities in character animation. With the release of a new generation of consoles in 2006 and their grown processing power came a demand for realistic looking games. Unfortunately the crazy stretching animation of *Jak and Daxter* had no place there anymore. However Nintendo released the *Wii*, and with it came games like *Super Mario Galaxy*. Although it did not push animation as far as *Jak and Daxter*, it did incorporate some smearframes in the form of motion trails. In recent years, the birth of the indie games scene has brought us many games that can use a more stylized aesthetic, as they do not have to cater to a huge audience. This also means they can easily incorporate smearframes, which many of them have done.

Chapter 2

State of the Art

This chapter will give an overview on where the industry is at the moment and also talk about emerging technologies. However it will not differentiate between film and games. Rather it will talk about both with respect to the used technique. This makes sense since in regard to smearframes, the difference is greater between techniques than between mediums.

2.1 2D Animation

As seen in the previous chapter, smearframes originated in 2D animation that was hand drawn on paper. With the rise of computers however, the term 2D animation has been broadened a lot. Before the digital era it would be only animation that was drawn on paper and then scanned onto film. There is of course a digital equivalent for that, which is perfectly fine. But the majority of productions, especially in TV, use 2D puppet animation. This is a lot more similar to the old technique of cutout animation, which is generally considered a form of stop-motion animation. When it comes to smearframes, there are of course differences between the more traditional frame by frame animation and 2D puppet animation. The latter suffers from the fact that the character basically has a rig that is used to move it around. This places some restraints on how far the character can be deformed. You could of course just draw smearframes individually, but ironically that would make the production more expensive. This explains why there might be relatively few smearframes, even if the animation has a 2D look.

However there are still films and TV series produced in the frame by frame technique. An example for a modern frame by frame 2D animation would be *Avatar: The Legend of Korra*. It is a TV series that was aired 2012 to 2014 and was created digitally. The series blends modern 3D rendered backgrounds with 2D animated characters. It uses both, motion blur and smearframes, sometimes also combining them like in figure 2.1. Since the series has a quite realistic look, it keeps the smears very subtle. There are of course also 2D puppet animations that use smearframes. An example for this is the Youtube series *Super Science Friends* [37]. It has a very reduced style with flat shapes and outlines. However it uses smearframes sparingly and mainly uses types that do not distort the puppet. For example in fast movements the limbs might be duplicated, or leave trails of colored lines behind them.

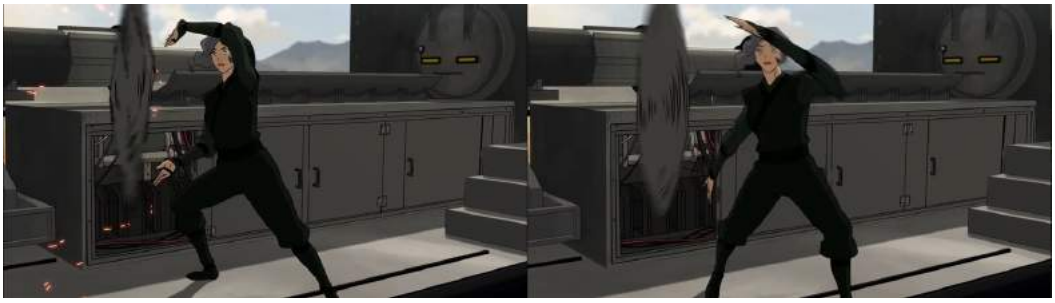

Figure 2.1: This is an example for a more classical type of modern smearframe found in *Avatar: The Legend of Korra* [10]. It mixes the classical smearframe with a bit of blurring. The short clip was found on *Sakuga Booru* [55].

Figure 2.2: Example for a smearframe in the video game *Skullgirls* [31]. It is a fighting game, which means that has to focus heavily on selling the weight of the attacks. Therefor the smearframes are exaggerated in order to inform the player on what is going on. Images from [8].

In games there have been a few examples that used smearframes extensively. Those would be *Cuphead* [16] and *Skullgirls* [31]. An image for the latter can be seen in figure 2.2. *Skullgirls* is a 2D fighting game that has hand drawn frame by frame animation done digitally. In order to sell the impact of the attacks, the animators made heavy use of smearframes. Hardware has become powerful enough to have multiple characters with high resolution sprite sheets with individual animation on screen. However the labor intensity of frame by frame 2D animation has reduced the amount of titles that are released in this technique. Compared to the example from *Avatar*, *Skullgirls* did not use computer generated motion blur but instead used only hand drawn smearframes. This has a lot to do with the style that is chosen for the project. *Skullgirls* obviously is a lot more stylized, so the very soft motion blur probably would not work.

Figure 2.3: These images show a smearframe from the feature animation *The Lego Movie* [19]. Since the movie uses no stretching of body parts and no motion blur, they replaced the character with a bunch of stacked together Lego bricks to create a smear. This works because the smear exists for only one frame, so it cannot be seen but rather is perceived as a streak of color. Images from [42].

2.2 3D Animation

Compared to 2D animation, the 3D counterpart is a lot more technical when it comes to animation. First of all you need a model that is made up of a finite amount of points. That means that you can not deform a model as wildly as you would in 2D. At some point you would just run out of points resulting in ugly deformations of the model. Secondly this model is deformed by a rig, which in turn again creates restrictions on the deforming capabilities. There are of course rigs that allow stretching and scaling, but the animator still has not full control over the shape of a character. And lastly, this model will usually be rendered with motion blur, which reduces the need for smearframes. There are of course ways to circumvent these limitations, but then you lose a lot of the speed advantages 3D has.

However there have been a few movies recently that used the technique of smearframes very creatively. The most notable example here is *The Lego Movie* [41] released in 2014. As the title suggests, the whole movie is made of Lego bricks, and even though it is a 3D rendered movie, it mimics the style of Lego stop motion movies. That means, there is no motion blur from the camera, only depth of field. So for movements that are too fast to see, they chose to replace the character with a wall of Lego bricks. This can be seen in figure 2.3. That works, because the bricks have roughly the same color and height as the character they are replacing. Also the effect lasts only a few frames, so the eye has no chance of actually seeing the bricks, instead it is perceived as a blur.

Another noteworthy example is *Spider-Man: Into the Spider-Verse* [14]. Note, that the film is not released yet, and all visual information is taken from the trailer. However it is so unique in its visual language and the way it uses smearframes that it has to be mentioned here. It heavily references the visual quality of comics with the overlaid halftone effect and action text in the environment. There is no classical depth of field, instead the blurring is done by offsetting the red and green channels to create a chromatic aberration effect. Like the *The Lego Movie* there is no motion blur. Instead they use

Figure 2.4: This image shows the usage of smearframes in the movie *Spider-Man: Into the Spider-Verse* [14]. It uses a combination of stretching 3D geometry and 2D effects to create the smear effect.

various types of smears. As shown in figure 2.4 there is stretching, scaling and duplicating the 3D model. But there are also 2D effects overlaid. In the right part of the image, the shoe leaves a trail of colors. There are also lines painted on top, visually similar to the action lines used in comics. This is a good example on how to combine the effects of 2D and 3D animation in a visually unique way.

In 3D games smearframes are not as common. This has to do with the fact that the camera is usually free to be moved by the player. This means that a smearframe has to look good from all angles, which is not always possible because of the extreme deformations done to create smearframes. Also it suffers from the same problem as 3D movie animations, which is that the character mesh is driven by a rig. This is only amplified by the fact that this rig has to run in a game engine in real-time. The most notable game using smearframes is *Overwatch* [26]. It uses smearframes mostly in cut scenes like in figure 2.5. The image clearly shows the head of the character elongated as it moves towards the ground. This technique of creating smearframes is very typical for 3D animation and is also often used in film. All smearframes from *Overwatch* work that way. There are even smearframes in gameplay animation that work the same. This is possible, because *Overwatch* is a first person shooter, which means the character is locked to the camera. That makes it easy for animators because they always know the position of the character in the game. But *Overwatch* also includes smearframes in animations that are not first person. They will be further analyzed in chapter 6. Another example of a 3D game using smearframes would be *Super Smash Bros. for WiiU*. It is a fighting game, which has the camera always on one side. Combined with the stylized look it would mean that smearframes could be used easily. However, they are not very common in this game. That just goes to show, that even if it is possible to implement smears in a game it is not always done.

There have been attempts at creating procedural smearframes, for example by a user of the *Unreal* game engine [54]. A picture of his result can be seen in figure 2.6. However the user himself stated, that his technique has limitations and does not work

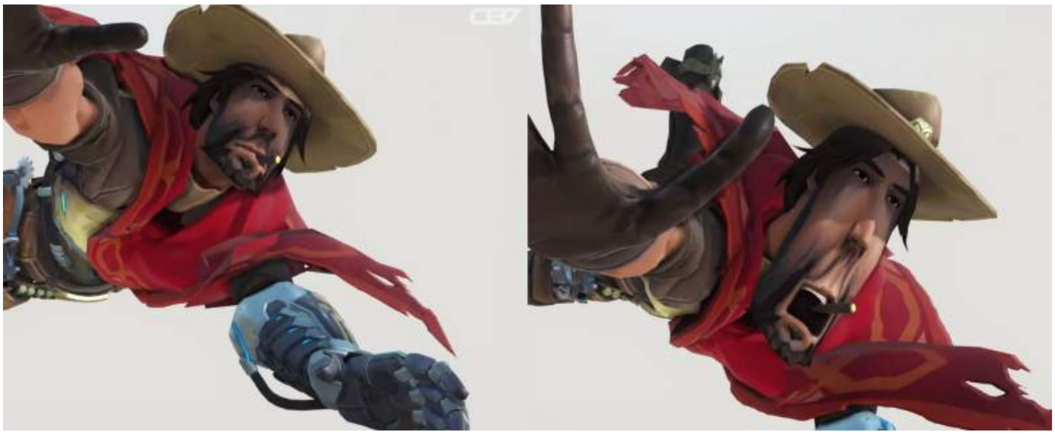

Figure 2.5: This picture shows the character McCree from the game *Overwatch* [26]. This footage is taken from the game, but it shows a so called Highlight intro. That is basically a mini cinematic showing off the character personality. During these, the camera is locked, allowing for easy creation of smearframes.

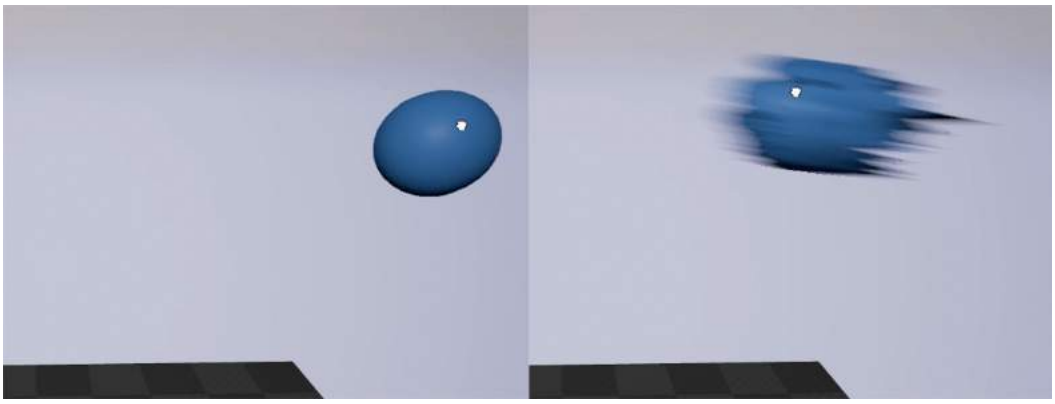

Figure 2.6: This is a procedural solution for creating smearframes for the game engine *Unreal*. It was created by the forum user Kashaar and still has technical limitations, as for example not working on skinned meshes [54].

on skinned meshes. It should be further noted, that this example lacks the readability of a handcrafted smearframe. The result is closer to standard motion blur due to the shape being heavily distorted. If compared to figure 2.5 it is clear that a lot less information would be preserved if applied to a real character.

2.3 Stop Motion

Stop motion animation has a somewhat similar problem with smearframes as 3D animation. Although physical instead of digital, the model has to be driven by a rig that the animator can use. Creating smearframes in stop motion is a bit harder than in 3D because you would have to undo every deformation applied to the character perfectly. Otherwise the model would start morphing and lose its original shape over the course

Figure 2.7: These smearframes were used in the stop motion movie *ParaNorman* [30]. They were 3D printed and work by replacing the entire head model with a smeared one. The image was found on an *Cartoon Brew* article [48].

of the shot. There are however two ways to circumvent this. The first is to just use the technique of multiples. That way, you just need two identical parts of a given limb that can be attached and removed in a very flexible manner. In this case the original model does not need to be deformed so the animator does not need to think about bringing the character back on model after creating a smearframe. An example for this is the still frame from *Wallace and Gromit* in figure 5.3 from chapter 5. It shows the character planting rails with three arms, one is holding the rails, two are planting them. This duplication works because the movement is so fast the the viewer perceives the arms as one being in two places at once. Another, more technical approach to this is done by creating replacements for the character model. In *ParaNorman* [30] this was done by 3D modeling and then 3D printing the models. The result of this work can be seen in figure 2.7, where they printed out smearframes for the head. This was possible, because they used head replacements to do the facial animation anyway. This made it easy to add a few more models to the face in order to create smearframes. This technique forms an interesting bridge between the digital and the physical world because the shape is defined in software, but it is still animated by hand. Also the smearframes can be targeted to the camera since the target medium was film.

2.4 Virtual Reality

Virtual Reality (VR) is a relatively new technology, especially for animation. Currently there are only two pieces of software that properly support animation, which would be *Quill* [46] and *AnimVR* [45]. However these packages are still a bit limited so the animators focus mainly on loops. Despite the fact, there is currently a lot of exciting development happening. Mostly on the social media platform *Facebook* in a group called Virtual Animation [57]. It currently has lots of active users that keep pushing the new medium into different directions. That said, smearframes are not commonly used as of now. That does not have technical limitations however. Animation in VR is like a blend of 2D and 3D animation. A user can create strokes as he would in 2D but the stroke is following the hand movement in the room giving it depth. There is also the possibility to create rigs for those strokes allowing for easier manipulation. This freedom means that smearframes can be easily created. The only problem that might arise is similar to games when the camera can be freely manipulated. But that does not mean it is impossible and the following years will most likely bring interesting development in this direction.

Chapter 3

Artistic and Neurobiological Background

This chapter will link the relevant scientific understanding of human perception to the technique of smearframes. It also explains certain terms that are used when describing a smearframe. As a result, it should be clear when a smearframe is useful and how it is created.

3.1 How the Eye Perceives Film

To understand how and why smearframes work, it is important to understand how the eyes work and how the mind processes visual information. The eyes are usually explained using a film camera as an analogy. That is however incorrect as eyes do not have a discrete frame rate. Instead, they continuously send visual information to the brain which then has to make sense of that data. This stream of color and luminance values has to be processed to extract movement information. Studies suggest that this is done by neurons that collect data for an extended period of time, thus smearing the signal in the direction of the objects movement. This creates what is called an *optic flow field*, out of which the movement of an observer and of objects in the field of view are reconstructed [6, p. 17]. This smearing in the direction of movement seems to be very similar to the technique of *speed lines* that are used in cartoons [2, p. 442]. These lines are used to indicate motion and apparently they work because they emulate the way the brain extracts motion from visual information.

Since movies are constructed of individual static images it would seem logical that they appear choppy. But the motion pictured is perceived as fluent. That is often attributed to the *persistence of vision* phenomenon, which describes the effect of very bright lights that leave a spot imprinted in our vision for a short time after they have been turned off. However this is actually considered inaccurate [1]. It is more likely due to an effect called *short-range apparent motion*. This describes the fact that two objects close to each other flashing on and off inversely appear as one moving object. The effect is similar to the impression you get when you move in front of a fence while observing an object that is behind it. Although the observed object disappears for a fraction of a second, the movement is still perceived as one continuous motion. The brain just fills in the gaps.

3.2 Terminology for Smearframes

As explained in the previous section, film is just an illusion that works because objects move only very little between frames. Film uses 24 frames per second as a default. However this is just the minimal number at which motion is fluid enough. It has been established in the beginnings of film as a nice balance of quality and cost, because analog film was very expensive. The gaps that are still left at 24 frames per second are usually ironed out by motion blur. This blurring has the effect of visually stretching the object along its path of motion, filling in the gaps. In film cameras, motion blur happens automatically, with the amount depending on the shutter. Not so in animation. Especially in the early days a lot of experimentation was done to prevent strobing. Before going on to explain how smearframes work, there is the need to clarify some of the terminology used in this introduction.

Path of Motion describes the course a shape takes over time. Start and end of the motion are not specifically defined but usually are between key or extreme poses. The shape in question could be a prop, a character, or a single part of a character. You could for example look specifically at the path of motion of a characters hands while neglecting the rest of the body. This is different to arcs, which is one of the 12 animation principles as described in *The illusion of life* [7, p.47] by Frank Thomas and Ollie Johnston. It states that most natural actions tend to follow an arced trajectory. The path of motion differs in that it does not need to be a nice arc. Imagine a robot moving in very erratic straight movements, which could not be described as arcs. So path of motion is just used to describe the course of a shape over time, neglecting how that course might look.

Leading and Trailing Edge describes the concept that an object moving along a path of motion has a side pointing in direction of movement and a side pointing the opposite direction. These are called leading and trailing edge. They are best understood with the help of figure 3.1. This concept implies that the edges can be seen as separate objects and indeed this helps when constructing smearframes. They do not need to move at the same speed and can have a delay on when they start moving, stretching the object in the path of motion. It is important however that they have a proper ease cycle. Each edge must accelerate and decelerate gradually.

Strobing Strobing is a visual phenomenon that is caused by the discrete nature of film. Because there are only 24 images per second it may happen that an object moves so fast, it leaves a gap between two frames. More specifically it leaves a gap between the trailing edge of the current frame and the leading edge of the preceding frame, like in figure 3.1. As a result, it is difficult for the viwer to understand the motion he just saw on screen. The bigger the gap, the stronger the effect. This is of course caused by the nature of the film illusion and the *short-range apparent motion* effect. In short, if the gap is too big the brain can not connect the movement of the shapes anymore and the object appears to be jumping from one place to another.

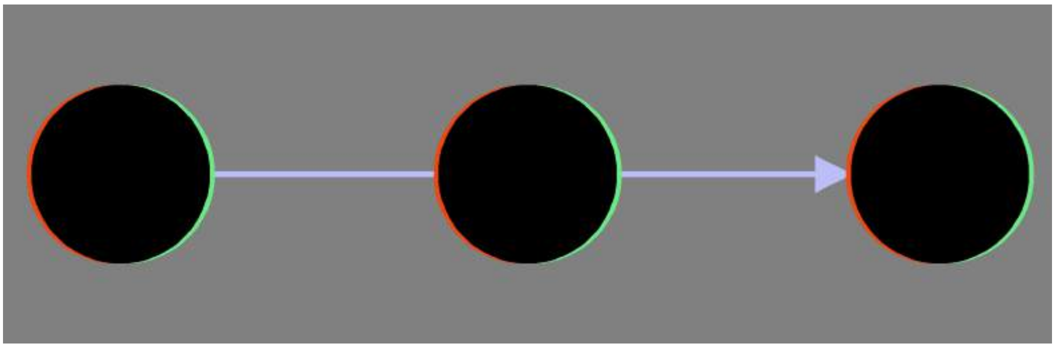

Figure 3.1: This image shows the concept of leading and trailing edge, path of motion and in extension strobing. The leading edge is marked green and the trailing edge red. The arrow behind the objects symbolizes the path of motion. Strobing is the space between the objects. It occurs because there is too much space for the brain to easily connect the objects.

3.3 How Smearframes Work

The preceding pages already hinted at the use cases of smearframes. If the distance on screen is too big between frames, the object needs to be stretched to prevent strobing. A short visual example with explanation can be found in figure 3.2. But why is strobing actually that bad? Apart from being jarring on the eyes the viewer will find it difficult to follow the movement on screen. To put it into animation terms: a smearframe improves readability. If the viewer does not understand what is happening on screen the animation does not read well. So smearframes improve that by allowing the user to follow the motion more easily and have a better understanding of the artistic intent. The logical conclusion to that is that not everything needs to be smeared. For example when a fast movement of an arm occurs it is usually enough to smear only the hand as opposed to the whole arm. The hand alone creates enough guidance for the eye to follow the motion. Also the hand is usually the object that should have the focus for story purposes. That means that it might be better to not smear an object if it should not get the viewers attention.

However smearframes are not the only tool to increase readability. Clear posing, again one of the 12 principles, is also very important. Especially if you consider, that a smearframe basically connects two poses on screen. If those poses do not read or do not tell the intended story a smearframe will not help. So smearframes are not a magical solution to every animation problem.

Also, as mentioned in the previous section, a smearframe is stretched along the path of motion. That means it also carries information about the objects path during the time of the smear. That is especially important if the path is curved. Then the smearframe has to be warped along this path as well, in order for the viewer to be able to follow to the next pose. See how the ball in figure 3.2 is bent. However it is often not enough to indicate the arc only with a smearframe. Usually it is best to start the arc in the frames preceding the smear to improve readability. Also since a smearframe is held for a very short time, there is usually no direction change during the smear. There are some exception, for example a ball bounce might include a smear right around the bounce, but that is usually only when the ball is very small on the screen.

Of course, the smearframe needs enough contrast to the background to be registered. This of course has to do with readability again. In low contrast, movement is just generally harder to register, so having a smearframe that blends into the background will not help. However that does not mean, that the smearframe has to have a clear outline. Generally the smearframe should blend into the look of the movie. So if the look of the movie is set to use blurring, then the smearframe should incorporate that as well.

The last important piece of information regarding smearframes has to do with leading and trailing edges. As stated in the previous section, the edges need to overlap between frames, so that no space is left between them. However just blindly scaling the object along the path of motion might lead to a jitter in the animation. The reason for that is, that the edges need to have their own spacing cycle. That means that they should accelerate and decelerate steadily. To further clarify this, see the spacing chart in figure 3.2. It shows the leading edge in green doing a big jump on frame 4 while the trailing edge stays behind. However the trailing edge still accelerated relative to its previous position. If it slowed down, or even worse traveled in the opposite direction, there would be a noticeable jump in the animation.

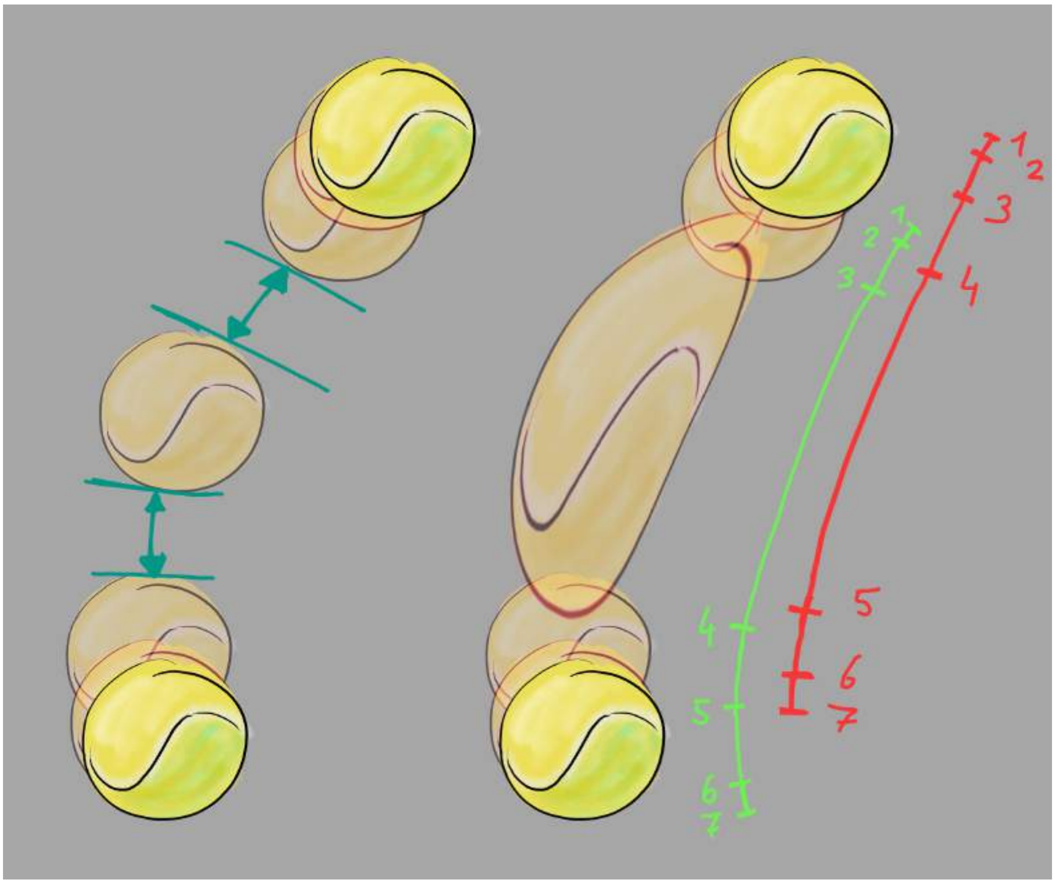

Figure 3.2: This is a more practical example on when a smearframe is used. On both sides the ball describes a very simple movement with two frames to ease in and out of the pose and a breakdown in the middle. The left side portrays what would happen without a smearframe. There is a noticeable gap between the frames leading to strobing. The right side incorporates a smearframe linking the edges and removing the gap. Notice how the smearframe is bent into the path of motion to portray the curve the ball is moving on. The arrows on the right example show the spacing of the edges during the smear. Notice how each edge eases in smoothly with the trailing edge just staying closer to the starting pose for one frame. It is very important that the easing of each edge is individually considered.

Chapter 4

In Search of a Definition

As seen in the previous chapters a smearframe is more than just motion blur in animation. But what exactly is a smearframe and how do they differ from regular motion blur? In order to create categories for them there needs to be a proper boundary to the term to differentiate the borderline cases. However smearframes are not yet scientifically researched and are therefor missing a definition. This chapter aims to solve that issue and attempt to give a precise definition of what a smearframe actually is, and maybe more importantly what it is not. It does that by exploring borderline cases in art that are not necessarily animation and finding images that are similar to a smearframe and pointing out where the difference lies.

4.1 Borderline

To have a baseline definition there are a few things that are obvious to a smearframe. It is an image and it has something to do with motion blur. So the gut feeling definition for a smearframe is: *An image with motion blur*. That is however not an exact definition as the following examples will show. These examples will make the definition process easier as they help ruling things out. Essentially an animation only consists of 24 images per second that in itself do not necessarily convey any movement. Looking at a single frame it reveals to be just a still image. The exception to this are smearframes. They try to convey more motion in a still image than a regular frame does. It is essentially compressing a lot of movement into a single image. But this technique in itself is not unique to animation. Other art forms have done this as well.

Photography In the realm of photography the techniques of long exposure and multiple exposure photography are most similar to smearframes. Technically both work very similarly, but the result is visually very different which is why they are looked at separately. First off a closer look at multiple exposure photography. This is a technique, where two or more exposures are superimposed to create a single image. An example can be seen in figure 4.1 (a). The photo was taken with a long exposure, but with periodic flashes to freeze each pose. Seeing it in a more abstract way, it takes two or more points in time and overlays them over each other. In animation terms this could be compared to multiples, a technique where the artists draw shapes that would usually span multiple

(a) (b)

Figure 4.1: Multiple Exposure photography by Gjon Mili [52](a). This photo was done by having a long exposure time and triggering the flash multiple times during that exposure. This technique is visually very similar to the animation technique of multiples. B shows a classical long exposure photography [23]. It works similarly but there are no flashes used, so the glowing parts leave trails of light. This can be compared to the motion trails usually found in games.

frames into a single frame. An example for this can be seen in figure 5.3.

Long exposure photography is similar, but instead of creating multiple distinct shapes, it creates a smear of lights. It works by exposing a photo for a long amount of time, but there are no flashes used so any dark parts usually disappear in the exposure. This leaves trails of glowing parts as seen in figure 4.1 (b). The cars leave glowing streaks, highlighting the path these objects have taken. This is visually similar to the technique of motion trails, which will be further described in chapter 5. This type of smearframe is often found in games. There it is used to highlight movement that is too fast to display. It is a way of showing the player what just happened without ever having actually shown this movement.

So much for the similarities, but to create the definition it is important to draw the line where a smearframe ends and photography begins. The differentiating factor in this case would be abstraction. A photo always originates from something that is real. Smearframes on the other hand arise from the imagination of the artist. So, adapting the definition to what was observed in this paragraph results in: *an image of an abstracted type of motion blur.*

Paintings An art that is visually a lot closer to animation compared to photography is painting. Paintings have been showing motion for a very long time. It goes back to the times of cave paintings. And there are even cave paintings that depict more motion than a single point in time. An example for this is the boar depiction in the Altamira cave in Spain seen in figure 4.2 (b). It is often referenced as one of the beginnings of animation, which can be argued about since it is only a still image. But with its legs drawn twice it could be a multiple in a modern day animation. Similarly Marcel Duchamp's *Nude Descending a Staircase, No. 2* in figure 4.2 (a) could be seen as a smearframe. It depicts a woman walking down a stair, but over a span of time, just like multiple exposure

(a) (b)

Figure 4.2: Duchamp's Nude Descending a Staircase, No. 2 [49] (a) can be seen as a smearframe, so could the boar depiction in the Altamira Cave [47] (b). But they are not smearframes because they are not a time based medium.

photography. He probably referenced Edward Muybridge's *Woman Walking Downstairs* [25], which to this day is still a valid source for human motion. Animators also often use Muybridge's work as reference for locomotion, so it can be seen as common ground. Just like a smearframe aims to compress various positions or a stream of poses into a single image. In the end, Duchamp's work even found its way back into animation, as it has been referenced by Chuck Jones who drew a Duck descending down a staircase [22].

After exploring these examples of paintings, the definition given before does not hold up anymore. Paintings can be abstracted so they would fall under the previously given definition. Luckily there is a pretty obvious difference between paintings and animation which is time. An animation consists of more than one frame, so a smearframe has frames before and after it. These are important to define the objects true form as a smearframe is only a temporary deformation that always morphs back to its original form. So the updated definition is: *An image of an object, temporarily morphing in a context of time.*

Comic Comics are an interesting medium to compare animation with, because they are actually quite similar. They tend to be visually close to animation, at least the classical hand drawn animation. That is not to say that all animation has to look like in a comic but the cross section is pretty significant. Like animation, comic is a visual medium and it can portray the passing of time. Even more interesting for this work: it can portray the passing of time in a single image. As Scott McCloud explains it in his book *Understanding Comics* [3, p. 102–110], a panel in a comic can last very briefly or very long depending on the authors intent. And with the passing of time comes the

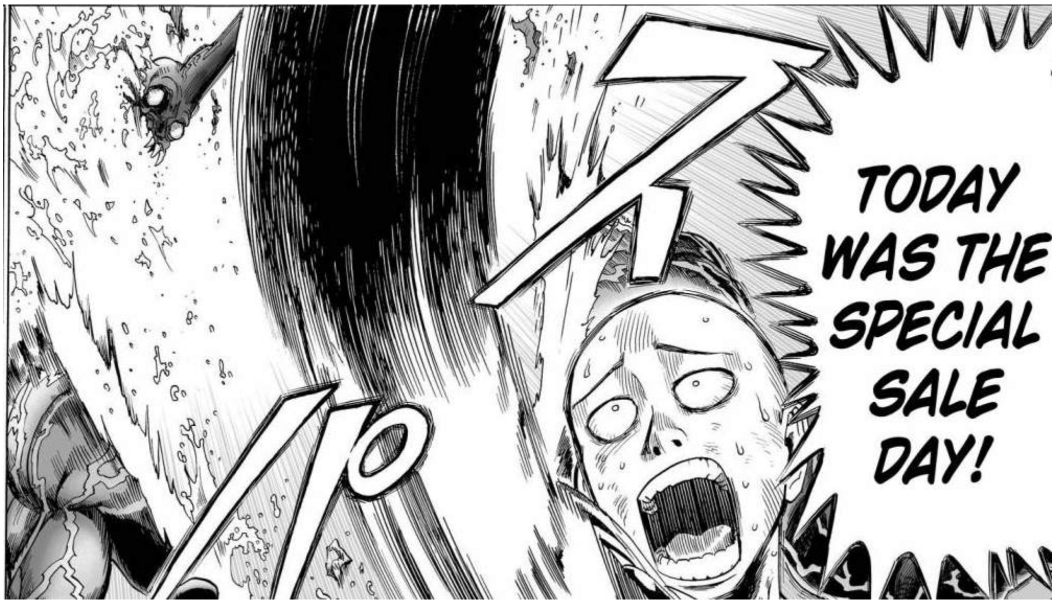

Figure 4.3: This image shows the use of motion lines in a panel from the Japanese comic *One Punch Man* [4]. The hero character is just hitting a monster with a very powerful punch. To indicate that this motion is moving very fast the arm is displayed smeared.

problem of conveying movement. To do so, comics uses a technique that is very similar to a smearframe. Scott McCloud calls it a *motion line* [3, p. 118]. Figure 4.3 shows a modern example of that technique from the Japanese Comic *One Punch Man* [4]. In this single panel, there are multiple events in time portrayed at once. A punch, the creature in the back tearing apart and the hero saying his line. This panel covers long timespan, so to sell the power of the punch, the artist used *motion lines*. This indicates, that the punch is actually happening very quickly.

Looking at the definition given before, comics would clearly fall under it. Comics have a time context because it has multiple panels. And the morphing is also temporary because in the panels before and after the motion line, the character has a defined consistent look. However, by the design of the medium, a motion blur drawing in a comic is constant. Always visible to the eye. That means, that a drawing like seen in figure 4.3 could be a smearframe as long as it is displayed shortly in a fast moving sequence of images. So the further enhanced definition is: *An image portraying a stylized and temporarily distorted object or character in a fast moving sequence of pictures.*

Morphing animation As a final borderline case, there is morphing animation. It can be stylized and it happens in a fast moving sequence of images. In a still frame it can even be visually similar to a smearframe, but it has a completely different feel and use, which is why it needs to be excluded from the definition. Morphing animation can be a lot of different things in different mediums. It may aim to be photo-realistic, but the category that I want to address here is visually abstracted. An example would be from *The Music Scene* [13] by Blockhead as seen in figure 4.4. The image sequence shows a deer that is seemingly dissolving into abstract streaks of color. This sequence lasts for

Figure 4.4: Three stills from *Blockhead - The music scene* [13], an animated music video with a lot of morphing animation. This example shows a deer dissolving into colored streaks that move to the rhythm of the music.

about 5 seconds and pulses in the rhythm of the music. The animation is full of things that dissolve and morph back into other things. The morphing is visually interesting and clearly visible. A smearframe however is designed to be felt rather than seen. That is achieved by holding the smear for only one or two frames in a 24 frames per second movie. It is like a lighting fast morph into a different object and back. A morphing animation usually takes some time, so the viewer can register what is happening and the object looks different after the morph than before.

The distinction of objects looking different than before is already included in the definition. That makes the main distinguishing factor between a morph and a smear the intention of showing fast movement. That updates the definition to: *An image portraying a stylized and temporarily distorted object or character in a fast moving sequence of pictures to convey fast motion.*

4.2 Definition

After this journey to the fringes of animation and beyond, a first definition for a smearframe is born. It leaves us with a definition that makes a smearframe unique to animation.

> An image portraying a stylized and temporarily distorted object or character in a fast moving sequence of pictures to convey fast motion.

However this definition is still not perfect and needs to be tweaked. Right now it would exclude two of the three major categories explained in the next chapter. The problem is that the object does not need to be *temporarily distorted*. As seen in the figures 2.3 and 2.4 from chapter 2 a smearframe can leave the original object in tact, and just add a trail or replace it entirely. If we cut this from the definition, it reads as if a smearframe was about the character itself. To fix that we need to rewrite that part into *an object or a character leaving a trail along its path*. This does not define how this trail looks, but rather that it follows the objects movement, which is a lot more important. Now it is actually not the character that needs to be stylized but the trail it leaves so the word *stylized* also needs to be brought back.

But the current definition still contains another inaccuracy when it speaks about *object or character*. It is true that smearframes can be applied to objects or characters, but this is very vague. A character could be seen as an object, or maybe it is just his arm. Leaving out the word character from the definition would be problematic too because an object is usually considered inanimate. To circumvent this confusion the better fitting term is *shape*. This opens up the definition somewhat but actually makes it more accurate. Anything that is distinguishable as its own shape can be smeared. So with these corrections we arrive at the final definition.

> An image portraying a shape leaving a stylized trail along its path in a fast moving sequence of pictures to convey rapid motion.

Hopefully this makes it very clear on where it is used and which purpose it has. The definition may not be perfect, and it will probably need to adapt as time moves on and technology evolves. But it is a start and it is the definition this work will be based on.

Chapter 5

Types of Smearframes

After defining what a smearframe actually is, it is time to categorize them. The categories are chosen by looks alone and are not depending on the medium they are presented in. However some types are just easier to create in certain mediums, so there definitely exists a correlation. This sorting of smearframe types will be very important in chapter 6 where the animation of the *Overwatch* universe will be analyzed. If possible all categories feature examples from games and film each in 2D and 3D. It has to be noted, that some of the examples feature a blend of different categories because they are sometimes used in conjunction with each other.

5.1 Elongated Inbetween

The term elongated inbetween was originally coined by Richard Williams in his book *The Animator's Survival Kit* [5, p. 96]. This is what is usually considered a classical smearframe. It describes a smear that scales the object along its path of motion by advancing the leading edge and dragging the trailing edge. Since the inbetween frame is usually the fastest, it is the one that needs stretching. Hence the name. It is important to not confuse this technique with squash and stretch, one of the 12 animation principles. They are very similar but an elongated inbetween does not retain volume. That is because it is not about the visualization of a squishy mass but about emulating a type of motion blur, which in turn also does not retain volume.

There are of course visual differences based on whether 2D or 3D was used. 2D tends to simplify the shapes more during the smear while 3D just stretches the object. This is due to technical reasons. With 3D you have to work with the existing rig, translating and scaling it to your needs. In 2D, where you have to redraw the frame anyway, it is actually less work if you omit the detail in the smear. The difference becomes clear when looking at figure 5.1. What they all have in common is that the object is elongated along the path of motion. However there is very little difference between games and film. Because they primary constraint is the rig, the smears look very similar. In figure 5.1 (a) is a frame from the game *Overwatch* where the character has his face stretched downwards. Compared to the still from the movie *Madagascar*, where the lions hand is elongated, the similarities are pretty striking. Due to technical reasons there is a visible texture stretching. Instead of losing detail, it gets warped with the underlying geometry.

(a) (b)

(c) (d)

Figure 5.1: Examples for elongated inbetweens from *Overwatch* [26] (a), *Johnny Bravo* [21] (b), *Skullgirls* [31] (c), and *Madagascar* [24] (d). The left side represents games, the right one film. From the image it becomes clear that the difference between 2D and 3D is greater than the one between film and games. Although they might be very different in style, the stretching along the path of motion is what unites them.

Also the deformation does not seem to be applied evenly. For example in the *Overwatch* image, the mouth and the eyes seem to have kept their original form while everything between is stretched. A similar thing can be seen on the lion, where it seems like the palm and the thumb was not scaled. The stretch was only done with the remaining fingers. This of course comes down to rig limitations again, where some controllers just do not allow scaling. So the effect has to be achieved with what is available.

The freedom of 2D animation allows for greater flexibility and visual reduction during a smear. Compared to the 3D examples, the smear in *Johnny Bravo* [21] is completely abstracted. From the frame it would not even be possible to guess what the gray streak is, if it was not for the phone that is still visible at one end of the smear. As already mentioned this just simplifies the drawing process. The advantage it has over an elongated stretch in 3D is, that the visual reduction is better at guiding the eye. It reduces the unnecessary information and by that increases contrast with the surroundings. Also in 2D all parts can be evenly stretched. This is very noticeable when comparing the two left images from figure 5.1. The smearframe idea is very similar. The faces are stretched because a fast movement is happening. However on the bottom example everything is stretched, primarily the eyes. Compared to the 3D example where the space between eyes and mouth is merely widened, it is a lot more expressive. In 2D the animator was able to choose which parts of the face should be visible during the smear and made them especially big.

(a) (b)

Figure 5.2: This is an example for motion trails. The left image is from the fighting game *Bayonetta* [11] (a). It shows the motion trail for an attack. Note how the sword does not deform, and how much contrast the effect has to the background. On the contrary, the frame from *Donald gets drafted* [17] (b) shows the motion trail very faint. The movement there is usually more predictable and does not need as much support.

5.2 Motion Trails

The concept of a motion trail is very similar to what can be found in comics. It is a streak of color that follows the moving object along its path of motion. However the original object does not deform. It may look like that in motion, but when looked at it in a still frame it is obvious that the original object did not lose its shape. The color of the streak usually coincides with the color of the object but it does not need to do that exactly. Looking at figure 5.2 it is clear, that the color can be pushed beyond what the original object has. To put it simple, a motion trail is a streak of color that follows the path of motion, but the original object does not lose its form.

This is the reason why it is very prominent in video games, where deforming a mesh is complicated, but spawning an object that helps visualize the path of motion is easy. It is especially common in sword swings, because the sword would usually swing in a big arc to create clearly readable poses. Without motion trails however, that leads to strobing as the attack is usually very fast and the sword in comparison very thin. An example for this can be found in figure 5.2 (a) from the game *Bayonetta*. It shows the motion trail after a big downward sword attack. Note that the color of the motion trail and the color of the sword are similar. Also the effect is a lot brighter than the sword, in part to make it more visible, but also to sell the power of the attack. A further advantage for games is that a motion trail is not very view dependent. Since the original object is not deformed and the newly spawned motion trail can just be a 2D plane, any ugly deformations can be avoided. A motion trail in games also has a gameplay purpose. Since the attacks are usually very fast, and have little anticipation, it informs the player of what just happened. Again this can be often found in fighting games, where the delay between button press and attack animation needs to be as short as possible in order to make the game feel responsive.

In 3D animation for film motion trails hardly exist. A few can be found in the trailer for *Spider-Man: Into the Spider-Verse*, which was mentioned in chapter 2. The problem a 3D animator faces with motion trails, is that he needs to create new geometry with a new texture for the smear object. This can not be done on the fly and has to be done by a texture artist beforehand. This makes it just a lot harder to do than other types of smearframes. In *Spider-Man: Into the Spider-Verse* they were able to do that because they probably had 2D paintovers already set up as the look of the whole movie depended on it. In 2D animation it is of course a lot easier. The animator can just add a few lines to indicate a motion trail. Even though this might get lost when the lines are inked, it can be brought back in coloring adding the streaks on top of the character color. An example for this is in figure 5.2 (b), where the fists leave white streaks. Compared to the example from *Bayonetta*, their contrast is not as high. This might be a technical limitation or a design decision. The effect is, that the movement does not feel as powerful. However motion trails for 2D animation have been seldom used in recent years. The example from figure 5.2 (b) is from 1942 and since then this style did not find much use anymore. Motion trails from more recent 2D animations are more similar to elongated inbetweens. They are multiple streaks of flat opaque color that start at the trailing edge of a moving object. That makes them a lot more similar to what is used in comics.

5.3 Multiples

The last category of smearframes is multiples. This technique duplicates the fast moving object along its path of motion. As a result there is more information left in a single frame. The individual instances of the object are not blurred but are rather discrete states of the fast motion layered on top of each other. It exists in 2D as well as in 3D, however it is a lot more common in 2D animation. It is usually used when the motion is oscillating between two poses. Any other type of smearframe would just create a meaningless mess of colors. However since a multiple retains so much information about the characters shape it works a lot better in such a case. The main difference between multiples in 3D and 2D is that 2D animation tends to draw the effect parallel to the view plane. That means the effect only moves horizontally and vertically but does not use perspective depth. The latter is of course a lot easier to do in 3D, analogue as well as digital. The top row of images in figure 5.3 shows that. Both of them have multiples clearly behind each other in depth. It can also be used in conjunction with elongated inbetweens as can be seen in figure 5.3 (c). The mouth is stretched along the path of motion but the eyes are duplicated. This is a pattern that can be commonly seen in horizontal movements. Even in the example for elongated inbetweens Richard Williams gives in *The Animator's Survival Kit* [5, p. 96]. The reason is that the mouth is already longer in the horizontal direction and can easily extended further. Since the eyes are two almost identical objects close to each other there are two options. Either fuse them into one shape and create an elongate inbetween which was done in figure 5.3 (b). Or duplicate them along the path of motion and create multiples. It is down to the artist to decide what he thinks is best.

Even though it is easier to do in 2D, it is possible to create this technique in 3D as well. The best case would be if the rig allowed for that type of smear. However you would need a pretty sophisticated rig for that. Something like the studio *Mindbender* did with their rig for their upcoming short *Food Thief* [39]. This particular rig has the ability to grow additional limbs and freely move them around on the body. Without that the animator would have to duplicate parts of the mesh and maybe cut them apart if they are too big. This is very labor intensive, not very flexible and probably not even pipeline friendly. However if enough thought is put into it, it can be done. For example in the game *Crash Bandicoot* as seen in figure 5.3 (b). The head is definitely duplicated while the character is doing his twist attack. The rest of the body might be too, but this is not clearly visible from the image. In conjunction with the motion trails it creates the illusion of a spinning motion. It is not clear how this was done, but especially early games went very deep in their optimization, so it might even be an effect calculated on the graphics card.

Multiples are especially easy to do in stop motion. They might even be the only viable option to create smearframes there. The problem with the other categories is that they require too much deformation. Especially with clay based stop motion this is hard to do. A notable exception was presented in chapter 2 in figure 2.7, which shows 3D printed multiple head replacements in order to achieve a smearframe. However it is just a lot easier to stick another arm to the character. Figure 5.3 (a) shows a frame from *Wallace and Gromit* where they did exactly that. In the shot, the dog is riding a toy train that has run out of rails so he has to build them as he goes. The motion would be too fast without smearframes, so they decided to use multiples that show him grabbing and placing the rails at the same time.

(a) (b)

(c) (d)

Figure 5.3: The image shows an example for multiples in animation. It includes *Wallace and Gromit* [44] (a), *Crash Bandicoot* [15] (b), *Spongebob* [34] (c) and finally *Cuphead* [16] (d). The right side represents games, while the left is from film. The effect is pretty consistent and independent of medium and technique. The most notable difference is, that in 2D animation the effect is usually parallel to the view plane while in a 3D animation it can easily incorporate depth.

Chapter 6

Use of Smearframes in *Overwatch*

This chapter will focus on the animation of the game *Overwatch* and how it uses smearframes. *Overwatch* is a multiplayer first-person shooter game, which features many different characters with varying abilities that players can choose. Important for this analysis is, that every character has its unique set of animations. Even though a seasoned *Overwatch* player will no doubt recognize the characters, they will not be named in this work to prevent confusion. After all it is about the animations and not the character that is performing them. Despite the gameplay lacking a traditional story, the universe it plays in is filled with lore. This lore is told through comics and, more importantly for this work, animation. There have been a lot of animated shorts produced to accompany the lore of the game. They are mostly 3D, but a few are 2D and there even is a stop motion example. This makes it perfect to analyze animations across mediums. To do that, the animations will be analyzed on their own and then compared with one another in the last section.

All images in this chapter have been captured directly from the game using version 1.27.0.1. The software used for capturing was NVIDIA Shadowplay, which recorded 1080p60 footage from which the stills were extracted. To add some consistency, the ingame animations were all captured in the same location from the same map. The stills from the animated shorts were taken from Youtube in 1080p.

6.1 Game Animations

The first section focuses on animation that happens in the game. This is not limited to animations that are actually used for gameplay but also includes cutscenes that play between the matches. These cutscenes are still rendered in realtime and use the same models and presumably rigs as during the game. Gameplay animation is split up to subsections for first and third person animations. The reason for this segmentation is because first person animations are pretty much locked to the camera. This fixed perspective creates a lot of opportunities for smearframes. However there is also great potential for comparison here, because for every first person animation there needs to be a third person counterpart because the other players in the game need to see it too. Since they are two completely different sets of animation, it is interesting how smearframes were used differently if the animation can be seen from any angle.

6.1.1 First Person

As already stated in the introductory paragraph, animations for first person are locked to the camera. No matter where the player is pointing, the animation is always the same. This makes it easy to judge when a smearframe is needed. The game generally uses a lot of motion trails, so as can be seen in figure 6.1 all of the examples feature them. It is of course easy to use this technique once it is set up and it can also be generated on the fly during gameplay. The color of the motion trail generally coincides with the color of the shape it originates from. They also tend to be slightly transparent. Though it is unclear whether this decision was made for aesthetic or gameplay reasons.

Figure 6.1 also shows three examples of elongated inbetweens. They were picked to show how they are used in the game and do not represent the ratio of motion trails to elongated inbetweens. In fact this technique is used very rarely. Most of the smears in first person are horizontal. That has to do with the standard aspect ratio of modern computer monitors, which is usually 16:9. This means there is just a lot more usable space horizontally. Typical for 3D animation is that the smearframe is created by just scaling the mesh. According to David Gibson, an animator of the *Overwatch* team, this was done with extra controllers on the rig that could be scaled non-uniformly [29, T=00:12:45]. The figure also shows that all examples for elongated inbetweens also feature a motion trail. In all the footage that was taken from the game there was not a single elongated inbetween that did not include a motion trail. Also the motion trail usually lasted longer than the elongated inbetween. This may be because the viewer is more likely to accept a motion trail that is clearly visible rather than a deformed character.

A technique for smearframes that is missing is multiples. As time of this writing there are no examples for that in first person animations. The reasons for this are not quite clear. It might be too obvious to have a multiple right in front of the camera or maybe there were technical limitations. They are however not completely absent from the game as will be shown in the coming pages.

6.1.2 Third Person

To start off this subsection let us quote David Gibson, an animator of the *Overwatch* team. In his GDC talk from 2016 at T=00:14:50 he said: “We tried to do this with ingame assets as well [...] smearframes are kind of tricky to pull off in game-space [...]” [29]. And this can be felt throughout the third person animations in the game. Some of them show subtle smearframes, but it is usually kept very restricted. Having that out of the way, the third person animations still have some really interesting uses of smearframe applied to them. As shown in figure 6.2 (a, b) they make use of multiples for some special attacks. The attacks are meant to show the characters move at ludicrous speed, cutting bullets with a sword in (a), and shooting in all directions at the same time in (b). There are slight differences between the animations. In (a) the original character is not moving but the duplicates move around him like a shadow. In (b) the character is moving rapidly, and he leaves multiples behind that fade slowly, but still move. The underlying principle however is, that the main character is not deformed or changed, but a second geometry with an almost transparent shader is created in the same position. Additionally in (b) the weapons are duplicated separately. In the end, the

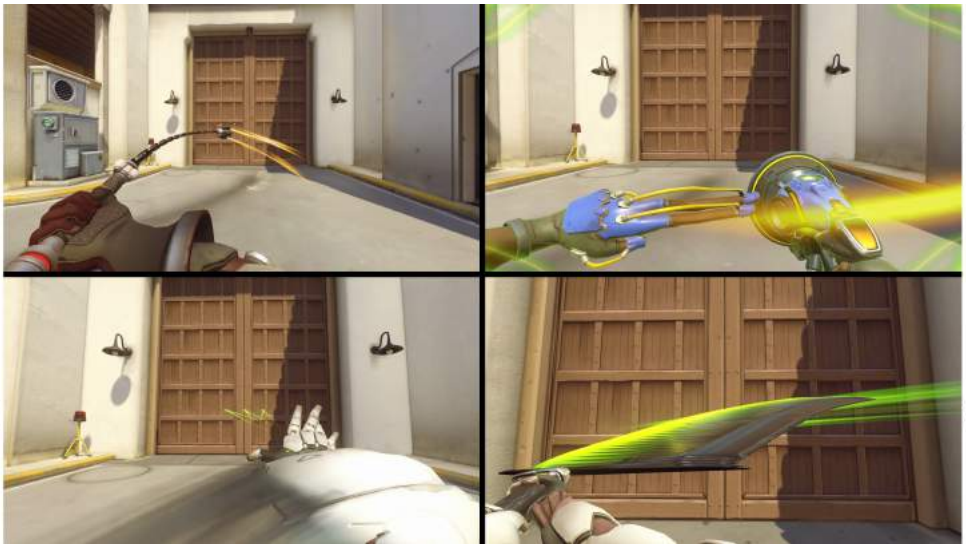

Figure 6.1: These four examples show how *Overwatch* uses smearframes in first person animation. In these images, all of them include a motion trail. This is representative of the game as almost all the fast movements feature them. All of the examples except (a) also feature elongated inbetweens. They were picked to show how this is achieved in the first person perspective and do not represent the ratio to motion trails.

motion of the individual limbs is not very fast, but very erratic. In combination with the original character, this creates the impression of very fast motion. Of course the third person animations also feature motion trails as can be seen in figure 6.2 (a, d). Again they follow the color of the character and are used to emphasize the motion. As can be seen in (d), the motion trail does not cover the whole character and is very transparent. This was done to keep the action visible to other players, while still maintaining the impression of a forceful movement. A very special form of elongated inbetween can be found in (c) in the characters arms. The movement he performs, is bringing his hands up very quickly. This can either be done by scaling up the shape, or as it was done in this case, by dragging the hands behind. The upper arm reaches its final pose first, leaving the lower arm very bent, when it snaps upwards. This works because the motion is very radial and the smear contains information about where the animation started and where it will end. The viewer has then an easier time to link those two together in their mind.

6.1.3 Cutscene

The cutscenes shown here are played after a match and highlight a player that has done a special thing during this round. They highlight the character that was used and are therefor also called highlight intros. For the sake of simplicity they will be referred to as cutscenes here. Like fist person animation the camera is locked, but it shows the whole character instead. This makes room for smearframes. However they are used quite sparingly for some reason. It may be due to the full body nature and the high framerate of these clips, that strobing occurs seldomly which would reduce the need for

Figure 6.2: This image shows examples for third person animation in *Overwatch* during gameplay. Very interesting are the uses of multiples in (a) and (b). They convey very fast erratic motion that would not otherwise be possible. An example for a special case of elongated inbetween can be found in (c), where the character pulls up his arms very quickly. The smear was done by dragging the hand behind, creating a huge bending shape. In (d) a pretty standard example for motion trails is shown. Note that the motion trails are very faint and do not cover the whole character. This keeps the character visible during gameplay.

smearframes. The animations of course make use of motion trails as shown in figure 6.3 (c). The motion trail preserves the information of the movement for the viewer. The slight curve of the effect clearly indicates a slight upward motion before hitting the pose in the picture. At first glance it might seem like this is an example where the color of the motion trail does not coincide with the character colors. It is not clearly visible in the picture but the lore states that the power to move quickly comes from a device that this character has installed in her chest. This machine glows blue, thus it makes sense to use this color for the motion trail. In figure 6.3 (a, d) the characters are shown with a similar type of elongated inbetween as seen in figure 6.2 (c). The effect, at least in (a), is a lot stronger however, increasing the impression of radial movement. The arms move in opposite directions in this case, but the principle is the same. The upper arm reaches the final pose, while the hand stays in the original pose for longer creating this long bend. In (d) the effect is similar, but according to the animator David Gibson this was also done to show the face during the movement [29, T=00:14:20]. This keeps a point of reference for the viewer to focus on. Figure 6.3 (b) shows an example for multiples during a cutscene. It is a very similar, if not the same, animation as in figure 6.2 (b). The effect is again achieved by creating slightly transparent duplicates of the character during motion and also the weapon duplicates are the same. Something that was not visible before was that the arm also exists multiple times. One is pointing left, one right and one directly at the camera, but without holding a gun.

Figure 6.3: These are examples for smearframes during cutscenes in *Overwatch*. The camera during those is locked. Again, all types of smearframes can be found. The animations can be very similar to ingame versions. Image (a) shows a stronger version of the elongated inbetween that was shown in 6.2 while (b) might be the same animation, but is then faded to a slow motion to end the cutscene in time.

6.2 Cinematics

Cinematics are short animations, usually about six to ten minutes long. The purpose of these animations is to expand on the lore and show more detail about the characters. They usually feature multiple characters from the game with one of them being the main focus. The shorts mostly play in a time period that precedes the game. The first cinematic for *Overwatch* was released in 2014 and was used as an announcement trailer. It is 6 minutes long and fully realized in 3D. Then there was a two year break until shortly before the game got released. When the game was released in 2016, six cinematics were published over the course of the same year. 2017 had two shorts published and 2018 one until August, resulting in more than one hour of animation until now. This counts only the animations done in 3D, but does not include the many 2D animated shorts that usually get released when a new character is introduced to the game. Although they are usually animated very little as they focus on story, some of them feature snippets of full animation. This leaves very little room for smearframes, but they were still used occasionally. Finally, for the second anniversary of the game's release, a stop motion animated short was published. Compared to the other shorts it does not add lore to the game, but just shows two characters that make a cake for *Overwatch's* birthday. To this date it is the only one of its kind, but more might come in the coming years.

6.2.1 3D Animation

This part focuses only on the 3D animated shorts. The images were only taken from two shorts. The first one is the *Overwatch Cinematic Trailer* [28] and the second one

Figure 6.4: These images represent the 3D animated shorts from *Overwatch*. They primarily use elongated inbetweens, which are hard to see in these examples because of motion blur. In (d) however there is an image of the animation before it was fully rendered. This means the motion blur is missing and the smearframe is clearly visible. The animations also use motion trails as seen in (b). They are very opaque but fade quickly.

a short called *Alive* [27]. Both of them show dialogue and feature quality animation and rendering. The problem for this analysis is, that they are rendered with a lot of motion blur. This makes the smearframes very hard to see. Luckily there is a playblast version for the first cinematic on a blog called *Behind the Cinematic* [53]. A playblast is a very quick render of the animation without any lighting and most importantly without motion blur. This made it possible to include an image in figure 6.4 (d) that shows the smearframe very clearly.

The animated shorts primarily use elongated inbetweens as a technique for smearframes. This can be seen in figure 6.4 (a, c, d). However in (a) and (c) they are a bit harder to see due to the amount of motion blur. Image (d) shows it very clearly. As it is typical for 3D smearframes the smearframes are achieved by stretching a mesh along the path of motion. It can be seen in (d), that this stretching can go very far, effectively removing any hint of bones in the character. The smearframes were probably created more pronounced than usual so they could still be seen after the motion blur was applied. As figure 6.4 (b) shows there were also motion trails used. They fade very quickly, usually in two or three frames. Also they are not used on every character, but rather seem to be linked to a characters ability. In the case of the example in (b) it is used to visualize the short range teleportation ability of the character.The motion trails are also very opaque, masking out what is behind them temporarily. That is not a problem however since they disappear so quickly. There was no use of multiples in the shorts, however in the playblast version of the Overwatch*Cinematic Trailer* there were animated multiples. They can be seen at T=00:01:23 in the video from *Behind the Cinematic* [53]. They did not make it into the final movie however, for an unknown reason.

(a)  (b)

(c) (d)

Figure 6.5: This image is an example for the use of smearframes in *Overwatch's* 2D animated shorts. Smearframes are very rare in that case because most of the shorts use very limited animation. Those that are more fully animated use them rarely. (a) and (b) show the way motion trails are used. The are fully opaque hiding what is behind them. (c) and (d) show elongated inbetweens that have a very distinct trailing edge that is broken up to convey motion.

6.2.2 2D Animation

As mentioned in the beginning of this section, the 2D shorts are very limited. They are mostly images with a slowly moving camera featuring a narrator that tells the story. For that reason they are not suitable for smearframes. One of them however is fully animated. The short is called *Doomfist Origin Story* [18] and was released in 2017. Figure 6.5 (a, b) show images from it. It is still only animated on twos however. That means that the movie runs in 24 frames per second, but the animation usually updates every second frame. There are exceptions to this in fast motion, but this might be the reason why this short lacks the use of elongated inbetweens and multiples. Although this is very easy to do in 2D they may have omitted these techniques because of the lower animation frame rate. The reason for this is that even though the spaces between shapes in motion are bigger, the poses are held longer allowing the viewer to catch up. It may however also just be down to a style decision. The short makes use of motion trails however as can be seen in images (a) and (b). They are fully opaque and are only white, but show a green glow on the edges. They seem to be character specific again meaning they are color coded to the specific character. The second short that features smearframes is called *Sombra Origin Story* [32]. The animation is mostly very limited, but there is a section that has a more complete style of animation. It is from this section that the images in figure 6.5 (c, d) were taken. They show the use of elongated inbetweens in 2D animation. Very typical for this is the relatively flat leading edge with a trailing edge that is very spiky. In motion this gives the impression of the edges fading into the background, even though they have a clear outline.

(a) (b)

Figure 6.6: This image shows how the motion trail effect was done in the stop motion animated short *Trace & Bake* [9]. Image (b) shows the setup that includes a blue ball and a LED strip [12]. It only required some compositing to then reach the result at (a).

6.2.3 Stop Motion

This last part is about the stop motion short that was produced for the two year anniversary of Overwatch. The short is the only stop motion short produced for *Overwatch* and it is called *Trace & Bake* [9]. It shows a character creating a cake and a second, less important character, lighting the candles at the end. Unfortunately there was not much done in terms of smearframes. It only uses motion trails, and leaves out elongated inbetweens and multiples. Luckily there is a behind the scenes video [12], that shows how the motion trail effect was done in this short. As it can be seen in figure 6.6, the motion trail was not completely done on the PC. Instead the creators used blue medical tube and LEDs as they explain at T=00:03:54 in the video. The motion trail was then finished up in post production to add glow and remove the wire.

6.3 Comparison

For this part, the animations will be compared by looking at each smearframe technique individually. As an example, the first part focuses on elongated inbetweens and highlights the similarities and differences between the animation types. That should give a clear structure to the text and avoid confusion. Not every combination of animation will be mentioned, because some examples are just too similar and it is enough to mention it once. For example it might be enough to compare game animation in general to 3D cinematic animation instead of going through first person, third person and cutscene animation individually.

6.3.1 Elongated Inbetweens

Since most of the elongated inbetweens were made in 3D they are all very similar. There are however some details in which they differ. Firstly it is worth noting that all game animation is very similar concerning elongated inbetweens as long as the camera is locked down. It does not really matter if it is first person or cutscene animation. The way it is achieved and the strength of the smearframe are about the same, as can be seen

(a) (b)

(c) (d)

Figure 6.7: This image compares the use of smearframes between game, 2D and cinematic animation. Note that the biggest difference is between (c) and the rest. This is because the smear is a lot more abstracted in example (c).

in figure 6.7 (a, b). Even though third person animation contains elongated inbetweens, they are very toned down. For image reference see figure 6.2 (c).

Cinematic animation on the other hand goes a lot further. Shown in figure 6.7 (d), the body is stretched further than anything found in game. This is of course then hidden behind a wall of motion blur after the image is rendered. See figure 6.4 (a) for the same frame rendered out. However the technique used to create the smear is the same as in the game animations. It is just a lot of scaling and letting some body parts overlap so their shape fuses. Comparing the 2D smearframe from image (c) to the others, it is immediately noticeable that it differs a lot. Not only is the smear a lot more abstracted, losing the original shape completely and abstracting it. It also smears the colors and texture of the arm into a simple gradient. In the 3D smears, the texture detail is completely intact, even if it is a bit stretched. With this abstraction the 2D smearframe has the advantage of presenting the viewer an undefinable shape that looks a lot more like motion by itself. In the 2D example it is also a lot clearer, which side the trailing edge is. Compare that to image (b), where it is not nearly as obvious.

To conclude this subsection it can be said that it is interesting to see that the elongated inbetween, a technique can be considered the original form of a smearframe and comes from 2D, finds so little use in its original medium. That being said, the sample size for fully animated shorts in the *Overwatch* universe might not be representative and future releases might change that.

6.3.2 Motion Trails

For this comparison the example figure 6.8 contains only motion trails of the same character. This makes it easier to compare the types of animation with each other. Firstly, looking at the opacity of the trails, all versions show it differently. In stop motion

Figure 6.8: For easier comparison all of the images show the same character, only in different mediums. (a) is from a 2D animation, (b) is from a cinematic, (c) is game animation and (d) is stop motion. Although they look similar at first glance there they are very different. The strongest unifying factor is color.

it is of course fully opaque as a result of the technique used that was explained earlier. But also in A, the effect is only slightly transparent. Most similar are the cinematic frame in (b) and the gameplay frame in (c). If inspected closely it is even revealed that they both apply some sort of distortion effect. Something that can not be seen in the images is the duration of the effect, which varies slightly between them. In game animation it is held for roughly half a second and also in the cinematic example the duration is between 0.4 and 0.5 seconds. The 2D animation uses vastly different lengths, sometimes keeping the smear on screen for seconds, other times dropping it within a frame. Stop motion keeps it around 0.3 seconds. A unifying factor that should be visible at first glance is the use of color. All of the examples use the color blue for the motion trail. That is because this color is tied to the character and can not change no matter which medium. There is another major difference that is not visible in the example image and that is the fact that in 2D animation, the motion trail sometimes leads the character. It is animated like lightning that flashes to the position the character will appear in shortly. In all other examples it is the other way around, with the game animation even adding the trail long after the character has already left the spot.

6.3.3 Multiples

Since multiples only exist in third person game animation, there is not a lot to compare. There is however one thing to be noted about multiples or better the lack thereof in first person animation. As shown in figure 6.9, the same action that creates multiples in (b) does not do anything in (a). Even though the same action is performed, the way it is visualized differs a lot. The reason for this is probably that having lots of arms flashing around the screen is very distracting for the player. On the other hand they are

(a) (b)

Figure 6.9: This shows how differently the same action can be displayed depending on the point of view. The multiples from (b) are completely missing in the first person animation in (a). The reason for this is probably that too much motion covering the screen is bad for gameplay.

a very strong signal to other players showing them which action this character is just performing and whether they should be cautious.

Chapter 7

Conclusion

The preceding chapter has shown how smearframes are used between different mediums. Some techniques are very consistent, for example motion trails. They play a big role in characterization, which hints at another great potential for smearframes. Maybe the other techniques can be used to achieve that as well. Linking character recognition to elongated inbetweens or multiples is something that has not been done to my knowledge. That is a pity because the blue line from the *Overwatch* character shows how much potential it has.

The reduced use of multiples made it hard to compare them in *Overwatch*. However when it was used it has a great effect. It excels at displaying erratic movement that does not look too confusing for the viewer. It is unclear to me why this technique was not translated into other mediums like 2D animation. However it should be clear that translating a smearframe type between mediums always requires some forethought. An elongated inbetween for example is easy to do in 2D, but needs a proper rig to do in 3D. On the other hand, motion trails might not be possible to do in 2D depending on how the animation pipeline is constructed. Maybe the creators of *Overwatch* tried to implement multiples into 2D animation but the look just was not right. That is not a problem at all, as long as the artist is aware of the fact and a good substitute is found.

Elongated inbetweens have a very similar appearance across mediums. The comparison showed that this technique is pretty much identical between 3D animation in games and film. For games this is of course only true as long as the camera is locked. But also without a locked camera there are subtle smears. They are just a lot less extreme, which I do not think they need to be. As long as the smear is well constructed in 3D space, the motion should be readable from all angles. Well constructed in this case means that the extended shape closely follows the motion of the original shape through space. That means the animator can not just wildly scale things up but needs to carefully sculpt the smear looking at it from all angles. This sounds like a lot of work and it probably is. It is highly likely that this would be too much work to justify the advantages of having a smear. However it may be possible to reduce the work the animator has to do with a post processing effect. As the example in chapter 2 showed it is already possible to create a type of procedural smearframe. In the current state this technique is not very useful however as it only works on non deforming geometry. Also it should probably follow the principles laid out in chapter 3. The effect would somehow need to be able to determine the leading and trailing edges and warp them in screen-space. That said the available procedural technique is an interesting step in the right direction. Sadly elongated inbetweens are not used in stop motion very often. As I already mentioned this has to do with limitations that the medium poses. But there are certain ways to work around that. One way would be of course to just draw the smear in post production, similar to how it is done in *Spider-Man: Into the Spider-Verse*. This may be too complicated however and some animators might want to construct the smear themselves. So why not use the same technique as *The Lego Movie*, where they just replaced the entire character with Lego bricks. This example shows, that the shape that portrays a smearframe only needs very little resemblance with the original. So in stop motion you could just replace the character with a block of clay for a frame or two. As long as the clay has roughly the same color as the original character, this should work perfectly.

Now that we have looked at how smearframes are used today, let us take a look at the future of animation. When talking about emerging technologies, there is no way around VR. It has not yet caught a hold of the publics attention, but a lot of development is happening in this area. Basically there are two directions animation in VR goes. The first one is to use classic 3D to either prerender an animation or have it interactive like in a game. The latter results in the limitation of not having a locked off camera and may require procedural smearframes as described before. The second one is this blend of 2D and 3D animation, where the animator can place strokes in 3D space using his arm movements. Already, users are creating simple animations that use smearframes. How frequently they are used may depend on whether the output is interactive or not. There is however the possibility that hand painting smearframes that work from all angles is feasible in VR because the animator is working without rigs anyway. It is fascinating to think about what the future may bring in this field. It may even be classified as a new type of smearframe.

There are of course also possibilities to expand the knowledge of smearframes. My work used *Overwatch* to compare smearframes across mediums, but there are other movies and games that have this option. For example it might be interesting to look at games that were adapted from film. An example for this are the *Harry Potter* games that always followed a movie launch. There are also examples of the other way round. The game *World of Warcraft* recently got a movie adaption. Even though this is life action it might be interesting to see how motion aesthetically differs. Also, it would be interesting to look at a character that originated from comic. Spiderman would be a perfect example. Not only are there animated movies, but also games and life action films.

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