

Integration of 2D animation into a 3D pipeline

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Bachelor's thesis
2021



Tomas Bata University in Zlín
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Fakulta multimediálních komunikací

Ateliér Animovaná tvorba

Akademický rok: 2020/2021

ZADÁNÍ BAKALÁŘSKÉ PRÁCE
(projektu, uměleckého díla, uměleckého výkonu)

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Studijní program:	B8209 Teorie a praxe audiovizuální tvorby
Studijní obor:	Animovaná tvorba
Forma studia:	Prezenční
Téma práce:	1. teoretická část: Integrace 2D animace do prostředí 3D
	2. praktická část: Bodies of Water – krátký animovaný film

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Rozsah příloh: viz Zásady pro vypracování
Forma zpracování bakalářské práce: Tištěná/elektronická
Jazyk zpracování: Angličtina

Seznam doporučené literatury:

O'HAILEY, Tina. Hybrid Animation: Integrating 2d and 3d Assets. 1. vydání. Oxford: Focal Press, 2010. ISBN: 978-0-240-81205-2.
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Datum zadání bakalářské práce: **1. prosince 2020**
Termín odevzdání bakalářské práce: **21. května 2021**



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ABSTRAKT

Táto bakalárska práca skúma spôsoby ako kombinovať 2D animáciu s 3D. Nahliada k technikám a technológiám, ktoré zvolili vo veľkorozpočtových projektoch a možnostiach, ako dosiahnuť podobné výsledky s voľne dostupnými nástrojmi. Praktická časť opisuje tvorbu krátko animovaného filmu *Bodies of Water* od jeho počiatkov až po produkčnú fázu.

Kľúčové slová: animácia, CGI, hybridná animácia, kombinácia techník

ABSTRACT

This bachelor thesis explores different ways of mixing 2D animation with 3D. It examines methods and technologies used in big-budget projects and how similar results may be achieved using freely available tools. The practical part describes how the animated short film project *Bodies of Water* was made from its concept to the production phase.

Keywords: animation, CGI, hybrid animation, combination of techniques

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INTRODUCTION

The future of 2D animation has often been debated. Its CGI competitor dominated the market with complex character models, camera movements, and textures. Both styles have their strong sides but rather than arguing which style is better, we would like to take a look at ways the two media may coexist within one product.

It is common to use 3D models to assist 2D animation in shots that require complex camera movement or models. Rarely do we see traditionally animated spaceships. Hybrid animation can use the advantages of both mediums, however, different elements are treated separately, and animators face numerous challenges when blending the two together. One always needs to match the style of another. We would like to provide insight into what complications may occur and how they are avoided. To resolve these complications, new methods have been developed to bring 2D and 3D even closer.

Many share the opinion that there is something irreplaceable about the hand-drawn feel of traditional animation—opposed to the geometry-based CGI. In the past few years, multiple attempts have been made to bring the pencil and brush strokes back into business. Two- and three-dimensional elements are becoming more interconnected, bringing a fresh look for the films but also posing new technological challenges. In this bachelor thesis, we would like to have a closer look at how the authors managed to create this new stylization.

Although leading animation studios had already begun the development of new tools for 2D/3D hybrid animation, most are still exclusive for internal use only. Without the privilege of working at such a studio, it might be difficult to get access to them. While we may wait to see whether the tools will be released to the public, existing software is already trying to implement support for hybrid animation. Most notable is the Grease Pencil by Blender. Thanks to being open source, it is available to anyone with a decent computer. Is it possible to get results comparable to big studio productions? Our goal is to explore what an animator with 2D training can get out of these new tools and hopefully inspire them to delve into hybrid animation on their own.

I. THEORY

1 2D ANIMATION WITH THE ASSISTANCE OF 3D

Choosing the medium of a film is usually the first decision an art director makes. They could either go for a strictly monogenous style, using only one type of medium or combine multiple mediums to create the so-called “hybrid animation.” This term refers to animation that combines 2-dimensional and 3-dimensional media. Experimentation with this style comes as early as 1985 where a 3D bauble appeared in Disney’s feature “The Black Cauldron”. [1]

Whether the film will be 2D or 3D is based on multiple factors such as aesthetic preferences, budget, and competence of the animators. Hybrid animation in most commercial projects is usually chosen as a time and money saver, rather than a deliberate aesthetic choice. Since it combines the two media, it is able to use the advantages of both. It doesn’t necessarily need to be used in the whole film, sometimes it only appears in scenes that would benefit from it.

1.1 Combination of 2D and 3D characters

Character design for traditional animation aims for simplicity. The line mileage increases with every detail added and although it seems insignificant in one drawing, if an animator were to draw that detail for thousands of frames, it would cost them hours of work. However, some stories require complex characters that would not have the same impact, if simplified. This is where 3D becomes useful. It is most commonly the case with machines and vehicles. Not only are these types of characters made of many small, moving parts to be believable, but they are also usually composed of geometric shapes and right angles that are quite tricky to animate traditionally without losing proportions. A prime example would be *The Iron Giant* from Dreamworks that displays the interaction between the 2D main character and a giant 3D robot.

An important driving force in storytelling is character interaction. Both action and acting often use the sense of touch to make connections between the characters and convey some part of their emotional state to the viewer. It could either be positive - a hug or a pat on the head, or negative – a slap, kick, or a punch. [2] Contact between characters from different media is comparable to a meeting between two different worlds and there is a risk that the technical issues of the film caused by mixing media may be distracting from the narrative. In order to make the interaction as seamless as possible, registration, timing, format, and

style matching need to be taken into consideration when figuring out the production pipeline.
[1]



Figure 1 Examples of using hybrid animation. *Gravity Falls* © Disney Television Animation, *The Iron Giant* © Warner Bros

1.1.1 Registration

Registration refers to when one object touches another in the scene. A place where the characters contact is called a registration line. In traditional animation, accurate registration poses a technological challenge. Printing of CGI imagery, pegging, and scanning all create small inaccuracies in character positioning that would subsequently create an offset in the registration line. With enough precision and pencil tests, it is possible to achieve a well-registered animation, which was proven by films like *The Iron Giant* or *Triplets of Belleville*. Fortunately, most registration issues are easily eliminated when using digital media for 2D animation.

Still, using digital software does not guarantee accurate contact. By default, the 3D character has spatial depth and to interact with it, the 2D character is usually designed to evoke three-dimensionality as well. The registration line between the characters thus should trace them with their volume in mind. A good understanding of movement in perspective is

fundamental. If the animator is sloppy, the 2D registration line will noticeably shift and wobble compared to the 3D model that is always in precise perspective.

A simple way to overcome this issue is to hide contact points, where it is possible. The 3D render can be broken into layers that would overlap 2D layers and vice versa. In the case of 3D models being only an extension of the character rather than a separate character (for example John Silver's robotic arm in *Treasure Planet*) sleeves or collars mask the sharp transition. However, the technical aspect of the film should be secondary to the story and if an emotional moment requires close interaction between the characters, it should stay visible. In this case, a 3D animator may include wireframe guidelines and placeholders for the 2D animator. Alternatively, a 2D animator can draw key poses that would later be replaced by 3D models.



Figure 2 John Silver and his 3D robotic arm. *Treasure Planet* © Walt Disney Pictures

A determining factor in the production pipeline for hybrid animation is which character is leading the movement of other. In an ideal setting, the entire scene would have only one leading character, which would be animated first. The second character would then be filled in and the scene would be ready for rendering. In some cases, the role of the leading character shifts within a scene. In a studio setting that would mean moving the scene back and forth between different media departments. To cut time spent waiting for the other animator to finish their part, one animator takes the leading role and drafts in where the other character is supposed to be. In both settings, the animation needs to be approved as final before moving to another medium. Any later changes to one medium could affect the other and cost animators extra time to redo both assets. [1]

Apart from action, the characters also react to each other depending on what material they are made of. Since most 3D characters tend to be mechanical, they are composed of hard surfaces that don't change shape when touched. That significantly simplifies the pipeline. It is usually the 2D character that is made of soft, flexible materials that react more noticeably to touch. In *Aladdin*, the 3D carpet is a soft material, which complicates the action and reaction. If viewed closely, the registration doesn't always match perfectly, but it's easily overlooked, since the scene emphasizes singing and expressions rather than sitting contact points.



Figure 3 Aladdin and Jasmine sitting on a 3D carpet. *Aladdin* © Walt Disney Pictures

A special case of 2D and 3D character combination is when it is the same character that switches media mid-scene. One exemplary scene comes from *Spirit*, which contains a longer shot with complex camera movement and multiple characters. In the beginning, the main character is 3D and as the camera comes for a closeup, the animation then switches to 2D. It remains this way until a wide shot landscape is revealed, where the character switches back to 3D. This seamless transition was achieved thanks to toon shaders that created an outline of the model in similar thickness as traditionally animated lines. The 2D animators used a 3D mock-up for reference to preserve proportions in perspective. Additionally, the hair on the horses was animated traditionally throughout the whole scene to further mask the transition. [3]



Figure 4 *Spirit* - transition from 3D body animation to 2D and back to 3D within one shot.
Spirit: Stallion of the Cimarron © DreamWorks Animation

1.1.2 Timing

In traditional animation, the framerate is at a fixed speed, but the animation does not always need to be drawn on every frame. Sometimes the animation is on twos, threes, or even eights, meaning one drawing is held for multiple frames, and how long the drawing is held may change within one scene. Fast action is often animated on ones to keep it smooth while slower action may stay on twos. Having animation on twos halves the number of drawings an animator needs to create and is commonly used by studios to speed up production. However, in 3D, the motion is calculated through graphs, so the animation always plays on ones. In the commercial setting, more frames are perceived as creating smoother, more natural movement and animating on twos in CGI only appeared with the release of *Spider-Man: Into the Spider-Verse*.

When assets from two different media interact with each other, the framerate and timing tend to be synchronized to keep the movement consistent. If the leading medium is 3D, it's easy for the traditional artist to match the animation. When 2D leads, it poses a slight technological challenge, since CGI software works in fixed framerate. Switching from animating on ones to animating on twos cannot be done using graphs to calculate in-betweens like in a typical 3D animation pipeline. One way to bring traditional timing into 3D is through constant interpolation. The character is first animated, and in-betweens are interpolated with curves on ones. Then a keyframe is created every two frames, a process that most software can generate automatically. Finally, the interpolation is changed to constant, which means that the program will not generate any in-betweens but will hold the keyframe pose as in animation on twos. These keyframes can be moved on the timeline, so the animator can combine animation on ones or twos just like in traditional animation. [4]

Additionally, to make the process of synchronizing easier on the animator, timing charts are a useful addition to the pipeline. They were heavily used in older traditional animation on paper to streamline the communication between the key pose artist and the inbetweener. Nowadays, their use is on the decline, especially in the 3D animation department. They can be used to let the animator from the different medium know where the keyframes are and where ease in and ease outs occur. [1]

1.1.3 Format

In a digital workspace, setting up a format guide is a matter of seconds but worthy of attention, when working with multiple people. For some productions, different image sizes are used to speed up the production. Rough animation and tests tend to be downscaled for faster software processing and rendering. When incorporating traditional media, printing, and scanning may distort the proportions and keeping track of the format could be done through initial printed guidelines and test screenings. [1]

1.1.4 Style Matching

In most cases, hybrid animation tends to be used as a time-saving trick rather than a deliberate aesthetic choice. It primarily aims to not distract the viewer. That is why studios make the art style of both media blend together. The hand-drawn is pushed towards

indicating depth, while 3D is being flattened. A basic art style can be simplified into two categories – line art and shading.

In the era of traditionally animated film, clean inked lines were the most compatible for hybrid animation. It is visually closest to vector lines considering earlier computer graphics were not advanced enough to create textures and imperfections that a pencil or a brush would make. Since then, progress has been made and a lot of this is now possible in vector graphics. However, the industry-standard still leans towards using clean lines, as they are easily readable and available in any software.

When it comes to shading, it would be time-consuming to make fully shaded 2D animation to match the 3D style, so it is the 3D models that try to mimic the visual art style of 2D. A shadeless or flat shading is applied, since shadows contain a lot of information about the spatial dept. In a more cartoony style, a flat shading works well, but in semi-realistic feature film style, lights and shadows play a role in storytelling and stripping the art style of shadows could negatively affect the visual appeal. Cel shading is a popular choice since it uses flat shapes mimicking the hand-drawn shadow. It was pioneered in videogames, where the early attempts tried to emulate the style of Japanese manga. The style is still present to this day, as it does not require a lot of computing power. It found its way to film and today it is often referred to as toon shading. A conventional cel-shading uses a Lambertian shading model with a 1D texture describing the transition from light to dark. For a realistic shading, it would be a gradient, in toon shading, the transition is sharp, creating the characteristic flat shapes.



Figure 5 Example of a toon shader applied to a 3D model. © Andrey Torchinsky

Traditionally drawn shadows undergo a level of abstraction, as opposed to 3D, which depicts shadow with mathematical accuracy. A traditional shading omits certain detail in objects that are less important or further away. [5] In the production of *Spirit*, the animators first rendered the shading on a 3D model and VFX animators would match the shapes to smoothly transition from 3D to 2D. [3] At present time, new toon shaders are being developed to consider shape abstraction by calculating the size and distance of the object. The 1D shadow texture would be given 1 extra dimension to describe how the shading changes with abstraction. [5]

A lot of hybrid animation is quite easy to spot due to improper style matching. Sometimes the assets visually match but their movement breaks the illusion of being from the same media. Movies, where the blending is so well done are for example *Brother Bear* – the moose antlers were too complicated for 2D animators and were animated in 3D and lined traditionally. Another example would include the bicycle scenes from *The Triplets of Belleville*. For easier registration, the bicycle and feet on pedals were in 3D, while the rest of the cyclist is animated traditionally. [1]



Figure 6 Example of a well-blended hybrid animation style. *Triplets of Belleville* © Sylvain Chomet

1.2 Backgrounds with depth and 3D camera

The animated film utilizes a lot of cinematography techniques from live-action films. Creating a setting that allows dynamic camera movement expands the possibilities of filmmakers to bring their audience into the world. In a traditional flat background, if the camera pans or zooms, the elements within the scene remain in the same proportion to each other, which isn't natural. In real life, objects closer to the eye move faster than objects far away. To create a more realistic scenery, the background would be split into layers, typically foreground, midground, and the background.

This concept was first introduced by Disney with his multiplane camera technology. It consisted of several glass plates positioned at varying distances from the camera. Each layer was individually operated and capable of moving on all three axes, allowing for pans and zooms. Moving the layers at different speeds produces a parallax effect, which refers to the illusion of depth created when images in the foreground move at a different rate than those in the background. [6] Although shooting with a multiplane camera produced visually appealing sceneries, its use was gradually declined due to its time-consuming nature and high production costs. [7] [8]

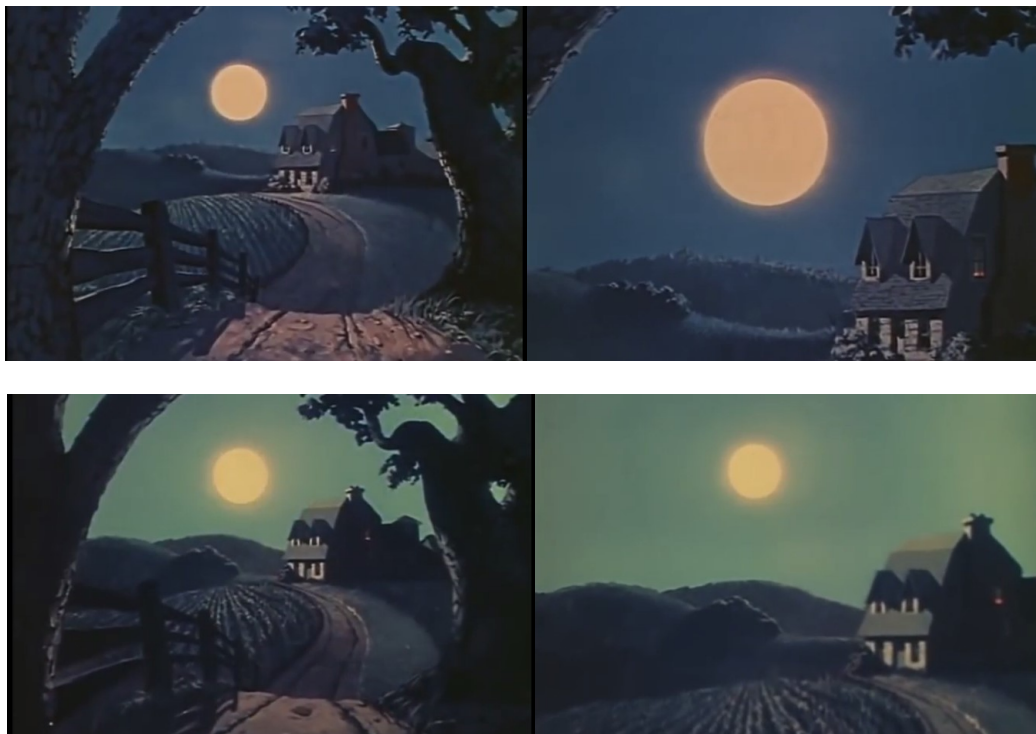


Figure 7 Zooming without a multiplane camera (top) and with a multiplane camera (bottom). *Walt Disney's MultiPlane Camera* © Walt Disney Pictures

Thanks to the advance in digital animation, multiplane made its return and is widely used in animation, games, and even website design. With the introduction of virtual cameras, instead of moving each layer manually, the animator can design a layered 3D set and move the camera through it. The speed of each layer is calculated automatically during rendering, providing more realistic results. Furthermore, cameras in more advanced software come with a depth of field setting, which refers to blurred parts of an image that is out of focus. Various implementations of 3D cameras can even be found in 2D-based animation software like Toon Boom Harmony or TV Paint. [1] Multiplane broadened the possibilities of camera movement but still limits the movement to axes. For more dynamic fly-throughs or rotations, using layers of flat imagery is not sufficient enough to convey depth; it would visually resemble a toy paper theatre, which could be a stylistic choice, but in most cases, it is not.

To use the virtual camera to its full potential, sets are built from 3D objects. If a project uses primarily painted backgrounds, a sharp switch into 3D is noticeable, and adequate style matching would be necessary. Disney's approach to this issue was the development of Deep Canvas. For Tarzan's famous vine-swinging scene, the background elements that Tarzan interacted with, like tree branches and vines, were first modeled as 3D objects with grid guidelines for the 2D animators. They would animate on top of the printed-out frames. To replicate the characteristic painted backgrounds old-school Disney is known for, digital painters would paint directly onto the model. The strokes were tracked and when the angle of view changed, the background was repainted by the software. [9] Deep canvas was only used in a few shots in *Tarzan*, however, in *Treasure Planet*, roughly 75% of scenes used a modified version of Deep Canvas, mostly used on ship models. [10] Due to *Treasure Planet* failing commercially and the studio's interest to transfer to CGI, Deep Canvas did not get further developments. A similar technology reappeared with the development of Grease Pencil and will be investigated more closely in a later chapter.



Figure 8 Deep Canvas Scene Progress. *Tarzan* © Walt Disney Pictures

As digital space makes creating deep space simple, the filmmakers can be tempted to use it everywhere they can. It is important to remember that spatial depth affects how the viewer emotionally perceives a scene. To quote Anthony Wong “Flat is funny, dynamic is dramatic.” This is reflected in flat layouts dominating the cartoon industry, while dynamic shots prevail in feature films. Some scenes benefit from the lack of depth and even in 3D, the composition can be flattened by using front views. Layouts should be designed to support the emotion in the story. [1]

2 2D AND 3D ANIMATION IN A HOMOGENOUS ART STYLE

During the boom of CGI animation in the past decade, large studios focused on the technology of rendering materials in a photorealistic manner and smaller studios also followed the trend to remain in the competition. Mixing media was reserved for cartoons and films with a less mainstream nature. After a decade of market oversaturated with 3D, artists began to realize hand-drawn animation brings a level of expressivity a moving geometry is not able to replicate. With titles like *Paperman* and *Spider-Man: Into the Spider-Verse* we begin to see experimentation with a new visual language to bring back the 2D feel. Unlike in hybrid animation, the assets are no longer limited to be in one medium or the other but can incorporate both media at once, creating a homogenous look.

2.1 Meander

In 2012, Disney released a 7 minute short called “Paperman” which revolved in its entirety around paper. The director John Kahrs expressed interest in merging the classic 2D animation people would feel nostalgic about with contemporary technologies. Two years prior to the release, the company began developing a hybrid vector/raster-based animation tool called Meander. The drawing system of Meander was designed to make vector lines based on real-time drawing. The lines use a stamp-based rendering, which is common for raster software. Brushstrokes contain a set of vector points, and at each point, a textured stamp is drawn. With this technique, the user is able to control the position and parameters of the drawing, without losing the traditional feel of digital drawing. It was originally developed as a 2D clean-up tool but later expanded to be used in combination with CGI. [11]

2.1.1 Use in *Paperman*

In *Paperman*, the production pipeline began with modeling, rigging, and animating a 3D character. Since line and texture would be added later, the model’s geometry was simplified. After the animation was done, motion render generates motion fields that describe where a pixel was in previous and will be in the next frame. Since traditional media line art usually describes silhouettes, silhouette ribbons are created to track outlines of shapes. The character is divided into cylindrical components to allow limbs to have their own silhouette, even if it moves in front of the body. Information from motion fields and ribbons will be then used for rendering the line. In the final stage, a 2D line is applied to the CGI model in Meander. Unlike in rotoscoping, where each frame is hand-drawn, animators only need to draw key

poses. In-betweens are rendered with computer-assisted drawing, which consists of motion pasting and motion betweening. Motion pasting refers to a process where an animator draws a set of strokes and pastes them on another frame. The computer automatically calculates the position of the strokes and the position of in-betweens (Figure 9). Motion betweening is the in-betweening of the stroke itself. This means the line could have animation on its own which is then motion pasted to the model. To complete the pencil-on-paper-like stylization, a motion paper texture was applied to the model. Temporal coherence was achieved thanks to the texture moving according to the 3D model and boiling, meaning a new texture was generated per frame. [12]

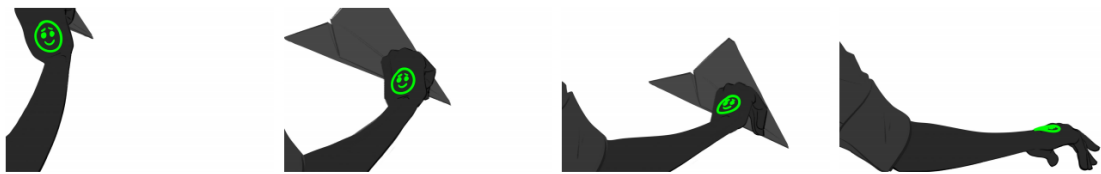


Figure 9 Motion pasting - smiley face was drawn by the artist only on the first frame. *Paperman* © Walt Disney Pictures



Figure 10 Paperman: 3D geometry, motion fields, applying line, final rendering. *Paperman* © Walt Disney Pictures

Computer-assisted drawing is not yet perfect – some predicted lines needed to be adjusted manually, but with this system, the animator would have to draw roughly only one in fifty drawings. Meander animation was later used in another short *Feast*, and 2D elements in *Moana*, but never for a visual art style of an entire feature film. Unfortunately, it is still not released to the public and only Disney employees have the access to experiment with this software.

2.2 The visual style of Spider-Man: Into the Spider-Verse

The concept idea of Justin K. Thompson, production designer of *Spider-Man: Into the Spider-Verse* was to tell a story from the perspective of Miles, the main character. Miles is a comic book hero, and Thompson wanted to create a world as Miles would see it – full of vibrant colour, line art with offsets, and Ben-Day dots. [13] This provided the art directors with a challenge - how to translate an iconic comics style in 3D.

2.2.1 Line art

The main element to figure out was the line. Hand-drawn lines were ideal for exaggeration of expressions and mostly populated characters' faces. Instead of generating outlines based on geometry like a toon shader, the expression line art was hand-drawn, rigged, and controlled like a 3D object. A difference in approach compared to Disney's *Meander* is that the lines were drawn inside of 3D software and were a part of the rig. This omits the extra step of rendering geometry before applying the line. For a scene with action and changes in expression, keeping the rig under control would be very time-consuming for the animator. Like *Paperman*, machine learning algorithms were developed to predict line movement based on the position of a 3D model and which was later refined by the animators to retain the traditional illustration feel. To push the style more towards comics, some lines were given an offset to mimic the imperfection of retro print. Although inaccuracies in print were considered a flaw, humans find imperfection appealing and using misprint can visually enrich the viewer. [14]

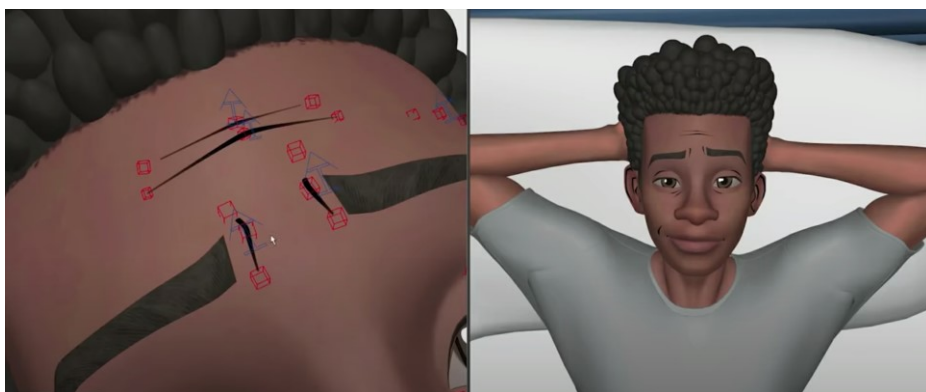


Figure 11 Line art on Miles. *Spider-Man: Into the Spider-Verse* © Sont Pictures Animation

2.2.2 Hard Edges

Another part of the traditional comic art style that *Spider-Verse* adapts is the lack of soft and blurred shapes. Objects appear rougher thanks to using posterization methods and textures,

but the softness is also removed by not using motion blur. Instead, it is replaced by drawings of smears with typical cartoon exaggeration such as elongated bodies or multiplied limbs. A special type of smear was introduced called a “burst card.” (Figure 12) It is a still frame that replaced the scene with an illustration to emphasize hits or big moments. [15] Depth of field is another source of blurriness in the film, which needed to be solved by applying a traditional approach. In paintings, everything that is out of focus is drawn with more abstract shapes that only suggest an existence of the objects or textures. It imitates the way the human eye perceives objects in peripheral vision. Concept art for the film had a direct influence on the backgrounds. VFX artists adapted 2D abstraction by running a procedural simulation with 2D particles made of simple shapes that would move or flicker. The New York setting is full of small light sources for which the flickering blobs were an ideal fit. This significantly reduced the number of light sources that would otherwise need calculation, causing the rendering process to be much faster. Some windows of cars were mapped with a texture of 2D illustration, saving time on modeling the interiors and occupants. 2D elements however were not suitable for objects that were blurry because they were close to the camera. Instead, the VFX team used RGB offsetting to break sharp edges, another technique that draws inspiration from misprint. [16] [17]



Figure 12 Burst card. *Spider-Man: Into the Spider-Verse* © Sont Pictures Animation

2.2.3 Animation

The character animation in *Spider-Verse* was done on twos to resemble traditional animation, with occasional animation on ones during action intense scenes. When Miles first learns how to swing on the web, he and the alternate Peter Parker are both animated on twos but with an offset of one frame. When the footage is viewed frame by frame, they appear desynchronized, which also reflects the storyline. When Miles finally figures it out, the

timing on the frames synchronizes, which is a nice detail derived from traditional animation. [18]

2.2.4 Special Effects

In comics, the lack of sound effects is compensated by visual representations of sounds and speech. It became a recognizable part of the comic aesthetic. Although sound in film renders them obsolete, visual sound effects remained present. When Miles is singing at the opening sequence, he taps his throat and that is also accompanied by tiny action lines. These lines also indicated the activation of Spider-Sense, which was a minimalistic way to solve how to portray a fictional feeling. Decorative elements like these make this film very interesting to watch. For a superhero movie, the appearance of explosions was inevitable. The design of special effects tends to be a by-product of computer simulation. In *Spider-Verse*, explosions were crafted from hand-drawn sprites. Just like the characters, the animation of explosions was also kept on twos. To place them in time and space, particle simulation drove the placement and timing of each sprite. [17]



Figure 13 Visual representation of Spider-Sense. *Spider-Man: Into the Spider-Verse* © Sont Pictures Animation

Spider-Man: Into the Spider-Verse took an advantage of an already existing franchise with a huge fanbase, which made the investment into more experimental techniques safe for the studio. The risk paid off and the success of the movie proves there is demand for stylized CGI. So far, projects have adapted existing 2D styles into 3D and hopefully, in the future, we will get to see new art styles rising from the possibility of mixing media.

3 OPENLY AVAILABLE TOOLS FOR 2D/3D HYBRID ANIMATION

The animation where 2D and 3D elements interlace has proven to have an audience in the mainstream. Movies like Spider-Man inspired animators to try mixed media animation, but the tools used to make these movies are still an in-house property of the studios. Over the past few years, an open-source 3D modeling and animation software Blender began the development of their tool Grease Pencil, which functionality-wise came closest to allow small creators to experiment with hybrid styles.

3.1 Grease Pencil

In the earlier versions of Blender, Grease Pencil was implemented as a review and planning tool. The user could write notes or sketch drawings on top of the model. It was not meant for artistic output, so the speed of drawing was prioritized over line quality. With later updates, the line system underwent major developments.

3.1.1 Line system

Just like any other graphic program, Blender uses mouse or drawing tablet input to generate strokes. The strokes in Grease Pencil are vector-based but use polylines instead of splines, which are common in vector graphics. A polyline is a set of straight lines that connect through vertices. This system allows for a more traditional feel but requires a level of smoothing, otherwise, it would appear jagged. [19] Similar to Meander the brush uses stamp-based rendering, the difference is that these stamps are treated as objects in three-dimensional space. The vertices are recorded in space, and Blender offers multiple choices where in space the line is drawn.

3.1.2 Drawing planes

There are two ways how blender interprets drawings. The first is drawing on a flat 2D plane in space. Depending on the settings, the position of the plane could follow the viewport orientation (the drawings are parallel to the screen), cursor orientation (a cursor in blender is an empty vertex placed in space and the plane follows the orientation of this vertex), or views determined by the axes (front, top or side view, optimal for drawing cubic objects). When using the viewport option, the plane orientation changes with the view, while in the other options, the plane's orientation is locked. Grease Pencil also supports using 3D

geometry as a guide for the lines. How far the line appears from the object is determined by the offset. [20]

3.1.3 Line customization and fill

As a vector line, each stroke can be later modified, allowing the artist easy manipulation and repurposing of drawings. Line properties like colour or thickness are set on a per-layer basis instead of per-stroke, which is faster for mass manipulation of line art. [19] The downside is that each new setting requires to be on a new layer which could be incompatible with more stylistically free art styles. Grease Pencil drawings are not completely detached from the 3D environment. They are affected by light sources in the scene, and it does not need to be animated separately from the background. Some limitations however include incompatibility with the depth of field setting, or faulty rendering when the Grease Pencil object is overlaid by a transparent material like glass. [21]

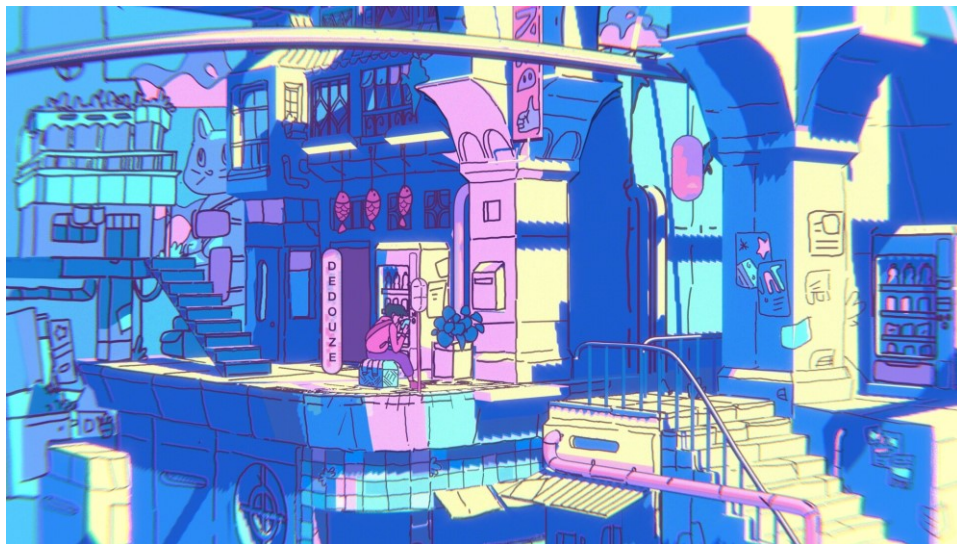


Figure 14 Grease Pencil illustration, fully 3D. © Andry "Dedouze" Rasoahaingo

3.1.4 Animation tools

Grease Pencil can be used for 2D animation by making use of the already implemented Blender timeline. To make the interface like 2D animation software, drawing on a new frame automatically clears previous drawings and inserts a new keyframe. Onion skinning was another implementation added to make the software 2D animator friendly. The 2.9 version is also capable of interpolation of lines.

3.1.5 Animation and real-life application

To showcase Grease Pencil 2.8 abilities, *Hero* a short fake trailer was produced. The characters were animated on a flat plane using traditional 2D methods inside the 3D environment of Blender. The artist can model the background, animate the camera and draw the character on top within one program. For hybrid animation, this means getting rid of time-consuming steps of rendering, exporting, and moving files between different programs. It also grants a higher level of flexibility when making adjustments to the scene mid-production.



Figure 15 Scene from *Hero* in Blender Interface. *Hero* © Daniel Martinez Lara

By using 3D models as a guide, a style like *Spider-Man: Into the Spider-Verse* is possible to achieve. Grease Pencil drawings can be parented and masked to the object and move with it while animating. The only functionality missing that differentiates Blender from custom studio software are predictive drawing systems. These may come with later updates or addons but even in this current state, the capabilities of Grease Pencil are sufficient.

The main disadvantage may be performance issues on slower computers. Traditional drawing relies on expressive strokes and lag can throw the user off. Lines are treated as 3D objects and complex scenes with modifiers need time to render the real-time animation. 2D/3D hybrid Illustrations made in Blender are less demanding. In film production, Grease Pencil would be a useful tool for creating animatics. The camera movement across space can be planned together with traditionally animated character poses. [19] On one hand, it is an innovative tool allowing people to experiment with new styles and production pipelines, on the other hand, it requires the users to have basic skills in both 2D and 3D animation which

for beginners may be overwhelming. To bring more people to this tool, Blender strives to educate potential users by releasing tutorials, appearing at conferences, and organizing seminars. [22]

3.2 Animation in VR

Virtual Reality headsets are becoming more accessible for commercial use and more creators began experimenting with this media. Quill brings a new dimension to painting and animation. Instead of using geometry, everything in Quill is painted by the artist using 3D brushes. That includes painting of the shadow and light, giving the paintings a stylized look similar to painted textures on 3D models. It has animation support for techniques such as frame by frame or puppeteering, which allows users to animate with no prior knowledge of CGI animation fundamentals.

Dealing with geometry and curves is a technical process while creative brainstorming often needs spontaneity to quickly capture ideas. An advantage of VR is its intuitiveness adapted from freehand drawing. Sketching out a 3D scene can be done without modeling. As a strictly painting program, elements like light sources are absent. Quill scenes can be exported to conventional 3D software like Maya or Houdini, where lights and materials can be rendered. [23] Blender released VR support in their 2.83 version, which was limited to scene inspection, as Blender may be too complex for full functionality within virtual reality. The main purpose is to enable users to view their models in VR at a scale that is a function that asset modelers for VR games or films may find especially useful. [24]

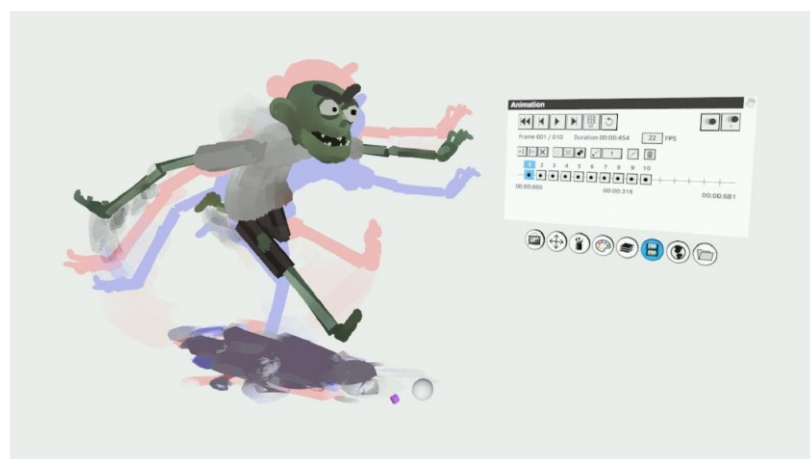


Figure 16 Quill interface © Road to VR

II. PROJECT

4 SHORT ANIMATED FILM – BODIES OF WATER

4.1 Concept

Water in animation had always been fascinating. It is a complex element with many different stylizations which provided a very intriguing setting for a film. The idea of having a story set near the sea or a lake has been present for years, but with no particular story attached. Later, during the first wave of covid-19, there were plenty of advertisements on TV showcasing exotic holiday destinations full of happy families. With the context of the pandemic, these advertisements looked comical, almost like an escapist fantasy. Not only were the people there blissfully unaware of a global disaster, but they also had perfect bodies, perfect families, and perfect life. This pushed our idea of using water setting further. We wanted to explore how those with less-perfect lives would deal with something as simple as a vacation.

Going swimming for pre-transition transgender people is often a similar escapist fantasy. Body positivity for cisgender people with body image problems (cisgender, or cis meaning identifying as the gender they were assigned at birth) doesn't work the same for transgender people. Wearing revealing clothing ruins their chances of passing as the gender they identify as which creates this cognitive dissonance between who they are and how they are perceived. This laid the basis for the main struggle of the protagonist, who is a trans man. He would be put in a position where he is socially expected to join the supporting characters in water-related activities but needs to overcome the fear of being judged or treated differently after exposing his physical self.

Producing the story concept happened during October and in a festive mood, we wanted to include a paranormal element in the form of an antagonist. It would contrast the protagonist, who would represent the normal. The only person, or rather, a thing that would treat him disrespectfully would be the ghost or a monster. The sea is not a typical setting for scary occurrences, but there are plenty of forest and lake creatures, thus we landed on the lake as the setting. With the basis of the characters, themes and setting figured out, it was time to brainstorm the story.

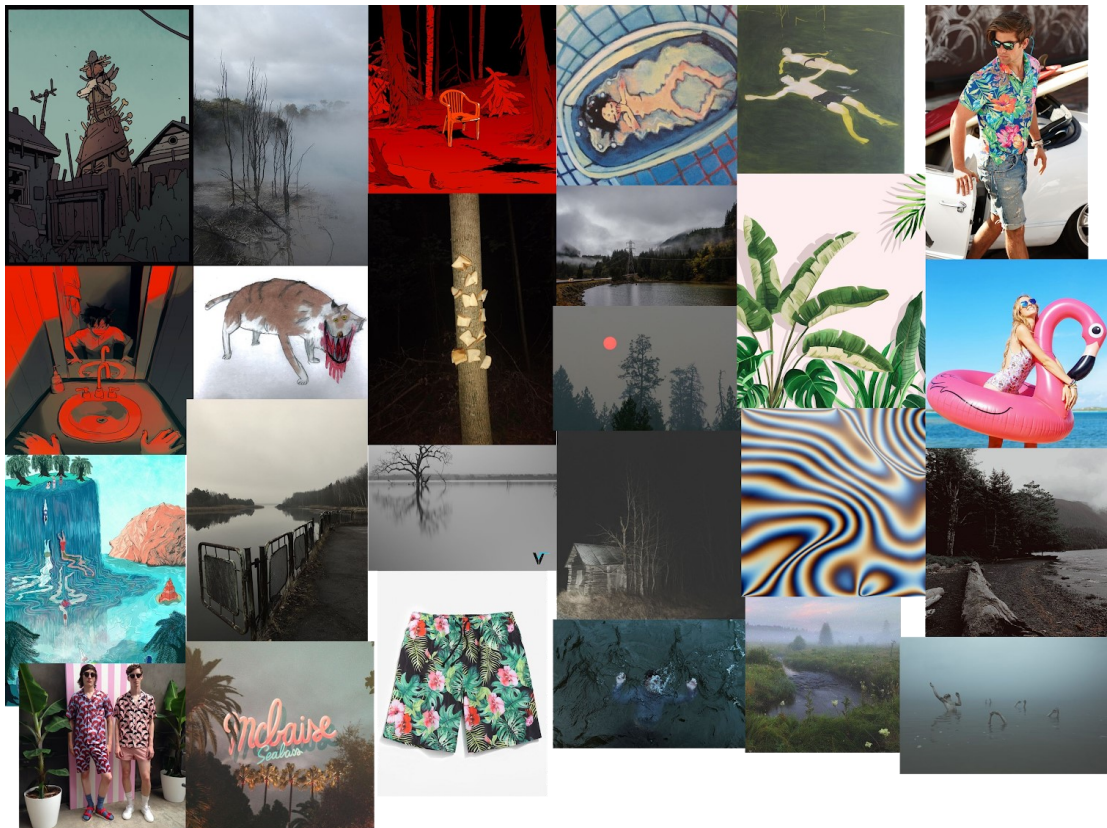


Figure 17 Moodboard

4.2 Story development

Movies with queer characters often fall into two categories – it either follows the character and their struggles until there is a tragic ending, often caused by violence or after the climax, everything turns out okay, the character is accepted and celebrated which tends to glamorize queerness. We wanted to avoid these stereotypes and make a story where the main character is always treated the same by his friends and the climax of the story would revolve around dealing with the paranormal creature rather than acceptance of identity. We also wanted to avoid slipping into making a psychological drama, the intention was to keep it light-hearted with a level of dark humour and sarcasm.

The first iterations of the story were following a group of 3 friends - Robin, Matt, and Corey – each of them representing one aspect of the story. Robin was the trans character who was anxious about revealing this information to his friends, Matt was an extremely relaxed guy, an incarnation of a holiday and Corey was a paranormal conspiracy enthusiast. They were all hanging out at the lake while doing their characteristic activities on their own. The story structure was a sort of a mosaic, cutting between the characters with visual gags until Robin

gets attacked by a lake monster and they have to deal with the situation together. The reasoning behind why specifically Robin is attacked is based on folktale logic where the creatures often target only one gender (sirens seduce men, Incubus assaults women, etc.) He was the only biological female in the group and the monster practically misgenders him. We tried to think of clever, minimalistic ways to tie the characters and their props to the way they get rid of the antagonist. The most viable ones were trapping the monster in a flamingo floatie or using hoodie laces to tie it up.



Figure 18 Robin, Matt, and Corey respectively

The mosaic structure was functional, but themes were all over the place and a core idea connecting the characters was missing. The first idea was using “chills” – as in relaxing, feeling cold and shivers from something scary happening. Later, we came up with “scars” – each character would get a scar, ending with Robin's mastectomy scars but both ideas still related to external qualities. The characters were supposed to be friends, but they were disconnected from one another, and the antagonist didn't have a concrete form. After two months of building and tweaking the story, while simultaneously designing the characters and environments, we hit a dead end.

The time was running out, but we didn't want to make a mediocre film. During desperate times like these, we like to turn to making music as a form of a vent. During one short jam session, we made a song about a person drowning themselves in a lake and turning into a heap of meat. Coincidentally, the mental images from this song sparked new fresh ideas, and the same night we wrote a completely new outline for the story from scratch while keeping only a couple of elements from the previous one.

4.3 Story development continuation

The story 2.0 was reduced to 2 characters – Robin, who was design-wise merged with Corey and renamed to Lake and Matt, now called Mac. They were roommates and Mac was fully aware that Lake is trans. This made the friendship much more organic and Lake was not just a disconnected anxious person. The reduction also made dialogue writing and character interaction easier. The structure of the story is following a format that we established earlier while writing a short comic for a 24hour comic challenge. It begins indoors with the main character having a breakdown, the secondary character offers to do something to cheer up, they go outside, it doesn't help, something paranormal happens, they deal with it, feel a bit better, and return home. The whole story and dialogue use a keyword or a phrase that keeps being reiterated and is a framing device for the plot which was inspired by Edgar Wright's *Shawn of the Dead*. In the case of *Bodies of Water*, it is bodies of water. Lake has a crisis in a bathtub, Mac tells Lake his body is made of water and meat to suggest he is just like everyone else, they go to a lake – a larger body of water, Mac motivates Lake to enter the lake by beer which technically is not water but is a liquid and Meatpile (The lake monster) is an abstract representation of a body with a pile of insides around it. Additional key elements are bodily functions like breathing and throwing up and a portion of the dialogue is about chromosomes. We believe this tied the concepts well together, although it might not be noticeable when watching the film without this information.



Figure 19 Lake and Mac

There are two common approaches to transgender representation in a story. The first follows the character which is perceived as cis until their trans identity is revealed, usually during the climax, the second informs the viewers about the character being trans from the start. [25] Our film is a combination of both. The characters know from the start and reference it in their dialogue but never directly say Lake is trans. An educated viewer can figure it out based on chromosome jokes at the beginning. At midpoint, Lake reveals he is wearing a binder, which is a visual statement of his identity. We realise this could be confusing for people unaware of trans issues. After deep consideration, we decided that the main goal of the film is not to educate but to provide a small window into a life of a trans person. Cisgender people don't verbally state their cisgenderness and Mac knows Lake is trans so to reinforce the idea that Lake is a normal guy, they would not state his transness. If the film motivates a confused viewer to ask questions or do research afterward, then education comes as a by-product. This also potentially prompts people to watch the film multiple times, which is welcomed.

4.4 Visual development

In the preproduction phase, we considered multiple techniques for this film. The film makes use of different materials, most notably water and meat, and an idea came up to make this film stop motion. The huge amount of dialogue seemed too overwhelming as we had little experience in that field and limited time. We also considered hybrid animation with 2D characters and 3D Meatpile. This was also rejected due to the complication of touch registration, which played a significant role in the story. The final art style of the film remained purely 2D, as it is a medium we are the most comfortable with and wanted the bachelor film to represent our strengths.

Bodies of Water deals with real-world issues but is told in a stylized cartoony way. The visual aesthetic of the film also reflects that. Mac and Lake shapes are stylized in a geometrical manner in contrast with Meatpile that features more unorderly organic shapes. The environment and shot composition also lean towards geometry. Semi-Realism is present in the coloring and how the light and environment interact with the characters.

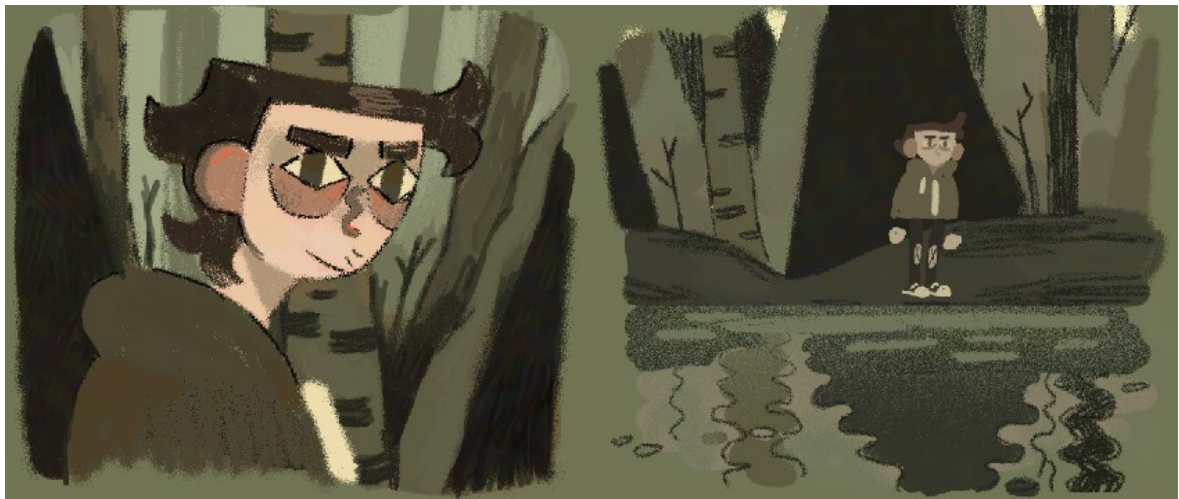


Figure 20 Style exploration page

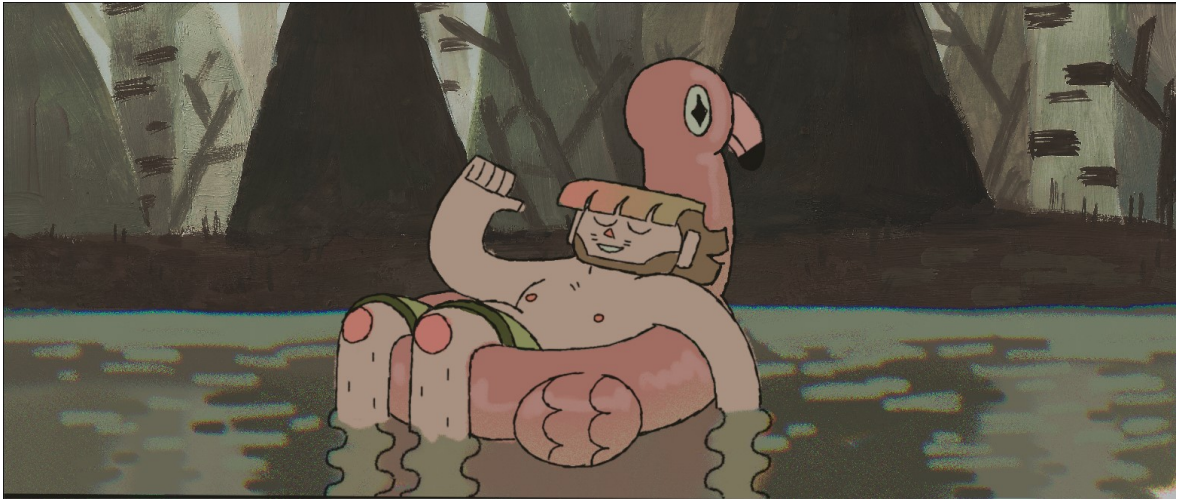


Figure 21 Traditional background experimentation

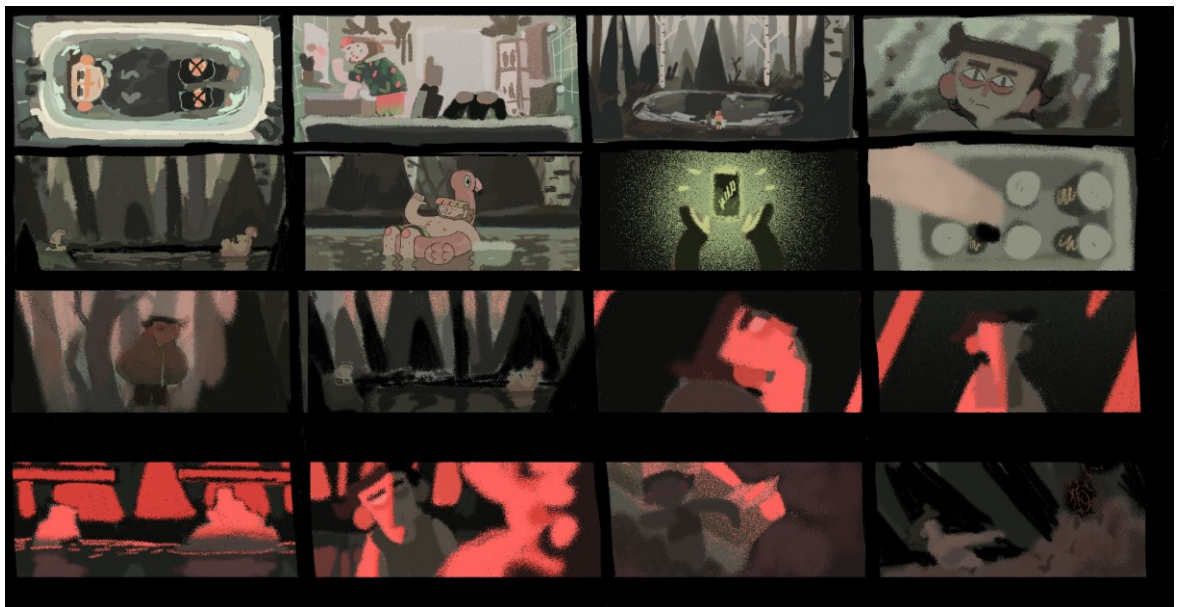


Figure 22 Color script thumbnails

4.5 Animatic and rough sound

During the creation of the animatic, we first drew all the frames and then timed them out. For the timing of the dialogue, we recorded a temporary voice-over for reference and added background music. The song's structure fits very well with the action and inspired us to time the later part of the story to the rhythm in an almost music video-like fashion. This song is copyrighted so for the final soundtrack, we intend to either find or compose music with the same structure, but different melody and instruments.

4.6 Working with voice actors

4.6.1 Casting

Half of the film consists of a dialogue between two characters for which we had to find voice actors. Specifically for Lake, a transgender voice actor was necessary. Many mainstream queer characters are played by straight cisgender actors, which has been heavily criticized as taking opportunity away from queer creators to represent their community. Although Bodies of Water is far from being a big Hollywood production, we wanted to cast the characters properly. We used social media platforms Twitter and Instagram to make an open call for voice actors. What we did not expect was over 100 people applying overnight, more precisely 40 Lake applicants and 81 Mac applicants. An excel spreadsheet was necessary to organize the voice demos and notes. This significantly sped up the choosing process.

A	B	C	D	E	F	G	H
	USERNAME	PLATFORM	STATUS	VA EXP	NOTES	RECORDING	
3	crashthecoyote	insta	NO			crashthecoyote 1.m4a crashthecoyote 2.m4a	
4	hei_the_porcupine						
5	properbino						
6	emcartstudios		NO			https://www.youtube.com/watch?v=x-7rw1_59cQ	
7	st4rii.gh2		NO		has better mic	st4rii.gh2.m4a st4rii.gh2.m4a	
8	_soul.doubt_				unsure which char		
9	delta.books					wait	
10	andreasunte		NO			https://youtu.be/8K2xN9Nf0E	
11	hammiesthawaiian		NO			138304909_720402035278441_1204518420060048443_n.mp4.m4a	
12	wandering_tribadour		MAYBE			wandering_tribadour.m4a	
13	kenpachi_mutt		NO			kenpachi_mutt.m4a	
14	@NContrerasVO	twitter	NO	YES		https://www.nicholascontrerasvoiceover.com/	
15	@BenLopezVO1		NO	YES		https://twitter.com/status/1348141012871487489	
16	@Krows_Nest		NO	YES		https://twitter.com/status/118544555293442049	
17	@GooleyChris		NO	YES		https://www.christopher-gooley.com/	
18	@LuisBermudezVO		NO			https://t.co/D1h4kusDN5?amp=1	
19	@CyrusRodas		MAYBE	YES		https://twitter.com/CyrusRodas/status/1271171210945138690	

Figure 23 Casting organization

In a large amount of Mac submissions, one person went the extra mile to record an improv based on Mac's character specifications. His interpretation matched so perfectly, it was almost uncanny. He was also the only person to include throwing up noises in the demo. He was a perfect fit for the character. When choosing Lake's voice actor, we also needed to consider whether his voice would be pre or post hormonal replacement therapy. Considering Mac had a deep voice, post-HRT sounded like a better option. The person chosen to voice

Lake did not have voice acting experience but had a great tone of voice and later proved to be very talented.

4.6.2 Recording

Both voice actors were from the USA and all the recording was done remotely. For Mac, we recorded the voice acting through a Discord call, allowing us to step in and direct. A notable moment was spending around 20 minutes to figure out the right sound for throwing up noises. For Lake, the approach was different. We would get a folder of the first voice acting pass, provide feedback and then get another pass. This process repeated until all the lines were hit. It was time-consuming but provided more comfort for the voice actor, which was prioritized.

4.7 Production

7 minutes of film had to be animated in the span of 3 months. To handle this workload, the rough sketch animation step was omitted. The production pipeline consisted of creating rough sketches of key poses and then directly moving onto the clean line art stage. This system worked thanks to stylized movement and muscle memory developed from gesture drawing. We have experimented with this pipeline in the past and although it seems counterintuitive, it usually produced smoother animations. In a traditional pipeline, the rough drawings tend to be sloppy and by the time clean lines are drawn, we are too tired to make drastic adjustments, which results in a sloppier cleanup. The line art was drawn with a scratchy technique which gives extra texture to the line while effectively masking imperfections caused when one line is drawn by multiple strokes.



Figure 24 Scratchy technique on the line art

The most challenging character to draw was Meatpile. It was a moving pile of pulsating flesh that was free-floating but moving with purpose. The movement was loosely referenced from slime mold, which in sped-up time-lapse pulsates and expands as it looks for food. Below the flesh was a humanoid silhouette that moved similarly to Lake's reflection in the water. On top of that, it also breathed and moved towards Lake. It was extremely difficult to keep track of all the moving elements using the previously described pipeline. The line mileage of each frame was comparable to special effects and some in-betweens took us 20-25 minutes each. In some scenes, Meatpile changes speed or moves in a more symmetrical manner but unfortunately, we did not have enough time to make big adjustments to these mistakes.

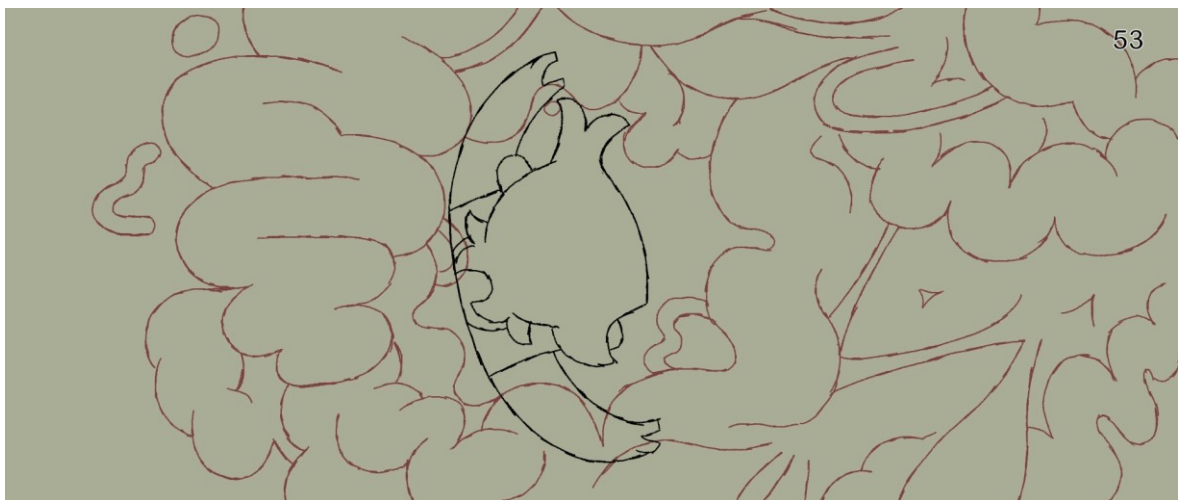


Figure 25 Example of an in-between that took 25 minutes

Throughout the production, TVPaint 10 was used for animation. It is very intuitive for hand-drawn animation but as we later found out, handles sound layers quite poorly. The project view shows individual clips which usually contain one shot. It is possible to add a soundtrack to the whole project, unaffected by the order and length of the clips. Our film contained both dialogue and music and to keep the waveform of all the layers visible, the sounds were loaded directly into clips. This enabled us to time the lip sync to spikes in audio. To preserve the timing from the animatic, each clip contained the full length of the audio and the beginning and end boundaries were set to specific points in time. TVPaint internally handled this system but during export, when the scenes were split into shots, some of them were missing snippets of the audio or frames. Although the audio would be later mixed by our sound production team, this was a major issue as the animation was precisely timed to a voice-over and music. Initially, it seemed that the frame drops happened during .avi to .mp4 conversion. We tried using a different converter, which brought similar results. The next

idea was that the problem was the framerate, which was set to 12.5fps in TVPaint and converted to 25fps in After Effects. Reexporting the scenes did not solve the problem. The only workaround we managed to find, was disabling all clips in project view except one and export them individually. It was a time-consuming process for a film with 80 shots, but it ensured every shot has a correct number of frames and full audio.

As of this day, the production is currently in the coloring phase and will continue onto shading and final compositing in After Effects.

CONCLUSION

Moving towards realism is not the only way of moving forward. In film, the visual carries the plot, and telling great stories is possible without accurate depictions of our world. The growing interest in returning traditional animation and techniques into mainstream movies supports that idea.

The art direction choices are often made based on what is efficient rather than what is best for the film. Although the 2D medium has its disadvantages, the direct input from the brush of the artists is a quality irreplaceable by the machine. The audience is subconsciously aware of that, as many report getting tired of cookie-cutter CGI that studios deliver on a yearly basis. Instead of seeing 2D and 3D media as separate entities, some projects invite us to see them as two parts of a broader picture that can coexist and naturally interact with each other, despite it being impossible in the real world. This reimagination of reality is what creates magic in animation and what draws people towards it.

Just like any other trend, graphic tools and styles are developing rapidly. What is possible now, may be outdated within a couple of years, or months. Being a risk-taker and experimenting with new visual storytelling devices may push the audience out of their comfort zone of what they consider visually appealing. We hope having insight into what a person can do with just a computer and a drawing tablet will be inspiring to implement some of these techniques in future projects.

Bodies of Water was a complex project that required finding the right balance in topics and visuals. The story development proved to be a challenge and we had to make an important choice of throwing a lot of progress away in favor of a better story. This caused us to find creative ways to compensate for the lost time. It was worth it in the end, as we made a film that pushed us out of our comfort zones.

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