

Harmonizing 2D and 3D in Modern Animation

Chris Luntraru

Politehnica University of
Bucharest

313 Splaiul Independetei, Bu-
charest, Romania
chris.luntraru@gmail.com

Victor Asavei

Politehnica University of
Bucharest

313 Splaiul Independetei,
Bucharest, Romania
victor.asavei@cs.pub.ro

Alin Moldoveanu

Politehnica University of
Bucharest

313 Splaiul Independetei,
Bucharest, Romania
alin.moldoveanu@cs.pub.ro

Florica Moldoveanu

Politehnica University of
Bucharest

313 Splaiul Independetei,
Bucharest, Romania
florica.moldoveanu@cs.pub.ro

ABSTRACT

This survey presents up-to-date techniques used to create hybrid animations - animations that use both 2D and 3D assets at the same time, sometimes as a creative choice, but often to accelerate the animation process in order to meet financial and time constraints. Although the concept of hybrid animation dates back to 1983, techniques are scarcely documented and there is still much room for improvement. This paper covers how some of the most impressive instances in the modern entertainment industry were created.

Author Keywords

Animation; hybrid animation; stylized 3D; non-photorealistic rendering.

ACM Classification Keywords

- Applied computing ~ Arts and humanities ~ Media arts

DOI: 10.37789/rochi.2022.1.1.11

INTRODUCTION

Hybrid animation is the art of combining 2D and 3D animation with the intention of obtaining a specific look. This combination of media is done in order to minimize time spent creating assets and animating, usually due to monetary and time constraints.

Traditionally, 2D animation was done by hand, frame by frame, using a technique called ‘cel animation’. It involved drawing the parts of a frame that were in motion each frame, while static elements were kept the same, in a sort of ‘background layer’. Since then, 2D animation has evolved a lot, giving animators more and more tools to achieve their target faster and with more creative freedom.

When 3D CGI was first introduced, a split occurred in the world of animation. This innovation meant that animations could be created fully 3D and software programs handled perspective, maintaining the physically accurate shape of an object from any angle and even automating less important, in-between frames. The automation of such error-prone

aspects of drawing meant that artists had a much easier job animating, but it also meant the loss of a more human, imperfect aspect of illustration and animation.

This issue paved the way for hybrid animation: 3D models replacing complex objects in 2D animations to simplify work while maintaining their style and 3D animations incorporating 2D elements to achieve a more traditional look or even hand painted backgrounds to simplify the creation of scenes viewed from a single angle. Combining two media to pick and choose the best of both worlds sounds great on paper, but it also brings a plethora of issues to light.

2D VS 3D ANIMATION

A large reason to opt for either 2D or 3D is visual target. Once a decision is reached regarding the target aesthetic, line mileage is another important aspect. It refers to how much line needs to physically be drawn. The more detail in an object or character, the higher the line mileage will be, making 2D animation harder: all the details need to be kept in sync frame by frame to prevent visual artifacts that distract the viewer. [10]

Certain objects, especially very complex ones are hard to animate traditionally. An example of this is the magic carpet in ‘Aladdin’. It was animated in 2D as a template, then reanimated and rendered in 3D in order to match a 2D style, while avoiding the need to manually draw the intricate pattern. [10]

A few more things to consider when deciding between 2D and 3D are team skills and budget. Individual 2D assets are much cheaper, while 3D teams can be kept smaller. [10]

HYBRID ANIMATION

Hybrid animation involves combining the two media to try and be as efficient as possible with the pros and cons of each. This, of course, comes with a number of problems, including style matching, registration and other more technical issues like frame rate and timing. [10]

Style matching refers to the process of working with a multitude of different software and techniques in order to achieve a look in a medium that does not visually clash with the other. [10]

Registration, on the other hand, comes into play when one object touches another, especially when the two objects are part of different media. One element is said to lead, while the other follows. Usually, the leading element is animated first, sometimes with a bare-bones placeholder representing the object in the other medium and the other is added on later, while taking care to perfectly match the movement. [10]

Frame rate and timing also play a large part in the way a scene is perceived. In ‘Guilty Gear Xrd’, a fighting game developed by Arc System Works in which characters and backgrounds are all 3D, the camera and background are animated at a higher frame rate than characters in order to obtain the intended 2D visual style. [9]

MAKING 3D LOOK 2D

Several different aspects of 3D scenes need to be aggressively customized in order to obtain certain 2D visual styles including character models, lighting, motion, and visual effects (VFX). [9]

Character Models

The more one relies on textures, the higher the chance of encountering resolution issues when rendering a final image. Many 2D styles rely on clean lines and transitions between color values. Conventional texture filtering does not allow for sharp color transitions and disabling it most often causes jagged lines that break the illusion since they’re an artifact associated with 3D.

A way to counteract this is to fit as much information as possible into a vertex data. This, of course, results in character models that have a higher resolution than one might expect from non-photorealistic rendering. [9]

Guilty Gear Xrd

‘Guilty Gear Xrd’ is what is popularly known as a 2D fighting game. This refers to the fact that gameplay mechanics take place in 2D space, and that the camera almost always maintains a side view perpendicular to the action. The actual assets used are almost entirely 3D. That being said, the side-view camera does help the game look very convincing in its endeavor to match an art style popular in Japanese animation. [9]

Since there are only 2 visible characters on screen at any point in time, having high-resolution character models is not an issue. A major benefit of choosing 3D was that dynamic 3D cutscenes for certain attacks were naturally supported. [9]

Motion

In traditional 2D animation, transitions between key poses are not as smooth as in 3D and in-between frames are both imperfect and fewer. Perspective errors are common and humans are very perceptive towards this type of details. [9]

Another common technique used in 2D is limited animation: reusing as much of a pose as possible between frames and only redrawing what actually needs to move. Other factors that affect a viewer’s perception of a video are the rate at which the background and camera pan. These motions are not as limited in 2D animation, since drawing a large background and panning over it increases line mileage much less than more complex movements. [2, 7]

Based on these observations, we arrive at a series of techniques that can be used to imitate 2D animation with 3D assets: keeping character animation frame-rates low, introducing subtle errors in their keyframes and avoiding synchronizing background and camera movements with those of characters all contribute to obtaining a convincing effect. [9]

Guilty Gear Xrd

In ‘Guilty Gear Xrd’, there are no interpolated frames between key frames and character frame-rates are much lower than 60 FPS. Backgrounds and the camera, on the other hand, pan seamlessly, as if panning over a larger painting, just like in 2D. [9]

Reducing the frame-rate and eliminating in-between frames was not enough, though, animations still looked too perfect. By intentionally changing the scale and position of certain body parts in each pose, animations become much more organic and man-made. Similar to 2D, pausing on a random frame in ‘Guilty Gear Xrd’ will likely capture a character in an unnatural pose. This, of course, isn’t directly noticeable to humans since each one stays on screen for too little time, but definitely changes how we perceive the final sequence. [9]

Spider-Man: Into the Spider-Verse

‘Spider-Man: Into the Spider-Verse’ is a visually unique film. The creators aimed to bring comic books to life in 3D by maintaining the comic book style in motion for the first time. In this case, motion mismatch was less of an issue since people don’t have a sense of how comic book characters actually move. When reading static panels, we assume what happens in-between, meaning that motion being too perfect no longer breaks the illusion. That being said, certain animation techniques are borrowed from 2D in general to reinforce this theme, such as the fact that in certain scenes the characters are animated at lower frame-rates than the backgrounds or camera. The character frame-rates aren’t even synchronized among each other in some sequences and this is meant to underline how alien the situation feels for Miles, the protagonist. [15, 18]

Lighting & Shading

Many lighting models in 3D rendering try to emulate reality to the best of their ability. Even non-photorealistic shading models like Gooch Shading make calculations based on 3D specific attributes, such as the positions in space of the light source and shaded fragment. This is, of course, necessary and also makes sense from a physical standpoint, but 2D artists aren't able to make these precise calculations while drawing. This means that in 2D, lighting tends to be rendered as an approximation based on where a light source is in comparison to the subject, rather than an exact calculation based on some parameters. As a result, updating the shading on character models on a frame-by-frame basis gives a scene an innately 3D appearance. [6, 9]

A starting point to resolving this is to define model-specific light sources that never move in relation to their subject. This solves the issue of lighting being too realistic when a character moves around in a scene. To improve on this, a key observation must be made. Only 2 values are relevant to calculating which fragments are shaded: the light vector and the normal vector, both of which can be controlled. In addition to these, a 3rd artist-controlled variable can be introduced: a threshold that defines how easily a vertex becomes shaded. This makes lighting more consistent across character poses. [9]



Figure 1. Default vertex normals (top) and custom vertex normals (bottom) in ‘Guilty Gear Xrd’, extracted from ‘Guilty Gear Xrd’s Art Style : The X Factor Between 2D and 3D.’, a GDC 2015 talk. [9]

Once these techniques are used to decide which fragments are shaded, colors need to be applied to them. One way to do this is through a variation on cel-shading that involves a base color texture and a tinted color texture. This is inspired by the fact that certain materials change color when light passes through them (eg.: skin turns red under light). [9]

Another way to communicate a 2D style to a viewer is to play to their familiarity with elements that they have already seen extensively. For instance, shadows in comic books are most often hatched and highlights and color transitions are usually obtained with the use of halftone effects. [9]

Guilty Gear Xrd

In ‘Guilty Gear Xrd’, each character has their own light source that only affects them, and unpredictable lighting situations are entirely avoided: if a character looks good in every animation, there is no need to further refine the lighting. An essential observation here is that the camera’s view angle only changes in scripted special attack cutscenes, meaning it was possible to check every possible pose a character could be in before release. [9]

Furthermore, default, auto-generated normals cause strange results in cel-shading as seen in figure 1. The images on the bottom half of the figure were obtained by baking the normals of a much simpler mesh onto the character model. [9]

Controlling these 2 components does a lot of the heavy lifting, but unpleasant artifacts can still occur. This is where the aforementioned thresholds come into play, allowing an artist to control the shading to an extent. [9]

The cel-shading itself uses the tinted color texture technique, in order to best match Japanese animation tend to be suggested by color intensity and opacity. [9]

Spider-Man: Into the Spider-Verse

‘Spider-Man: Into the Spider-Verse’ creators took note of common stylistic effects in comic books and incorporated hatching and halftoned highlights into the film. They also made sure to rely on color work more than on material properties, similar to ‘Guilty Gear Xrd’ creators. [15]

Lines

Techniques that successfully draw silhouette edges in 3D renders already exist, one of the more commonly used ones being procedural geometry silhouetting, based on rendering mesh backfaces behind the normally rendered frontfaces. [7, 11]

In 2D animation, inner lines are also commonly paired with silhouette edges. Lines in 2D are innately stylistic and explicit, while in non-stylized 3D they are given by scene composition and camera location and are most often implied. Rendering these explicit lines in 3D is susceptible to the same issues as abrupt color transitions including jagged lines. A possible solution to prevent this that works very well with simple visual styles that employ solid colors is to rearrange and stretch the UV map in order to obtain inner lines aligned to the texture map axes. This is shown in figure 2. With all lines either perfectly vertical or horizontal in the texture, no filtering needs to be done and both lines and color transitions look clean. This concept cannot be applied to textures that have smoother color transitions, as it in-

volves aggressively stretching certain areas in the texture. It also has the added benefit of trivially allowing variation in line thickness by modifying the UV map. [3, 9]

Guilty Gear Xrd

Silhouette edges in ‘Guilty Gear Xrd’ are implemented with a version of procedural geometry silhouetting tweaked to support vertex displacement of the outline to allow for variable line thickness. [7, 9, 11]

Inner lines are drawn into the aforementioned axis-aligned color textures. The UV map in figure 2 corresponds to the character on the left of figure 1. Since colors are all solid and there are no gradients between them, the stretching is not an issue. [9]

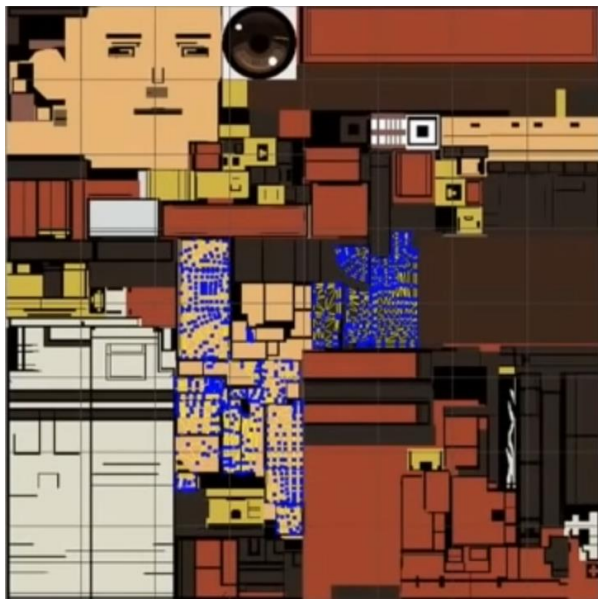


Figure 2. UV map and texture of a character from ‘Guilty Gear Xrd’, extracted from ‘Guilty Gear Xrd’s Art Style : The X Factor Between 2D and 3D.’, a GDC 2015 talk. [9]

Spider-Man: Into the Spider-Verse

In ‘Spider-Man: Into the Spider-Verse’, drawn-on lines, especially in facial expressions, make major strides towards achieving a comic book aesthetic. Line work in this film is drawn on in 2D, but the process has been simplified: concept artists initially drew a library of models from different angles and fed it into a machine learning model that would output line work for any model. When necessary, manual adjustments to the lines were made and the corrected version was fed back into the model, allowing it to improve organically. [18]

VFX

Visual effects also leave an impression on viewers and hybrid animation makes heavy use of VFX that is either 2D or made to look 2D. One way to use VFX to make a scene look 2D is to simply draw them. Another option is to set up

a sequence of separate meshes, using the lack of keyframes to suggest hand-drawn motion. [9]

Guilty Gear Xrd

‘Guilty Gear Xrd’ usually implements VFX as a sequence of entirely distinct meshes. Smoke and certain sword attack trails are implemented this way, while hit effects are actually 2D and certain more complex morphing animations have multiple meshes show up at once. [9]

Emphasis & Focus

Camera focus is an inherently 3D concept but, emphasizing certain image elements through shape language, color, and level of detail is something that has been done throughout the art history. Camera focus is often used in 3D media to achieve a similar effect, making for an elegant combination of these 2 concepts.

Spider-Man: Into the Spider-Verse

‘Spider-Man: Into the Spider-Verse’ is a visually unique film. The creators aimed to bring comic books to life in 3D by maintaining the comic book style in motion for the first time.

Similar to ‘Guilty Gear Xrd’, this movie takes heavy inspiration from its target style and from the issues and technical limitations that come with it. The staff wanted any single frame in the movie to look like an illustration and for it to match the concept art as well as possible. This meant that they had to avoid motion blur and depth of field, two 3D-specific techniques that a highly dynamic Spider-Man movie would have heavily benefited from. Their solution was to use color separation, a printing issue where colors are mismatched in comic books, to highlight what is in focus. They also used traditional 2D smears instead of motion blur to highlight quick movement. [16, 18]

Many background elements in ‘Spider-Man: Into the Spider-Verse’ are heavily simplified, for instance passengers in a bus from the background are a rough painting, and cars and buildings in the distance are simply colored blobs. [18]

STYLIZED 3D WITH 2D ELEMENTS

Hybrid animation doesn’t necessarily need to look like it was created in a single medium. Using it as a stylistic choice is also a valid decision, and an increasing number of productions have been doing so, including ‘Spider-Man: Into the Spider-Verse’ which we have already discussed partially and ‘The Dragon Prince’.

Hyperbole

A common element in 2D illustration is the exaggerated nature of how certain scenes are laid out. Artists tend to prioritize what looks good over what makes sense, making for visually impressive scenes that might not make sense if someone were to imagine them from a different angle.

Spider-Man: Into the Spider-Verse

When Miles is on a rooftop, the city of New York is deeply deformed for dramatic effect, as shown in figure 3. Buildings are laid out to reinforce a sense of scale and are 8-10 times as tall as in reality, resulting in a bizarre layout that looks amazing in the final render. [18]

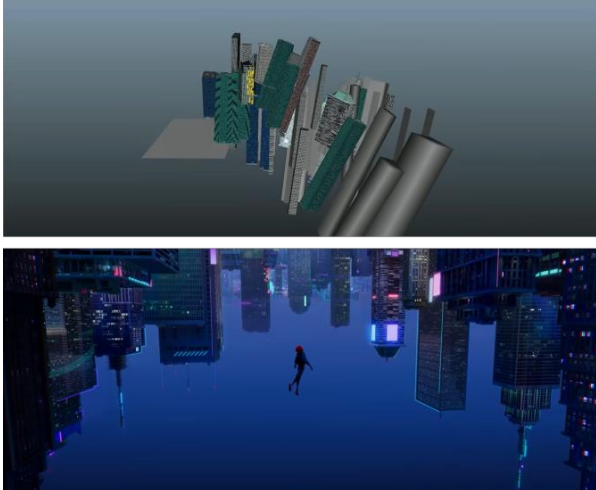


Figure 3. Stylized New York scene layout (top) and movie scene (bottom) in ‘Spider-Man: Into the Spider-Verse’, extracted from ‘How Animators Created the Spider-Verse.’, an interview by Wired. [18]

Production Efficiency

Hybrid animation can also save time by allowing for flexibility when choosing the medium that a scene element will be created in. Creating entire 3D models that will only ever be seen from a specific angle is a huge waste of time, as is hand drawing an intricate object from every possible angle. [5]

The Dragon Prince

‘The Dragon Prince’ is an animated TV series following the journey of 2 young princes on their way to reach a neighboring kingdom. This means that the characters had to cross an impressive number of different areas and landscapes. The aesthetic the series went for was that of a relatively straightforward 3D animation stylized with outlines and hand painted textures on backgrounds. [5]

The sheer number of different scenes that 3D artists would have had to model to animate this series would have been overwhelming, so the staff came up with creative solutions to accelerate the process. Backgrounds are often either fully painted or painted onto heavily simplified geometry, since most scenes are only shown a handful of times from a single angle. ‘The Dragon Prince’ also makes heavy use of multi-planing: separating backgrounds into discrete painted layers (usually only 2 or 3) so that they are partially affected by perspective changes. [5]

Shadows

Opting to use hybrid animation can cause a variety of issues outlined at the beginning of this survey, including those pertaining to registration. Shadows are notable offenders from this point of view. Projecting shadows from 3D characters onto 2D backgrounds doesn’t make physical sense, meaning that an alternative must be found. A solution is to roughly map out the entire scene in 3D with basic shapes, light the scene programmatically and overlay the rendered shadow texture onto the final scene. This has the added benefit of projecting simplified shadows, akin to hand drawn ones. [5]

The Dragon Prince

In scenes that are fully 3D, such as those that need to be shown from a variety of different angles, shadows were not an issue. With painted or partially simplified backgrounds, shadows would normally also need to be painted on for every frame. To avoid this, scenes were roughly laid out in 3D and the generated shadows were used in the final shot. [5]

OTHER NOTABLE ANIMATIONS

We would like to mention a few more animations that made use of hybrid techniques, but didn’t offer enough behind the scenes information to cover in full detail.

Arcane: League of Legends

One thing Fortiche Production does incredibly well in ‘Arcane: League of Legends’ and in general is including imperfect camera movement in their cinematography. Even though the series is animated, it feels like there is a person behind the camera as it subtly bobs in action scenes and follows organic trajectories when moving, giving the animation a much more personal feel. This pertains more to stylization in general than to hybrid animation, but we believe that the two concepts complement each other perfectly and both work towards creating media as entertaining as possible. [17]

Hybrid animation is frequent in ‘Arcane: League of Legends’, especially noticeable in their visual effects that perfectly complement their 3D scenes. This case is an example of blending media as more of a stylistic choice than an attempt at replicating a previously existing style. [12]

Klaus

‘Klaus’ is a 2D animated movie by The SPA Studios that, unconventionally, uses 2D animation to replicate a traditionally 3D aesthetic. The intention was to create a modernized style based on classic Disney films from the 1990s. The biggest contributor is light, which was obtained by creating a proprietary, in-house tool that renders lighting as CGI, but keeps components separate. Direct light, shadow, rim light, bounce light and more were all kept separate, allowing artists to pick and choose what type of light is applied and where, heavily automating the process of painting illumination, while preserving creative input. [8, 13]

‘Klaus’ is not purely 2D, as it uses 3D models for man-made, less organic objects, such as the sled. Masking these additions was less of an issue, since the lighting and character models were already heavily inspired from 3D styles. [13]

AUTHOR DISCUSSION

In this survey, we chose to cover recent examples of hybrid animation that we considered successful. Our goal was to gather as much information as possible on ways to stylize 3D by using 2D techniques or to enhance 2D animation with 3D elements that are much more reusable. Another benefit was centralizing information pertaining to what we as viewers or players categorize as 2D or 3D in order to know what to leverage and what to avoid when creating hybrid animations.

Embracing Imperfections

‘Embracing Imperfections’ is actually the title of a featurette from Sony Pictures Animation on ‘Spider-Man: Into the Spider-Verse’. One of their main goals with the film was to ‘bring the artist’s hand back into animation’, something we believe they achieved to an impressive degree. One aspect that most of the works outlined in this article have in common is the fact that they take inspiration from what are considered flaws in their target visual style. From this, it can be concluded that human imperfection and physical limitations of media have a noticeable effect on consumers who learn to appreciate these features with time. Familiarity evokes a sense of comfort in humans, something most often desirable in animation. Color separation in comic books, perspective errors in cartoons, frame-rate mismatches between characters and backgrounds in limited animation and even imperfect camera movements may have begun unintentionally, but have established themselves as key elements of specific styles of animation or illustration. They also have great potential when reinterpreted with intention, as proven by the use of color separation as a stylization of camera focus in ‘Spider-Man: Into the Spider-Verse’. [14]

‘Guilty Gear Xrd’ also bases its animations on this concept, introducing intentional perspective and scale errors in each of its character’s poses. This technique would also work just as well in films, as demonstrated by cutscenes in the game. Unfortunately, it would be hard to generalize where free camera angles are involved since individual poses can’t all be checked and deformed before release, but we do believe the concept has potential in these situations too if properly adapted. For instance, research into procedural techniques on this would be warranted, eliminating the need for an artist to manually introduce said deformations. Moreover, in ‘Guilty Gear Xrd’, lighting is also initially calculated in a physically correct way and later tweaked by artists, but perhaps shading models could be adapted to artificially introduce imperfections, bringing 3D even closer to a true 2D aesthetic. [9]

Lines

Line art is a major part of stylized 2D illustration and animation. In this survey, 2 ways to handle this in 3D have been covered. One of them involves separating inner and outer lines and solving the issues independently. Outlines can be rendered with well-known existing methods, tweaked to suit the needs of the project. Inner lines can be embedded in the texture, and UV maps deformed to allow for sharp color transitions if the visual target allows it. This method can be used for any sort of sharp color transition, as long as the art style is based on solid colors. This includes a multitude of commonly used styles and could be applied to most of American, European and Japanese animation, not to mention most video games with stylized visuals. A drawback to this approach is that lines will always be in the same place and can’t be moved around on a frame-by-frame basis to emphasize different elements or communicate character emotion.

A different approach is to draw line art onto the rendered image using artistic judgment on a case-by-case basis. This process can also be automated to reduce the line artists’ work to per-frame adjustments instead of drawing them from scratch every time. The issue of not being able to move lines no longer exists with this solution, but it involves much more work for animators.

Line work especially benefits from creative freedom and contributes a lot to expressiveness of both 2D and 3D. Both solutions allow for freely adjusting line weights and placement. An interesting observation about lines is that the presented approaches are drastically different and obtain results fine-tuned to a certain visual style. This also means that further research in this direction is worth pursuing, especially when recreating art styles different from those presented here. An example would be a way to procedurally generate axis-aligned UV maps based where an artist decides to place an inner line on a character model.

Light & Color

3D artists have a penchant for realism and tend to think in terms of light placement. This is due to software structuring scenes in ways that are very close to how we see reality. 2D cartoonists, on the other hand, have extensive experience with elegantly simplifying reality to assume a visually pleasant form, while still communicating the intended message. This means that they tend to have more control over color and think less in terms of physical light sources. Of course, they still need to imagine specific placements for lights, but creating a pleasing drawing takes precedence over physical accuracy. More importantly, they have complete freedom to do this.

A corollary of the artistic freedom in 2D is that illustrations tend to be less focused on material properties and textures, and more responsibility falls to color and transparency, resulting in another way to reinforce a 2D look in 3D assets or vice-versa. This can be seen in both ‘Spider-Man: Into

the Spider-Verse’ where complex materials are intentionally avoided to suggest illustration and in ‘Klaus’ where the opposite is true: materials are used to suggest 3D.

Arc System Works presents an interesting solution to migrate this into 3D by defining custom vertex normals and a more artistically inclined tint texture alongside the usual diffuse one. This opens the compelling subject of additional artist-driven rendering inputs that distinguish themselves from fully painted lighting by allowing 3D software to deal with lighting calculations while still maintaining a degree of creative freedom.

The concept of tint textures can easily be extended to facilitate specific visual targets, for example a 2D animation with slightly more complex cel-shading could be simulated with a second tint texture or more specific lighting conditions could be achieved with specialized tint textures. Another interesting direction for research would be the generation of such textures based on environment parameters, such as multiple levels of darkness for different scenes. There was no need for this in a fighting game, but the approach chosen by Arc System Works opens the question of how flexible it really is.

Motion

Static images are much harder to classify as illustrations or renders once they are stylized. A painting with near-perfect perspective isn’t unheard of. An entire 2D animation, on the other hand, is. Such detailed paintings take much too long to be feasible to create 12 to 24 times per second, the standard frame rate for this type of work. This detail, with time, trained consumers, especially those with a keen eye, to subconsciously recognize the medium an asset belongs to based on frame-to-frame perspective transitions. As detailed before, individual pose deformations do a good job of faking this effect.

In limited animation, a technique often used in 2D to save animator hours, backgrounds are usually drawn larger than what is visible in a frame to allow for the camera to pan across it. This tends to result in characters poses being updated more rarely than the background or camera position. This is not hard to simulate in 3D, even with less natural (in 2D) camera movements like zooming by making use of limited space techniques such as multi-planing. [2]

A multitude of cinematographically standardized camera spaces and movement exist independent of 2D and 3D and we believe these are also worth exploring in detail when stylizing scenes. Procedurally calculating the ideal camera position to bring a 3D scene as close as possible to limited space, for instance, is a direction worth exploring.

Bertin’s Visual Variables

An interesting observation is that all of the topics discussed in this survey can be associated with one or more of Bertin’s visual variables: size, value, color, texture, shape, position, orientation and movement. These are the variables

that humans most easily observe changes in when looking at an image. A proposed association of these topics with Bertin’s variables is illustrated in figure 4. [1]

The character model affects the size and shape of what a viewer sees, while the actual animation determines position, orientation and movement, but can also affect the size of what a viewer sees. Lighting and shading directly influence color, value, and even texture when stylistic effects like hashing or halftone are used. Emphasis and camera focus fall into the same category as lighting and shading, as 2D artists use traditional tools to direct a viewer’s gaze, and even the 3D-specific depth of field effect modifies the texture of the background by blurring it. We categorized camera techniques and animation separately to illustrate that camera-specific concepts such as limited space and multi-planing can also affect how a viewer perceives a scene. Images where certain objects may be scaled, positioned or oriented otherwise than one would expect from a real-life reconstruction of a scene can easily be produced without them feeling abnormal to a viewer. Finally, VFX are an extremely powerful tool, as they can affect almost any of the visual variables. For example, a cloud of smoke that partially covers the characters in a scene changes the color, value and texture of what one would see, and even alters the character’s shape by covering part of it. Rainfall, on the other hand is, of course, in motion itself, but by giving raindrops an angle, an animator can also create the illusion that objects in the scene are moving in the opposite direction. [4]

Size	Value	Color	Texture
Character Model	Lighting & Shading	Lighting & Shading	Lighting & Shading
Animation	Emphasis & Focus	Emphasis & Focus	Inner Lines
Camera Techniques	VFX	VFX	Emphasis & Focus VFX

Shape	Position	Orientation	Movement
Character Model	Animation	Animation	Animation
Outlines	Camera Techniques	Camera Techniques	VFX
Camera Techniques			
VFX			

Figure 4. Topics in this survey categorized by Bertin’s visual variables. [1]

Based on this information, it can be concluded that Bertin’s visual variables also strongly apply to how viewers subconsciously detect differences between 2D and 3D animation. This fact offers a concrete starting point for further research on the topic by defining a way to isolate different aspects of both 2D and 3D animation and allowing for more specialized research into what can be improved on.

CONCLUSION

In this survey, we have detailed modern techniques in computer graphics used to bridge the gap between 2D and 3D animation, focusing on ways to make 3D assets look 2D and integrate objects from different media into a single, cohesive work. We focused on modern iterations of hybrid animation in popular culture to establish a concrete starting point for research on the topic at this point in time.

State of the art literature on hybrid animation is hard to find. Most information on up-to-date solutions is scattered among separate, hard to identify, behind the scenes featurettes or 3rd party press articles that build on interviews with film staff and offhandedly mention the occasional technical detail. I believe centralizing this information is valuable, setting the tone for future research and clearly establishing reference results to compare new work to.

Currently, a viewer with a keen eye can almost always distinguish between 2D and 3D elements in an animated film or game, making each attempt that is slightly more successful than the last truly impressive. We live in a time where true artistic freedom is starting to make its way into 3D and back onto our screens, paving the way for interesting non-photorealistic rendering techniques in an entertainment industry focused on realism.

REFERENCES

1. Bertin, J. (1967). *Sémiologie graphique*. Mouton/Gauthier-Villars, Paris, France.
2. Block, B. (2021). *The Visual Story: Creating the Visual Structure of Film, TV and Digital Media*, 3rd Edition, Chapter 3. Routledge.
3. Block, B. (2021). *The Visual Story: Creating the Visual Structure of Film, TV and Digital Media*, 3rd Edition, Chapter 4. Routledge.
4. Block, B. (2021). *The Visual Story: Creating the Visual Structure of Film, TV and Digital Media*, 3rd Edition, Chapter 7. Routledge.
5. *The Dragon Prince, The Dragon Prince Behind-The-Scenes — Show Environments*. https://youtu.be/NNqcqjA9_HY
6. Gooch, A., Gooch, B., Shirley, P., Cohen, E. (1998). A Non-Photorealistic Lighting Model for Automatic Technical Illustration. *Computer Graphics and Interactive Techniques*.
7. Gregory, J. (2018). *Game Engine Architecture*, 3rd Edition, Chapter 15. CRC Press.
8. Lehane, S., How ‘Klaus’ Uniquely Combines CG Lighting Techniques with Traditional 2D Animation. <https://www.awn.com/animationworld/how-klaus-uniquely-combines-cg-lighting-techniques-traditional-2d-animation>
9. Motomura J.C., *Guilty Gear Xrd’s Art Style : The X Factor Between 2D and 3D*. <https://gdcvault.com/play/1022031/GuiltyGearXrd-s-Art-Style-The>
10. O’Hailey, T. (2015). *Hybrid Animation: Integrating 2D and 3D Assets*, 2nd Edition, Chapter 1. Focal Press.
11. Raskar, R., Cohen, M. (1999). Image Precision Silhouette Edges. *Proceedings of the 1999 symposium on Interactive 3D graphics*.
12. Ressencourt, A., *Arcane S01 e101 2DFX smoke Line test Animation*. <https://youtu.be/Y3Iy-KMwSz0>
13. Snyder, C., How Netflix’s Oscar-nominated ‘Klaus’ made 2D animation look 3D. <https://www.insider.com/how-netflixs-klaus-made-2d-animation-look-3d-2020-1>
14. Sony Pictures Animation, *Embracing Imperfections — SPIDER-MAN: INTO THE SPIDER-VERSE*. <https://youtu.be/WsRVXGjM6j0>
15. Sony Pictures Animation, *Bringing a Comic Book to Life — SPIDER-MAN: INTO THE SPIDER-VERSE*. <https://youtu.be/rDqgpIHGSd4>
16. Sony Pictures Animation, *Telling a Story in Every Frame — SPIDER-MAN: INTO THE SPIDER-VERSE*. https://youtu.be/1Nw_c_CqPso
17. Stream Wars, *Making of ARCANE – Best of Behind the Scenes*. <https://youtu.be/7rAbZUZCnL8>
18. WIRED, *How Animators Created the Spider-Verse*. https://youtu.be/l-wUKu_V2Lk