Abstract

In creating animation using static two-dimensional artwork it is often desirable to produce the illusion of movement in three-dimensional space. The use of panoramas as a component of such a construction opens the possibility of selectively revealing an illustrated scene in a way that simulates cinematic camera motion through space. The requirement of joining together compositions which are then revealed over time makes the design of these panoramas unlike a typical illustration layout.

To demystify the design these layouts we present an analysis of sequences from animated films. We reconstruct background panoramas and camera movements to identify patterns in their design. We draw conclusions about the narrative purposes these shots are used for, and suggest some directions for exploration of the use of multiple perspective layouts in animation.

Introduction

The starting point for this investigation of the design of backgrounds for animated films is a shot I created for my animated short *Pecking Order (Haines, 2003)*.

The story called for an external establishing shot which locates a character sitting on a bench in a park. There is a trail of books lying on the ground leading to the seated character and a second character who arrives following the trail of books, picking them up.

The initial storyboard for this sequence opened with a drift-pan down from branches above the park bench to locate the character in a park setting and set the mood for the scene. This is followed by other shots of the books lying on the ground and the second character picking them up. This approach doesn't clearly locate the characters spatially in relation to each other and involves multiple views of characters and backgrounds to establish the two characters and the trail of books.

The case for a panorama

I wanted something cinematic and slow-moving to set the tone for the park scene. But how to create the impression of camera motion through three-dimensional space in a flat drawing? It has something to do with moving the camera around, doesn't it? Moving it how, and over what?

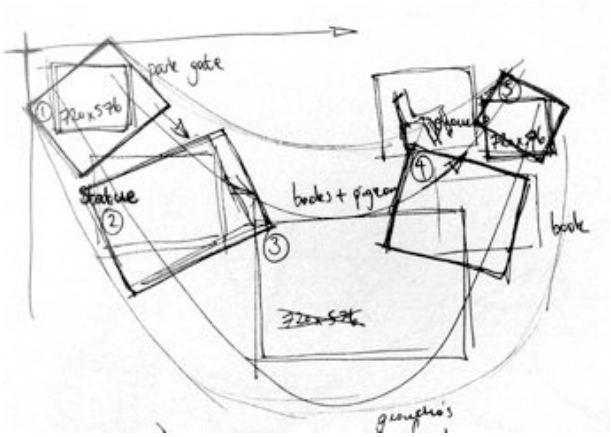

Figure 1 Initial concept for a panoramic layout of an establishing shot for the park scene in Pecking Order.

Through storyboards and composition sketches (Figure 1) this developed to a clearer understanding of what I wanted to show in the shot; the park gate and a shop front across the road, a trail of books leading into the park, and the main character seated on a bench in the park. The key compositions were then of the park gates, books on a path, and the seated figure.

Figure 2 Second draft for a layout showing key compositions in the park shot.

After playing with rough animations of this layout (Figure 2) I felt the key compositions were a bit disjointed and the transitions between them seemed arbitrary. I needed a way of unifying the space between of the main elements. A print (Figure 3) by M.C. Escher (Escher, 1989) inspired a solution.

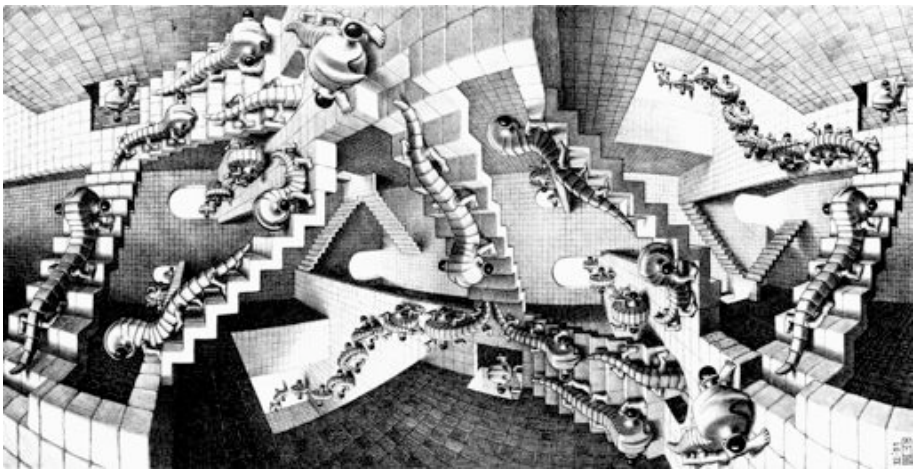

Figure 3 House of Stairs by M.C. Escher employs a cylindrical projection to unwrap a 180 degree view onto a panorama.

My third layout (Figure 4) was a 180 degree view of the park looking down from some viewpoint among the trees. This connected the key compositions in a way that implied a camera position fixed somewhere above the path between the gate and bench. The camera rotates to keep the horizon where it should be at the end of the shot. This was the layout which was the basis for the production artwork used in the shot.

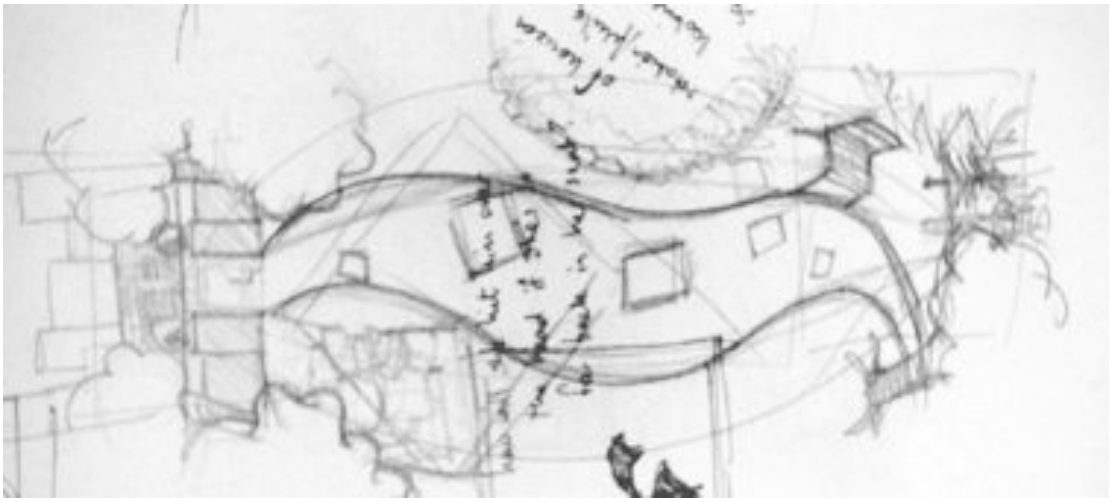

Figure 4 Panoramic layout for park shot.

Alternatives to panoramas

Given that the desired effect is that of motion through space, why not model the environment in 3D and render the view from a precise camera path?

1. The single image solution provides consistency with the style of the characters, the style of other static backgrounds in the film, and has a characteristic non-photorealistic aesthetic which may be desirable.
2. Precise movement is not always called for by the script. The continuity of a motion may be of no value when the narrative purpose of the shot is to show separation of characters. Maybe moving between viewpoints in three dimensions would be too slow, important details might be missed or unnecessary details revealed. The smoothness of camera paths characteristic of keyframed 3D animation is not the only option for creating cinematic effects.
3. Modelling in 3D requires knowledge of a different toolset than for 2D production.
4. Panoramic composition has more in common with storyboard composition. The process of extrapolating geometry from a storyboard sequence is more complex than generating an extended 2D illustration from the same sequence.

Research aims

This research is concerned with the construction of layouts rather than the reasons for choosing them as a production method over other animated representations of space.

It aims to reveal the variety of purposes of these shots and salient features in the design of background panoramas to support them. It is based not on theory but on an examination of professional practice.

The paper considers methods for creating these panoramas and the kinds of camera motion that can be simulated. It presents an analysis of a number of sequences from animated films and reconstruct underlying panoramas that

contribute to the effect. These are summarised and some conclusions drawn about the design and purpose of these panoramas.

Background

Motivation for this work

The use of background panoramas in animation is quite common and well supported by current desktop video compositing software. An artwork which is larger than the frame dimensions serves as a scrolling background to an animated character executing a walk-cycle in the foreground. This is one of the simplest compositions for locating a character in a space and technically easier to produce than a walking character against a static background.

The layout of such a background requires little forethought - an extended avenue of trees, a fence or the wall of a house can be repeated horizontally with no change to the geometry of the depicted features. The sensation in such an animation is of the camera moving parallel to the viewing plane.

A complex motion requires a more considered approach. What is it in the background artwork that contributes to an impression of depth, and how can a two-dimensional artwork imply movement of the camera viewpoint through a space?

Image-based rendering

In looking for 2D solutions to the problem of creating cinematic camera motion in animated film we face the problem of generating the panoramas to simulate this motion. The creation of distorted perspective projections of scenes is addressed by a relatively new research field in computer graphics. Image-based rendering seeks to create new views of a scene from one or more (two-dimensional) source images rather than a 3D model.

Rademacher and Bishop (Rademacher, 1998) introduce the multiple-center-of-projection-image which they describe as "a single image acquired from

multiple locations". It is an image which contains smoothly connected but distorted projections of a scene from various angles.

Agrawala (Agrawala et al., 2000) presents a software tool for creating what they call multiprojection images and animations which are characterised by "attaching local cameras to the scene geometry". Thus each object in the scene has its own projection which best reveals its features. They cite the paintings of Georgio de Chirico and Paul Cezanne among others as inspiration for this approach to 2D representation.

Wood (Wood et al., 1997) describes an approach for automatically generating Multiperspective Panoramas for Cel Animation given as input a scene modelled in 3D and a camera path through it. They take their inspiration from the "warped perspective" of the panorama from the opening shot of *Pinocchio* (Disney, 1940) (see Figure 18).

While such software tools remain in computer graphics research labs and beyond the reach of most layout artists, various solutions for simulating camera motion regularly appear in traditional animation. The rest of this paper considers the solutions to this problem found by human layout designers for animated film.

Terminology

In this paper a *background panorama* is a static piece of artwork which is used in an animated composition as a background layer. It acts as a backdrop which establishes the space in which action takes place. It is considered here separate from other elements of the final composition which are layered in front of it like on a stage set.

A *viewing window* is a rectangular section of the panorama. Necessarily, the panorama's dimensions are greater than those of the viewing window. An

animated view, at its simplest, is created by moving the camera[1] across the panorama (following a *viewpath*). In the simple case this might be analogous to a real camera trucking through a scene.

The term *layout* denotes the combination of a panorama and a viewpath across it. It fully specifies how the final animated background will appear, describing translation, rotation and scaling of the viewing window. The layout does not include the colouring, lighting or texture of the artwork, rather the spatial composition of visual elements making up the whole work. The layout may be fully specified while the artwork is only at line-drawing stage.

In referring to *perspective* this paper assumes the conventions of linear perspective projection, originally attributed to Brunelleschi (Panofsky, 1997). The visual characteristic of linear perspective projection is that parallel edges in a scene are projected as converging straight lines. In a cylindrical (or spherical (Adams, 2004) or curvilinear (Flocon and Barre, 1987)) projection parallel edges are depicted as converging arc segments (curved lines).

Discussion of the way the viewing window moves across a panorama refers to the *transition region* of a panorama. This is the area that lies between the start frame composition and the end frame. In some types of composition it has different graphic characteristics from the start and end frames. For example it might be less detailed.

Types of camera movement

This paper investigates the simulation of camera motion by the use of perspective in layout design. It is necessary to define the types of camera motion that might be simulated in this way.

[1] The term camera is used here to represent the idea of a viewpoint and its projection plane used to create a conventional linear perspective drawing and is not intended to imply that the work is shot on film or video camera.

In attempting to automate the creation of what they term *multiperspective panoramas* Wood (Wood et al., 1997) characterises four types of camera motion which can be simulated in a layout;

pan

camera rotates about an axis orthogonal to its projection plane

tilt-pan

as for panning but with camera tilted e.g. downwards

zoom

change in focal length of stationary camera and

truck

camera moves perpendicular to gaze direction

In discussing types of camera motion in the next section we also refer to the following motions;

roll

camera rotates about its gaze axis

spin

camera rotates about a vertical axis lying in front of it. The panorama looks the same as for a pan motion, but with the addition of a character in the foreground the motion simulated is of the camera spinning around that character

We differentiate what's been defined above as simulated camera motion from the viewing window transformations required for producing an effect using a given panorama. In keeping with the terminology used by AfterEffects to describe moving artwork under a virtual camera these will be referred to as changes in rotation, position, anchor point and scale of the panorama. For example, to simulate a panning camera motion the layout will probably include a translation of the viewing window across the panorama.

Depth cues

The intention in using this kind of construction is to establish the illusion of motion through a three-dimensional space. There are many ways of representing space in an image. This is understood well by artists and has been extensively analysed by psychologists. The following breakdown is based on classifications by (Levine, 2000) and (Kaufman, 1974) of monocular depth cues involved in visual perception of two-dimensional images;

Pictorial cues

size

of image projected on retina — objects at greater depth are smaller

interposition

cutting off of one part of the view of an object by another — nearer objects obscure objects at greater depth

lighting and shadow

cast shadows and highlights — indicating relation between objects

relative brightness

distance between object and source of light

perspective

characterised by the convergence of parallel edges in a scene

texture

detail perspective or textural density — texture features are diminished at greater depth (due to dust, moisture in atmosphere)

Kinetic cues

parallax motion

the relative movement of objects at different depths as the viewpoint moves

Overview

This work focuses on the role of perspective to provide an understanding of the compositional basis of layout design for background panoramas. Most of the works examined also employ parallax motion of foreground elements on top of the panorama for various purposes. The illusion of depth in the graphical skeleton of the layout thus produced can be enhanced by the artistic application of lighting, texture, interposition, etc.

The animated sequences referenced in this analysis were selected on the basis of their apparent use of background panoramas. There was no further criteria for their inclusion and no selective exclusion of sequences. Film titles were sourced informally from the suggestions of peers (animation cognoscenti). In addition, reproductions of some background panoramas (*The Old Mill (Jackson, 1937)* and *Pinocchio*) were obtained from books. The original art from the author's film *Pecking Order* was also analysed.

The process for estimating a background panorama for each of the sequences is as follows;

1. Animation sequence is digitised from video.
2. Key frames are extracted from the sequence.
3. Overlapping visual details in consecutive frames are matched.
4. Frames are composited to make a single image which is the reconstructed background panorama.

The method presupposes that the visual elements to be considered as part of the background panorama are static. This appears to be true in all the examples except the rotating fridge shot from *Who Framed Roger Rabbit?* (Zemeckis, 1988) (see discussion below). An artefact of the reconstruction method is that some parts of the panorama are obscured by animated foreground elements and that these elements may be replicated across the panorama.

The validity of the working method was established by comparing the original artwork for the *Pecking Order* shot with a reconstruction by the described

method. While there is the possibility of error in the alignment of frames making up the reconstruction when compared with the original, the conclusions drawn from these reconstructions are not of a quantitative nature so that these discrepancies and the absence of graphical detail are of no consequence to them.

For each of the reconstructed panoramas the following layout design issues were considered;

Purpose of camera motion

Does the motion establish mood, environment, spatial relationship between elements or transition from one location to another. Indications of where in the composition the viewer's attention is being directed.

Use of perspective in the background panorama

Linear, cylindrical or distorted perspective. Are straight edges projected as curved or straight lines? Do parallel lines appear to converge within the frame or beyond it? Is the projection coherent across the panorama?

Analysis

Eight background panoramas are discussed. They are categorised in the following order of increasing layout complexity;

Rotational camera motion

pan, spin, roll

Translational camera motion

truck, zoom

Multiperspective transition

camera transitions between discrete viewpoints

Rotational camera motion

Monster: title sequence

A three-second shot in the opening titles of the Japanese television series *Monster* (Kojima, 2004) shows a head-and-shoulders view of a man walking along a tree-lined avenue. He hears something, stops and turns to face back the way he has come then spins right around in the opposite direction.

Figure 5 Reconstructed background panorama from the title sequence of the Japanese television series Monster.

The camera initially pans left tracking the walking figure but as he turns it pans to the right and moves behind him keeping him in centre frame. The spinning is disorientating, the background beyond the trees is almost featureless and the viewing direction unimportant. The sensation of camera motion derives from the opposing relative motion of the foreground figure against the background. The viewer's interest is directed at the figure — he is central to the composition, the background details are blurred and unremarkable.

The panorama (Figure 5) is essentially a projection of the avenue of trees from a single viewpoint. Edges of the tree trunk silhouettes lie perpendicular to the plane of camera rotation. There are no features on the ground or in the sky, no converging parallel lines, but the size of the trees and lighting of the distant landscape imply depth. Compositionally, the trees are close enough together that in any single frame there are at least two trunk silhouettes visible.

Midori no Hibi: title sequence

A similar horizontal panoramic layout is used for an eight-second shot in the title sequence of the television series *Midori no Hibi* (Kobayashi, 2004) which shows the main character, a young guy, and his best friend (who is literally his right hand) standing in a clearing. In addition to simulating motion the background shows a kind of metaphorical seasonal change (see Figure 6). The trees transition from green foliage, through autumn colours to pink blossom. This is probably achieved by blending three differently-coloured versions of the background panorama to make the sequence rather than using a single panorama as reconstructed here.

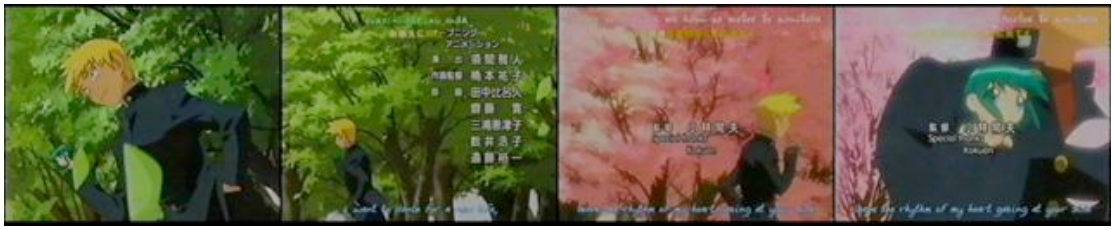

Figure 6 Keyframes from the opening titles of Midori no Hibi.

Starting at the right side of the panorama, the camera rolls anti-clockwise as it pans left. The figure is standing still and the camera continues to spin around him, first moving away, then towards him. This forward/backward movement effect is not indicated in the panorama but is achieved by the varying size of the figure against the background. The panorama establishes a low viewing point looking slightly upwards. The animation is, however, not consistent with a camera motion in three-dimensional space; the figure appears to be sliding around on the ground as the camera traces an elliptical orbit around him.

Figure 7 Reconstructed panorama from the title sequence of the television series Midori no Hibi.

No ground is visible in the composition of the panorama (Figure 7) and depth is hinted at only by a limited view of the sky through between tree trunks. The panorama could be considered a linear perspective projection from a viewing point on the ground with a single vanishing point high above the trees indicated by the inward leaning of tree trunks at the right and left ends of the panorama. The perspective cues are not strong however and the background conveys more a sense of being surrounded by trees than a particular spatial relation between the figure and his environment.

Fantasia: the reclining hippopotamus

In a seven-second shot in the *Fantasia* (Hee, 1940) segment 'Dance of the Hours', the hippopotamus ballerina reclines in a suddenly empty amphitheatre after her routine with the elephants. High above her, hooded and peering down at her, appear three alligators.

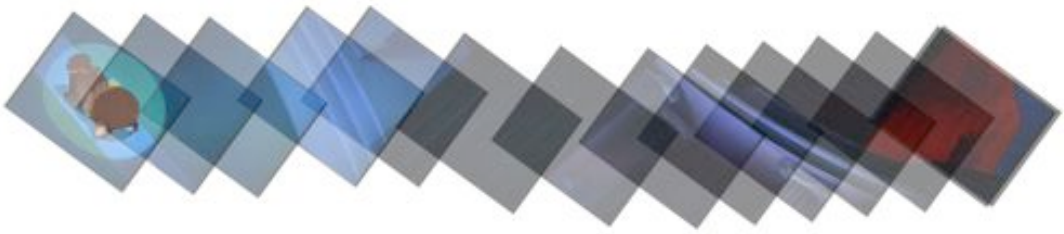

Figure 8 Reconstructed panorama for the reclining hippo shot from Fantasia.

The camera pans diagonally (Figure 8) from the hippo up and right, passing in shadow behind a column. The shot ends looking upwards to where the three hooded figures are revealed. The purpose of the shot is to show the spatial relationship between the characters — how far away from the hippo the alligators appear. The transition can happen very quickly because there is no graphical detail to be noticed by the viewer.

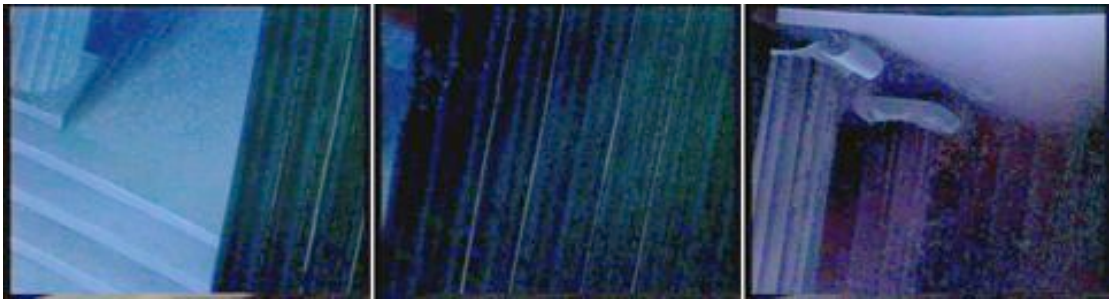

Figure 9 Frames from Fantasia selected to highlight the discontinuity in viewing angle between the left and right halves of the reconstructed panorama. The middle frame shows the foreground column which obscures the transition.

The parallel lines of the steps are across the direction of travel helping make the panning motion read clearly. There are strong parallel edges in the composition which converge beyond the frame borders implying a viewing position a long way from the action. The foreground column element effectively breaks the composition into left and right sections. Taken as a whole, it is not clear how the left and right sections lie spatially in relation to each other — the way they join up is obscured by the foreground column (Figure 9). Examined individually, each conforms to a single viewpoint and direction and forms a locally coherent projection.

The Old Mill: interior

The panorama reproduced here (Figure 10) is a draft for a background for the film *The Old Mill* which shows an interior view of the mill. At the top of the panorama the apex of the mill's roof is visible, while at the bottom the view is looking down onto the grinding stone.

Figure 10 Draft for The Old Mill.

The representation of both top and bottom of an interior space usually requires cylindrical perspective resulting in straight edges being projected as arcs. This panorama manages to achieve a kind of pseudo-cylindrical projection without distorting the straight edges of beams. Clues to the perspectival deception being perpetrated are the presence of foreground elements (beams and stairs) which are inclined towards top and bottom vanishing points.

Fantasia: alligators and columns

This four-second shot from the film *Fantasia* starts looking upwards along the length of a column at nine hooded alligators three of whom quickly begin to descend, each spiralling down around a column. Moving down the column the central alligator appears and vanishes around the back again before leaping out at the base of the column.

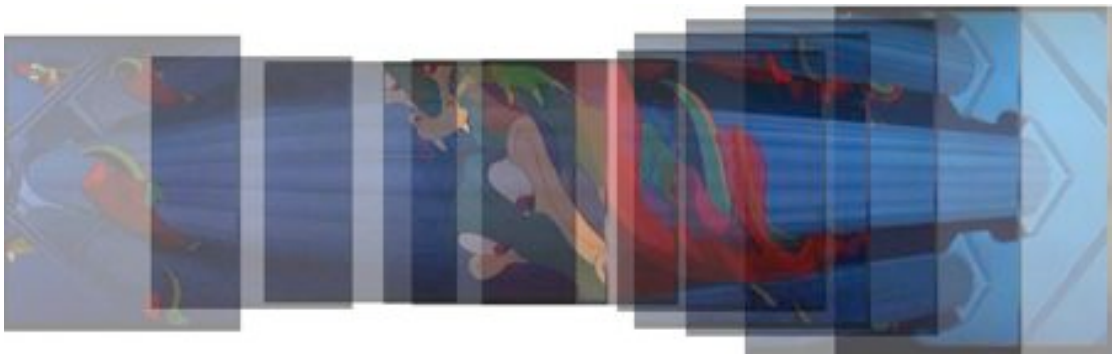

Figure 11 The descending alligators panorama from Fantasia.

The camera simply rotates in a vertical plane from the top of the column to the bottom following one of the alligators.

This layout (Figure 11) employs cylindrical perspective to include views of both zenith and nadir vanishing points of the parallel vertical edges of the doric columns. The transition from lines converging above to lines converging below coincides with a flash of the alligator's red cape filling the screen.

Pecking Order: chicken in the park

The seventeen-second shot from the animated short *Pecking Order* is a view from a crane looking down on a meandering path. The shot begins looking out through the park gate and across the road and follows the path through the park, revealing a trail of books leading to a figure seated on a park bench (Figure 12).

Figure 12 Keyframes from the short film Pecking Order.

The camera pans through almost 180 degrees as well as rotating through 180 degrees, such that the horizon on the left edge of the panorama and its opposite are both oriented as expected. The effect is of a crane-mounted camera looping through space starting above the trees, sweeping down to the ground to show the trail of books close up and finishing up in the air above the park bench. The books are an important detail and this is reflected in the slowness of the transition.

Figure 13 The original park panorama from Pecking Order.

As mentioned the panorama (Figure 13) contains two horizons, offset 180 degrees, at the left and right ends. It is essentially a cylindrical perspective projection of the park environment. There are clear parallel straight edges in the start (road and gate posts) and end (park bench and path) frames. There

are few parallels in the transition region but the edges of the path exhibit the bulging distortion which is characteristic of cylindrical perspective projection and the size of the books reinforces the impression.

Translational camera motion

Beauty and the Beast: Belle walking into town

This thirty-seven second shot from the start of the feature film *Beauty and the Beast* (Trousdale, 1991) shows Belle leaving her cottage and walking along a path up the hill in front of her house and down again, across a bridge and into town. Being the first time in the film the character of Belle has been shown, this shot introduces her and the nature of the environment she lives in.

Figure 14 Keyframes from the Beauty and the Beast sequence.

The camera zooms out from the house as Belle walks towards the hill then trucks horizontally parallel to her and follows behind her over the bridge (Figure 14). The camera seems to accompany Belle on her walk through the landscape such that there is a smooth transition between the initial view of the house and the final view of the town.

Figure 15 An approximation of the extent of a static background panorama for the opening sequence of Beauty and the Beast.

This is quite a complex shot with many multiplane elements layered on top of the background panorama (Figure 15). The silhouette of low hills was used as the main registration marking in estimating the layout of the panorama. It is present in each frame and sits behind the house at the left end and disappears behind the elements of the town at the right end. The start and end frames are all about architecture while the figure is central to the composition during the transition between views. The house and town compositions each show converging parallel lines. In the transition region the depth of the landscape is conveyed more by the relative motion of mid- and foreground elements against the background.

Who Framed Roger Rabbit? rotating refrigerator shot

This three-second shot from the opening animated sequence of the film *Who Framed Roger Rabbit?* (Zemeckis, 1988) shows a baby sitting on a tiled floor in front of a fridge, staring up and noticing a cookie jar on top of it. It comes in the middle of the 'kitchen sequence' so the location has already been established. There is no action in the scene, rather the shot shows the baby wide-eyed, and rotates to reveal what he has seen. The action is all in the viewpoint revealing and exaggerating the spatial relationship between the baby and the cookie jar.

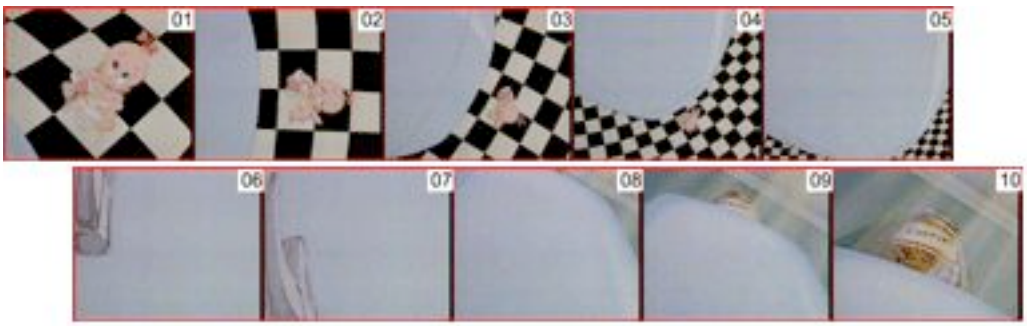

Figure 16 Keyframes from Who Framed Roger Rabbit?

The simulated motion of the camera starts looking down on the baby and ends peeking over the top of the fridge. This involves zooming away from the floor, panning and rolling and zooming up the front of the fridge to show more of the cookie jar (Figure 16).

A frame-by-frame examination of this shot suggests that there is not a single background artwork and that the refrigerator, cookie jar, floor and ceiling are separate elements of the composition and that the tiled floor is animated rather than static. The treatment of these parts as a static panorama (Figure 17) is nevertheless instructive for understanding the design of this kind of shot.

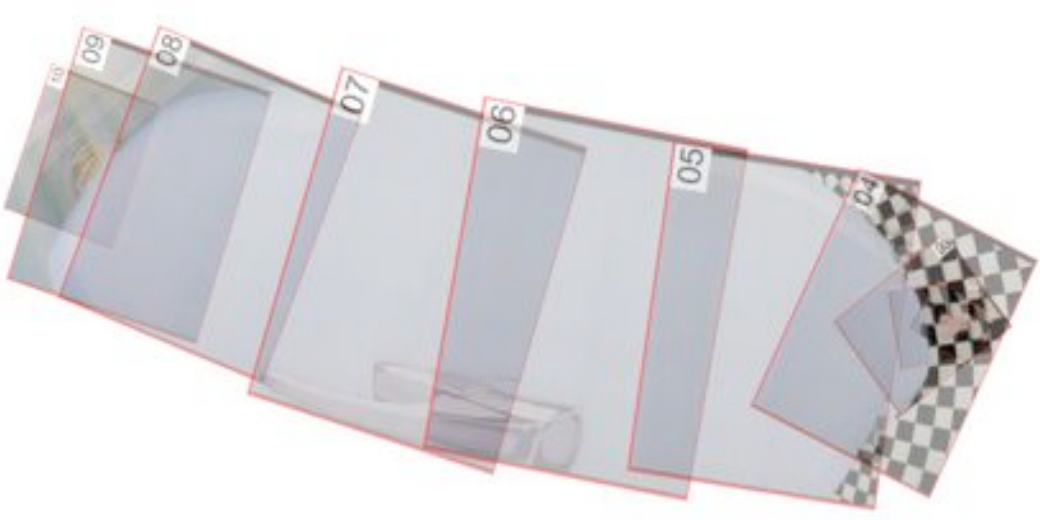

Figure 17 A reconstruction of the layout of the rotating refrigerator shot from Who Framed Roger Rabbit?

This composition includes both zenith and nadir vanishing points of the parallel vertical edges of the refrigerator. This is consistent with a cylindrical perspective view of the refrigerator. The stronger converging parallels are the start and end frames — the lines of the floor tiles converge out of frame behind the baby and the parallel lines of the cookie jar converge in the end shot. It is of interest to note that in the frame numbered 4 (see Figure 16) the tile edges converge *in front of* the baby. This simulates moving the camera away from the fridge as it rises from the floor.

In the transition region, in which the body of the fridge fills the frame, the handle is the only visual cue indicating that the camera is moving at all.

Multiperspective panorama[2]

Pinocchio: town and workshop

The twenty-second opening shot from the feature *Pinocchio* (Disney, 1940) establishes the location of Gepetto's workshop at the end of a cobbled street, in the evening as a full moon rises over the village and the surrounding mountains. The shot creates a sensation of sweeping from high above the village rooftops down to ground level in the street opposite the workshop.

Figure 18 The background panorama from the opening of Pinocchio.

The camera moves, apparently continuously, from above the town to the street level and advancing towards Gepetto's workshop. What is not clear from the panorama is the use of a foreground element which obscures the transition from the right half of the panorama with a view of rooftops to the left half where the viewpoint is down at street level. So although the impression is one of continuous motion it is achieved by obscuring the background with a foreground element moving relatively to it.

The panorama (Figure 18) depicts the village from two distinct viewpoints; one above the rooftops, the other at ground level. The right and left halves of the panorama have different horizons. They are quite distinct linear perspective compositions. This bifurcation of viewpoint leaves a viewer of the complete background panorama with a paradox about his own location with

[2] Wood et al define a multiperspective panorama as "a single image [...] used to incorporate multiple views of a 3D environment as seen from along a given camera path."

respect to the scene; am I above the town or on the street? Both of these situations are represented in the single panorama.

No single frame of the animated panorama contains visual detail from both viewpoints. For a given frame there is only one interpretation of the camera location and the transition from one location to the other is obscured by a foreground element. Thus the dislocation which is apparent from examining the panorama as a whole is not apparent in the animated view and what remains is an impression of translation from one viewpoint to the next.

Discussion

The analysis is summarised in Table 1 to compare layouts that are and how the simulation of different types of camera motion is produced. It indicates a range of uses of camera motion and certain considerations for layout design for these different purposes.

Sequence name	Purpose of shot	Primary depth cues	Transition speed	Transition detail w.r.t. start/end frames
Monster / Midori no Hibi	locating foreground figure	parallax of figure against background	quick	same
Fantasia: hippo	spatial relation between characters	linear perspective	quick	low
The Old Mill	reveal environment	linear perspective	n/a	n/a
Fantasia: alligator	figure moving between locations	cylindrical perspective	quick	low
Pecking Order	environment, spatial relation between locations	cylindrical perspective	slow	same
Beauty and the Beast	environment, spatial relation between locations	linear perspective, parallax in transition region	slow	high level of detail, no perspective
Who Framed Roger Rabbit?	spatial relation between character and prop	cylindrical perspective, linear perspective, parallax	quick	low
Pinocchio	environment, spatial relation between locations	linear perspective	slow	low[3]

Table 1 Comparison of layout characteristics.

[3] The shadowy foreground element which obscures the background during the transition from one viewpoint to the other is considered here to constitute the transition region.

The space between things

If the purpose of a shot is to show how far apart in space two characters are, the panorama might establish strong linear perspective composition locating the first character and similarly for the location of the second character, but the space in between them need only be suggested A single strong visual element in the transition region is sufficient. This approach is taken in *Who Framed Roger Rabbit?* as well as both *Fantasia* shots.

For rapid transitions graphical detail isn't required to establish depth — relative motion of foreground elements against a flat background is a simple alternative layout.

For transitions between different projections it is not necessary to show the transition. This region of the panorama can be obscured by reduced contrast or an element of foreground scenery passing in between the camera and the background, or cylindrical perspective used to obscure the view by distortion.

Piece-wise linear perspective

It is not necessary to rigidly adhere to a particular projection scheme between different sections of a panorama. Representing multiple viewpoints in a panorama works provided that any given frame's composition is based on only a single viewpoint. The layout will be read as a continuous transition provided the join between disjoint projections is obscured by a fig leaf[4], as demonstrated in the *Pinocchio* and *Fantasia* hippo shots.

The examples that use multiperspective or cylindrical perspective use frame compositions that reveal only a section of the panorama without exaggerated perspectival distortion. None of the examples shows discontinuity of

[4] Talking about the use of early system of perspective projection (non-linear) based on a 'projection circle' and it's inability to "foreshorten correctly a checkerboard pattern [...] such awkward discrepancies were concealed by an escutcheon, a festoon, a bit of drapery or some other *perspectival fig leaf*." Panofsky, E. (1997) *Perpective as symbolic form,* Zone Books, New York.

projection within a single frame. For example, the *Fantasia* alligators panorama uses cylindrical perspective to show the top and bottom of the column, but the individual frames show only mildly distorted straight edges.

Reading camera motion

For panning motion across an area where graphical detail isn't high, lines perpendicular to the direction of camera motion help make the motion read clearly. This is demonstrated in the *Monster* shot as well as the *Fantasia* hippo shot.

In all the examples a certain 'uprightness' of frame composition (or horizontality of horizons) is maintained throughout the animation even though the panorama has a multiplicity of horizons (for example refer to *Pecking Order*, *Roger Rabbit* or to a lesser degree *Pinocchio*).

The role of parallax in showing continuous translational camera motion. In each example involving the camera moving through space (*Monster*, *Midori*, *Beauty* and *Roger Rabbit*) instead of simply panning or zooming, the smoothness of the motion is a result of parallax of the foreground element. The background is in effect just a pattern against which the relative motion of the foreground figure plays regardless of perspectival cues in the panorama.

Revisiting *Pecking Order*

In considering how this observations might apply to an actual production I reconsider the design of the establishing shot for the park scene in *Pecking Order*. Here are some things I might do differently.

1. Make the shot quicker. A few seconds of stillness to establish the atmosphere of the park and then into the action; the second character approaches, picking up books. The seventeen second one-eighty-degree shot seems quite laboured in retrospect.
2. Not being bound to a single viewpoint when designing the panorama. Cylindrical perspective is a precise way of capturing a panoramic view of an environment but it's elegance is not necessarily appreciable in a

restricted viewing window. This research has suggested other ways of joining up two perspective compositions that would serve this shot well.

3. Use strong start and end compositions and quick transitions. There were three things I needed to show in the shot - the gate, the books and the park bench as the second character approached. Rather than treat this as a single continuous shot it could be more succinctly communicated in two shots; from the gate to the books and the books to the bench. These might be visually linked using the approaching character or some other feature in the park, like the statue, as a foreground element.
4. More use of foreground elements to obscure background transitions. The panorama relies unnecessarily on perspective to establish depth in the scene. There is some parallax motion, but only of mid-distance elements against the background. Integrating foreground elements the move quickly across the screen would enhance the depth impression and bring the viewer closer to the action.

William Robinson: Back Creek Gorge to the Coomera

As an extreme example of distorted perspective which might serve to inspire layout designers, I briefly investigated using the remarkable landscape paintings of William Robinson as background panoramas for animation.

William Robinson (Klepac, 2001) is an Australian painter who describes his landscape paintings as "multi-time and multi-viewpoint"[5]. They depict landscapes as a composition of locally-coherent but globally ambiguous

[5] Robinson says of his landscapes "These paintings are not solely multi-viewpoint although this is a consideration [...] I try to include the observer [myself] in the work, and so as much as anything, the observer is a free-floating eye within the picture; therefore I feel I can break down any rules of distance, middle distance and foreground. Yet these things are included in some way, because when the eye is in one of the positions, some distance, mid-distance and foreground may apply. The rules of composition still apply." Klepac, L. (2001) *William Robinson: Paintings 1987-2000,* Beagle Press, Sydney.

projections. A single work, like *Back Creek Gorge to the Coomera* (Figure 19) contains multiple, distorted horizons and vanishing points.

Figure 19 William Robinson's Back Creek Gorge to the Coomera 1994 oil on canvas 137 x 182.5 cm

As an illustration of some of the layout principles derived in this research I've animated a viewpath across this panoramic landscape painting with the intention of preserving the sensation of being within the environment. It serves as example of the way an extremely distorted projection of a scene is only selectively revealed through the viewing window. This allows the viewer to make their own interpretation of the environment.

Figure 20 Keyframes from the animated sequence based on the painting Back Creek Gorge to the Coomera.

Figure 21 Reconstructed panorama from the sequence revealing viewpath across the painting.

About perspective drawing

A summary of the representational limitations of linear perspective and what to do about it can be found in Dubery (Dubery, 1983). A comprehensive description of constructing curvilinear perspective projections can be found in Flocon (Flocon and Barre, 1987). Adams' (Adams, 2004) formulates a system for creating spherical perspective drawings. A collection of articles online regarding perspective and projections is provided by Bourke (Bourke, 2004).

Conclusions

The examples of animated background panoramas considered in this research are used for the following purposes;

1. locating objects in relation to each other
2. revealing environment
3. transition between viewpoints

The panoramas employ a variety of projection schemes to represent space.

1. no perspective — depth indicated by interposition, size, parallax
2. linear perspective
3. cylindrical (curvilinear) perspective
4. multi-perspective — different projections are used in different regions of the panorama

In addition, the amount of panorama detail presented in each frame can be restricted.

1. obscuring parts of the panorama by frame composition
2. obscuring parts of the panorama with foreground elements
3. drawing attention away from the background to a foreground element

It is hoped that the reconstructions compiled here and the analysis provided constitute a comprehensible introduction to the design of background panoramas for animation. It is not intended to be definitive rather to identify some of the situations in which this type of shot is used and to demystify the production of them.

Bibliography

Adams, R. (2004) *Spherical Perspective - a brief tutorial* http://www.treeshark.com/Persptut.html

Agrawala, M., Zorin, D. and Munzner, T. (2000) *Eurographics Rendering Workshop*.

Bourke, P. (2004) *Projection* http://astronomy.swin.edu.au/~pbourke/projection/

Disney, W. (1940), RKO Radio Pictures Inc *Pinocchio*

Dubery, F. (1983) *Perspective and other drawing systems,* Van Nostrand Reinhold Co., New York.

Escher, M. C. (1989) *Escher on Escher: Exploring the Infinite,* Harry N. Abrams, Inc, New York.

Flocon, A. and Barre, A. (1987) *Curvilinear Perspective,* University of California Press, Berkeley.

Haines, S. (2003), *Pecking Order*

Hee, T. (1940), RKO Radio Pictures Inc. *Fantasia: Dance of the Hours*

Jackson, W. (1937), RKO Radio Pictures Inc. *The Old Mill*

Kaufman, L. (1974) *Sight and Mind: an introduction to visual perception,* Oxford University Press, New York.

Klepac, L. (2001) *William Robinson: Paintings 1987-2000,* Beagle Press, Sydney.

Kobayashi, T. (2004), Studio Pierrot *Midori no Hibi*

Kojima, M. (2004), Madhouse Studios *Monster*

Levine, M. W. (2000) *Fundamentals of Sensation and Perception,* Oxford University Press, New York.

Panofsky, E. (1997) *Perpective as symbolic form,* Zone Books, New York.

Rademacher, P. (1998) *Proceedings of SIGGRAPH '98*.

Trousdale, G. (1991), Disney *Beauty and the Beast*

Wood, D. N., Finkelstein, A., Hughes, J. F., Thayer, C. E. and Salesin, D. H. (1997) *SIGGRAPH 97 Conference Proceedings*, 243-250.

Zemeckis, R. (1988), Disney *Who Framed Roger Rabbit?*