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Emulated Defects: adding physically accurate flaws on flawlessly rendered pixels



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Abstract

While sharing many analogies with motion picture filmmaking, computer animated films are not burdened by the limitations of the physical or technical means of photographing real-world scenes. Unlike live-action photography for film, which has always been done within (though sometimes also taking advantage of) the limitations of the mechanical means used to capture images - namely and especially cameras, lenses and film stock -, computer animated films rely mostly on computer generated imagery alone. Though certainly having its own drawbacks, these digital images are not bound by the same rules as traditional image capture. Accompanying the increase of the use of CGI in visual effects for live-action film, a tendency towards an approximation to real-world, physically accurate cameras (in all aspects, including their defects) in the making of CG animated fiction films is becoming clear. The technical shortcomings and what have traditionally been considered downright errors of real world cinematography, which are being emulated in animation fiction films, might improve viewing experience by approximating the rendered frame to the familiar image of cinema.

Keywords

Film, cinematography, 3D, computer animation, CGI, digital visual effects, camera, lens, distortion, chromatic aberration, grain.

1. Quality and Realism

Not only has the industry (especially Hollywood) always pushed for technical innovations and improvement for quality's sake,³ major *novelties* in filmmaking technologies have historically been used as marketing strategies and publicised as much as film stars and genres. [1]

The general tendency in mainstream motion picture production has almost always been, and continues to be, to aim for the *cleanest* possible image, both photographically and technically (from an operator's perspective). Overall, from the very beginning of cinema history, technological progress has led to cameras becoming more portable and compact, lenses faster, sharper, prone to less distortion, and film stock becoming increasingly accurate and sensitive, and thus less grainy. [2]

One of the most obvious reasons for such a movement would be that, along with so many other aspects of film production, a seamless,

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³ Author Kristin Thompson states that “photographic beauty became a staple of Hollywood’s quality product.” [3].

discrete camera and optimal image quality play a major role in creating and maintaining *suspension of disbelief*.

In broad terms, willing suspension of disbelief refers to the acceptance of the reader or spectator of a story (told in a medium such as prose, poetry, theatre, film) of things that may be illogical or unrealistic, for the sake of the enjoyment of said story. Filmmakers should hence aim for an “*Involuntary response (or lack of response), created when questioning certain details is made impossible by the distraction of the mind*” [4]. The responsibility of creating this “arrangement” the audience concedes in - ideally unwittingly - falls upon the filmmakers. One of the many ways the illusion is established is by not calling attention to the mechanics of filmmaking, avoiding the audience’s attention being placed on the technical aspects of the film, or - worse - on *the act of watching a film*, rather than the plot.

While the idea of aiming for extreme subtlety and better concealment of the craft behind the making of a motion picture has been prevalent historically, even within mainstream Hollywood, some tendencies take advantage of the shortcomings of technical means for aesthetic purposes have surfaced.

Soft focus photography is an early example of deliberately employing mechanical defects in lenses for stylistic and aesthetic purposes. From the mid 1920s into to the 1930s the style adopted by a majority of cinematographers working within the Hollywood Studio System was the Soft Focus style. Heavily influenced by portrait photography, many techniques were used to somewhat blur an image - or parts of it - while maintaining a focused subject. Sometimes gauze or scrims were used in front of the lens - as well as light sources - for obtaining various degrees of diffusion, however (totally or partially) uncorrected spherical and chromatic aberration⁴ (the later for black and white images only) in a lens could also obtain and enhance the Soft Focus effect. Explained by cinematographer Karl Brown in his article “Modern Lenses” published in 1922 by American Cinematographer [5]:

Most soft focus lenses depend upon spherical aberration, chromatic aberration, or a combination of the two in various degrees. The unusual soft focus image shows a more or less firm main image overlapped and underlaid with a less intense out-of-focus secondary image, the spread and intensity of which can be varied (...).

Images obtained using soft focus techniques are often described as dream-like and ethereal, and while having somewhat practical advantages in glamour photography (by rendering any imperfections less noticeable and softening facial features overall) the *general feeling* of the effect has led to its communicating very specific meanings to film spectators. Soft focus and misty effects (especially blurred highlights) are often used in dream sequences or to convey hallucinations and flashbacks, for example.

Towards the end of the 1930s, concurrent with a continuation of the soft focus style, technical advances in coated (faster) lenses, more sensi-

tive stock and more powerful light sources were being put to use by a new emerging trend of staging and shooting in depth - or what is known as deep-focus cinematography [6]. Deep-focus refers to shots which have more than one plane of either props or action in good focus simultaneously, and can be achieved on film by manipulating depth of field (through objective and film stock choice and lighting) or optical and printing tricks such as matting⁵, rear-projection⁶, and, more commonly, a split-field diopter.⁷

Often pointed out as a master of the Deep-Focus Style due to its use in *Citizen Kane*, his collaboration with Orson Welles released in 1941, cinematographer Gregg Toland indicates realism as the reason behind epic experiments with deep staging and extreme deep focus in *Citizen Kane* and some of his prior works: “Both Welles and I (...) felt that if it was possible, the picture should be brought to the screen in such a way that the audience would feel it was looking at reality, rather than merely a movie.” [7, 8]

Also, according to Bordwell [9], the realism achieved in *Citizen Kane* is that of time and of space, in the sense that deep staging and focus allow for fewer cuts (by allowing more of a scene to be staged - and clearly discernible - within a single shot) and that it better resembles how the human eye sees - with great depth of field and “completely automatic” focus changes.⁸ Toland’s claims to realism have some following. Film critic André Bazin, for instance, one of the main proponents of realism as a quality to which film should aspire, points to *Citizen Kane* as an admirable step towards film realism, precisely because the increased depth of field allows further freedom for staging (in depth), rather than editing and *découpage*. [10].

Toland argues that film’s reduced depth of field (compared to that of the human eye), despite being accepted by filmgoers out of habit, is a “conventionalised artificiality which bespeaks the mechanics and limitations of photography” [11] and will therefore prevent the audience from accepting the film as reality by calling attention to technique and method of production.

Despite being recognised and lauded for its technical aspects and cinematography from its release date to the present day, Welles’ and Toland’s heavy stylisation in *Citizen Kane*, including extreme depth, was at the time criticised as artifice and as failing to achieve one of the goals of “good” cinematography, that of serving the story without making the audience conscious of the craft.

Of course, audiences have become accustomed to seeing things this way on the screen, with a single point of perfect focus and everything falling off

5 matting refers to the process of selecting part of an image or shot for replacing it with other elements, and can be done in various ways, from hand drawn mask, chemical processes and of course digitally.

6 rear projection is a technique in which previously recorded footage is projected from behind a translucent screen, in turn placed behind the actor or scene. The scene and the projection are then filmed together - the projection as background;

7 split-field or split-focus diopter refers to using an attachment on the lens which “splits” the image in two, one side of the lens focusing nearer and the other on a farther distance.

8 “While the human eye is not literally a universal focus optical instrument, its depth of field is so great, and its focus changes so completely automatic than for all practical purposes it is a perfect universal-focus lens.” [12]

with greater or less rapidity in front of and behind this point. But it is a little note of conventionalised artificiality which bespeaks the mechanics and limitations of photography. [13]

After the end of the Studio System, heavily influenced by European cinematographies such as Nouvelle Vague and Italian Neorealism which stylistically reflected their much “looser” modes of production, American film from the 1960s and especially into the 1970s does free itself somewhat from “virtuous” cinematography. Cinematographer Andrew Lazlo describes an approach to his own work - which can illustrate a sort of paradigm shift in the late 1960s and 1970s - he calls *good/bad cinematography*:

(...) gravitating away from the standard, studio-type lighting of pretty, pleasant images and towards a technically imperfect, at times rough photography. (...) Even if the photography wasn't perfect, “good” photography, it would be preferable to making the “look” of the film fall within the line of convention. [14]

From the 1960s onwards rules are frequently broken if justified by storytelling and *author* style. The directors and cinematographers that came to prominence in the New Hollywood are the first generation of American filmmakers to have been brought up watching films in theatres. As the ethereal soft-focus picture came to be used especially to signify dreaming or flashbacks (as in the example given above), so many other results of the craft - be it mechanical limitations such as optical defects or techniques invented to overcome them, such as split diopters - came to play certain roles and take on certain meanings, familiar to filmgoers. Film production since the New Hollywood generation (fluent in film language) somewhat embraces camera limitations and the pictures that result from them - utilising their significance and further cementing it in film grammar through using known image-styles in films - while at the same time relying on and ever pushing for more advanced technology.

2. Digital Cinematography

In recent years there has been a notable rise in the use of computer generated imagery (CGI) in aiding film and video production and, though certainly having its own limitations, CGI is not bound by the same restraints as traditional image capture.

Cameras, however, continue to be of importance in the digital three dimensional world of CG imagery. Whereas in live action shooting the camera-setup is the essential piece in image-getting in a number of different ways,⁹ the camera in computer generated imagery serves one single fundamental purpose (which it also shares with the real-world camera): defining the point of view for an image within the three dimensional space. The live-action camera exists and moves in the real world captur-

⁹ the live action camera setup serves multiple essential purposes for acquiring (multiple) images to simulate motion: focusing light rays onto a light-sensitive plane and moving the film strip at a definite speed are some examples.

ing actual, substantial light from a certain position in which its placed. The camera in digital visual effects and animation is used fundamentally for defining a viewpoint or perspective from which to look at the *virtual* three dimensional world - and its various assigned attributes.

2.1. Emulating Real World Physical Cameras

While cinema cameras, tangible objects with mass and weight that they are, obey laws of physics that govern how they can move and function (mechanically, optically, etc.), cameras in the digital realm share no such constraints, the only rules shaping how they operate and how they are restrained being those imposed by the software written for them. According to author Rickitt “However, because the audiences are so familiar with the look produced by the traditional film camera, the virtual camera has had many of the characteristics of a real camera imposed upon it.” [15]

The main force behind the development of computer graphics for audio-visual production has been its use for visual effects, mainly to produce elements that are to be seamlessly integrated with live action footage. CG imagery integration with live action demands an impeccable matching of the *perfectly* computer-rendered elements with the flawed, distorted traditionally captured footage.

Though seemingly crisp and clear to the audience watching a film, the various steps from capturing to printing or encoding and projecting the image for distribution all might somewhat degrade image quality. For purposes of discussing which of those processes play a part in seamless CG imagery integration, however, we must focus on the ones which occur before the making of a digital plate for compositing work. Those would mainly concern film stock and lens.

The main aspect to bear in mind regarding images shot on a determined stock and integrating CG elements into those images is *film grain*, as the lack of grain in digital elements is quite striking if put over a filmed plate. Digitally-acquired live action shots do not have grain but do have analogous¹⁰ image noise, which will create the same displeasing effect. Blending CG elements into a live-action plate therefore requires that CG and live action elements share the same quantity and quality (grain size, distribution, softness, etc.) of grain [17], which can be achieved either by overlaying matching grain on the rendered elements alone or on the composite made with a plate which has been digitally cleaned of grain and noise. For such a purpose, either a computer program may render the properties and qualities of an emulsion (either emulating existing emulsions or creating virtual ones), or else real stock can be digitalised.¹¹

Other than matching grain and noise, the optical properties of the lens used for image-capturing must match those of the added elements.

¹⁰ The *effect* of film grain results of discerning individual particles of silver or dye that make up the photographic emulsion. It is increased by projection/magnification of the image and by observing the frames in rapid sequence (which results in the particles appearing to move). Digital images, on the other hand, are captured by a sensor which is not made up of silver or dyes, but of pixels. A less than perfect conversion of the light of a scene into an electronic signal results in “random variations in pixel values” [16], which can be perceived much in the way film grain is;

¹¹ the film is captured against a medium grey background;

As discussed above, the camera in a virtual three dimensional environment has no need of a lens for focusing light. The lens in 3D image generation serves rather as a means of controlling a necessary set of attributes such as angle of view (a.o.v.), perspective and depth of field (d.o.f.) - attributes upon which lens choice *does* have an influence in real photography. The virtual lens and camera have, as a result, adopted the characteristics of *familiar* actual lens and camera set-ups: focal length which influences and a.o.v. based on gate/sensor size and camera distance, aperture which along with focal length and sensor size determines d.o.f., for instance.

Other than the theoretical overall features of a lens, the materiality of a photographic lens¹² causes a number or undesirable effects. As professor Michael Langdon affirms, “(...) every good lens is really a skilfully solved set of problems concerning the control of light”. [18] Even the best photographic lenses cannot solve all the issues brought about by the interaction of multiple elements that constitute the compound lens.

“Firstly, these errors are due simply to imperfections in the individual optical components and are very difficult to avoid, even when the best components are used. Secondly, errors in fabrication and in the alignment of the individual optical components can result in further aberrations.” [19]

Of the noteworthy aberrations caused by poorly resolved optics, we shall define the two which are most commonly emulated in CGI rendering:

Chromatic aberration is caused by light dispersion, which leads to different wavelength components of a refracted white light ray to be focused at different points (on the optical axis - longitudinal aberration or on the image plane - lateral aberration). Colour fringing is mostly the result of lateral chromatic aberration. As all the other types of aberration listed here, its effects tend to worsen at the corners of the image and can generally be minimised by stopping down.

Pin Cushion and Barrel Distortion occur when the field of view is larger - pincushion: straight lines curve outwards especially near the edges of the frame- or smaller - barrel (see fig. 2): straight lines curve outwards especially near the edges of the frame - than the image plane. Both types of distortion can take place at the same time causing “complex” (also called “moustache”) distortion.

All other aberrations¹³ tend to manifest as a lack of sharpness in some parts of the frame. Some are hardly discernible from one another, and also not as common in modern lenses, factors which can explain why these have not been applied as much to CGI and animated film. A selec-

¹² photographic lenses are more often than not composed of various elements with different properties than complement and correct each other;

¹³ *Spherical Aberration* causes light rays to focus at different points of the optical axis after being refracted by a spherically shaped (high curvature) lens. *Coma* is caused by light rays that hit the lens at an angle, and are focused on different points (off the optical axis) by different zones of the lens. Quite similar to spherical aberration, only causing a “tail” rather than uniform “blurriness” around a point. *Astigmatism* is caused by light rays that hit the lens at an angle (off-axis) are spread out in a line (can be radial or tangential). *Curvature of Field* results of a curved focal plane which creates a lack of sharpness of a flat object towards the edges of the frame.

tive lack of sharpness is very commonly used to degrade image quality for “expressive” purposes (some examples have been discussed above), but these other defects tend not to match an actual, existing camera-lens set-up, rather being used to create overall distortion.



In terms of effectiveness and productivity, and taking into account the ever-growing need to seamlessly integrate digitally rendered assets with less than perfect imagery from live-action capture, it is no wonder the visual effects industry has adopted a similar terminology and methodology - “filming” digital assets, using programs which aim to perfectly mimic the physical behaviours, flaws and errors included, of the equipment used to capture the real scene.

Fig. 1 *The Haunting*
(example of deep focus)

Fig. 2 *Silence* (example of chromatic and spherical aberrations, barrel distortion)

3. Camera and Lens in Computer Animated Fiction Films

This tendency in rendering bleeds through to computer animated fiction, for which the need to keep absolute likeness to captured imagery (otherwise risking the suspension of disbelief, as is the case with digital visual effects) is probably of less importance.

Pixar’s *The Incredibles* (2004) is arguably one of the computer animated films of the early 2000s that most heavily relies upon deep composition in its staging. *Monsters Inc.* (2001), the studio’s previous film for instance, features extreme depth of field in a large quantity of shots and sequences, but these are not especially designed for multiple *relevant planes of action*. *The Incredibles*, on the other hand, does have a large number of shots composed so that separate planes in the frame each contribute with important narrative information, much in the way of the deep staging techniques of live action filming (described earlier). Whereas in the case of live action depth of field is the by-product of the optics of the lenses used, in CGI and computer animation depth of field is not an inevitable aspect of the image. The CG image without modification - an image that appears sharp from the closest to the furthest point from the “lens” - is what all the manipulation and technical apparatus used for deep focus in live action aim at producing. What might be interesting to point out, in the case of *The Incredibles*, is that while honouring the split focus technique and being able to effortlessly get the same or even an idealised version that effect, the filmmakers still simulate depth of field and other techniques such as rack focusing¹⁴ in those “deep” shots.

¹⁴ changing the focus distance during the shot;

Throughout the film depth-of-field is also generally simulated following the way it would be expected in live action - shallower inside and longer in exterior shots, with some exceptions., the most notable of which being night and dimly-lit scenes - such as the cave scene - one supposes for the sake of intelligibility.¹⁵

While telling an original story, Gore Verbinski's *Rango* (2011) draws heavily on Spaghetti Western films and on the Western genre in general.



Fig. 3 & 4 Deep staging and focus in *The Incredibles*

A genre as old as cinema itself, the Western is not related with one but with a myriad styles and techniques of cinematography, but still (perhaps precisely due to its privileged place in early cinema and during the Classical American Cinema period) is one of the film genres most commonly associated with *film stock* and its characteristics, particularly grain, format and colour. As are all other computer generated images, the shots in *Rango* are rendered with no defects such as grain and distortion, and yet its status as a pastiche justifies that these be added on top of the rendered images. Compositing supervisor Nelson Sepulveda describes the process of post-production in *Rango* saying “[it] mucks it up and makes it look more like a piece of film: a little bit of chromatic aberration, a glint on the highlights”. [20] The film features “simulated film grain and the lens flares of the anamorphic lenses used for super wide-screen ratios”.¹⁶ [21] One other aspect that approximates the approach to *Rango*'s cinematography to that of live-action filming is the work of cinematographer Roger Deakins as a consultant, whose role is, in his own words, “to make the animated film that they're working on look like live-action.” [22]

In Pixar's most recent films, and as digital imaging technology advances, the tendency has come to be not to render images according to the principles of how a lens and camera work, but to model the lenses and cameras used on concrete, actual lenses and cameras. The most commonly reason given by artists and technicians for such a choice is realism. Despite featuring highly stylised animal characters, like talking fish and other sea creatures with various given human attributes, several aspects of the film *Finding Dory* (2016) have been described as realistic, and amongst those, its cinematography and rendering of the underwater environments: the film-makers who “had to select cameras and lenses to mimic in order to make

¹⁵ in a live action scenario these would typically feature shallower depth of field from to using larger apertures due to less available light;

¹⁶ however, a major visual influences for *Rango*, Sergio Leone's Spaghetti Westerns, were not shot with anamorphic lenses despite widescreen and anamorphic processing. These films were shot on a format - Techniscope (2-perf) - which uses spherical lenses. [24]

the film look realistic.” [23] The Pixar short film that precedes *Finding Dory* in theatres, *Piper* (2016), was again lauded by its realism despite featuring heavily stylised bird characters that are also not anthropomorphised but display a human-like range of emotions. Piper’s director Alan Barillaro states that “computers are getting to that place where, like a live action director, you can make a specific lens choice to your own taste, and a filter, and all of a sudden have a style that’s unique to you.” [25]



Fig. 5 Rango (2011)

Fig. 6 Piper (2011)

Conclusion

Being relatively recent, the computer rendered image, as well as all the changes brought about by digital film production, might create a somewhat hostile response from the viewer, as technical *disruptions* tend to do - the introduction of sound, colour and recently high frame rates have had this same sort of response. [26] Whereas there is no doubt about the takeover of digital techniques over the analogue and traditional ones in (at least in mainstream) film production, many features of digital images are shunned by filmmakers, film-goers and film critics alike. Film stock, for example, has evolved from coarser to finer grain and digital capture - as well as CG - creates grainless images which are in many ways the definitive ideal of such evolution. *Unnatural*, however, is still (after more than two decades of generalised professional digital image capture and creation) a commonly used word to refer to the clarity of digital images. [27]

The traditional film theory idea of realism, as posed by Bazin and briefly mentioned above, is that of the closest possible relationship of the filmed image to human perception. Hence, when speaking of *realism* in digital imagery and in animation in particular - a concept so many animators and filmmakers mention when talking about the emulation of traditional image capture - one finds the strictly traditional film theory concept of “realism” cannot apply, as most of what is built and rendered in a computer lacks a (direct) real-world referent - or are distorted to the point of detaching from their referent.

Professor Stephen Prince discusses *Jurassic Park* (1993) and the watery-creature from *The Abyss* (1989), among other works of CG, in an 1996 essay, stating that the realism of CG imagery (creatures, characters and otherwise) can only be perceptual, when corresponding to the experiences and expectations of the viewer - when the virtual objects move as a similar object would move, reacts to light as it would in the real world and so on. These anchors “[enable] viewers to correlate those images with their own spatio-

temporal experience, even when the digitally processed image fails in other ways to obey the experience (...). Satisfying the viewer's demand for reference permits, in turn, patterned or stylish deviations from the norm." [28]

All the aspects of traditional cinematography brought to CG imagery discussed here can do little to anchor scenes depicted in animated films to reality, but can maybe evoke *film image* itself, lending a sort of familiarity or habituation to this new type of image. The emulation of the grain produced specifically by a batch of a certain brand of film stock can do nothing to approximate the viewer's experience of seeing a film to that of perceiving the real world, but it might make that image correspond to their references of film-going. The heightened sense of realism given by emulating these aspects mechanically/traditionally capturing an image comes, then, from the rendered frame bearing resemblance to *other* cinema frames.

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