

The Shadow Protocol

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'All this may have had something to do with Leonardo da Vinci and others sometimes being led to wonder whether shadow might be not just a local negative of light but an active opponent of light, radiating from denseness as light radiates from a light source' (Baxandall 1995: 44).

The rewriting of the past is dynamic, oriented towards the future. Its role is to endow the present with meaning by offering a focus of desire to a community with reason to doubt its future' (Debray 29)

Rafel Lozano-Hemmer's *Body Movies (Relational Architecture #6)* comprises hundreds of photographic portraits projected into open urban space, triggered to appear in the shadows cast by visitors as they pass in front of powerful lamps illuminating the plaza. These shadows, which can be twenty-five metres tall, encourage interactions between visitors, and between visitors and people recorded passing through the same streets during the run-up to the show. The relational architecture is obviously crucial to the work, its true content, but the technique is what interests me here. I don't want to stress the quasi-cinematic aspects of the piece either, although it would be quite simple to trace the art of moving images back to shadow hand-puppetry round the campfires of our first ancestors. What is so intriguing about these shadows is their content, or rather the fact that they have content.

I begin here, even though I want to end with a possibly banal comment on shadow colour in computer-generated imaging, because Lozano-Hemmer seems to move in the opposite direction to the historical trajectory I want to trace. I will argue that something has happened to the depiction of shadow in the period since the late middle ages, or rather two things have happened. The first is a move towards geometric understandings; the second towards an arithmetic of shadow. I refer to these (and their predecessors) as 'protocols' because they are not so much impositions of rule but compromises, agreements on how to proceed, and guidelines with a degree of free play allowable. That they are not absolute, and that they apply to the depiction but not necessarily the

production of shadows, is clear from the example of *Body Movies*. This distinction is important in the history of light, where it is all too easy to mistake the representation of light (in terms of hue, reflectance, texture and brightness for example) for its production (fireworks, projection, fluorescence etcetera). Shadow is not the opposite of light but a complement. Shadow in representational images adds depth to surfaces, creates space by insinuating that one thing is in front of, above, below or beside another. The creation of optical space has become integral to our aesthetic appreciation of both pictures and the world. If there has been a shift from geometric to arithmetic space, that would be a major change in the aesthetic. It would be good to know how and why it occurred. But the first question is, has it occurred?

When Lozano-Hemmer documented his 2001 installation of *Body Movies* in Rotterdam, he included a curious artefact of the Dutch baroque, a shadow theatre designed and illustrated by Samuel van Hoogstraten (1627-1678) in a print called *The Shadow Dance* engraved in Rotterdam in 1678, the last year of his life. Hoogstraten, a pupil of Rembrandt's, began working in the mode of his master, visible even in later canvases like the *Annunciation of the Death of the Virgin* of about 1670, now in the collection of the Metropolitan Museum. Here one of the more delightful aspects for the connoisseur of Dutch love affair with the *memento mori* is the shadow cast by the angelic emissary's hand over the clouds that swirl around him. The shadow is of course the shadow of death. Unusually, the shadow falls on the cloud rather than on the pale and resigned Virgin. It is a virtuoso touch. The light, white as heaven, careens in from the left of the frame, casting another shadow by the angel's face onto his wing, and from his other arm onto the cloud, where the cloud merges first with what appears to be a stormy sky, but which then blends into the dark wall of the room where the visitation takes place. The same light picks out the outline of the Virgin's bended knee, as if with backlight, so that she is propelled forward in the picture's space, explaining why the shadow on her neck and most advanced shoulder do not match the structure of the light around the angel.

But this is probably not the Hoogstraten that is most frequently recalled. Instead, we remember him as the artist who constructed the delightful little perspective peep-show box in the National Gallery in London. Here the structure of the elaborate space and its inhabitants requires an equally elaborate play of light and shadow, but even this doesn't quite lead us to the intrigue of shadow as Hoogstraten developed it most fully, as the painter of illusionistic still lifes, like the *Trompe L'Oeil of Objects Attached to a Letter Rack*

of 1664 from the Dordrechts Museum. Here the achievement is to make the objects stand proud of the picture plane by a judicious use of techniques rather similar to those which lift the Virgin in front of the angel in the Metropolitan *Annunciation*. Here the light falls directly from above, highlighting the topmost edges of the depicted objects, and casting their lower edges into stark shadow: the crumpled pages of the notebook, the scrolled sheets of paper, the teeth of the comb, highlights on the silver surfaces and the plunge of the scissor blades and the point of the pen into darkness. Perhaps most fascinating in this *jeu d'esprit* is that, unlike the *Annunciation*, the shadow no longer has any allegorical significance. It is completely devoted to the replication of appearance, and to the power of technique to produce illusion. That these are the possessions of a wealthy person, and one probably involved in business, is almost incidental. The gold medallion seems as contingent as the gleaming sealing wax. The pairing of highlight and shadow in a regular projective geometry which coheres throughout the assemblage of artefacts is the point. Such coherence is general to the shadow protocols of modernity.

In the different modes of shadow in the *Annunciation* and the *Trompe L'Oeil* we see a moment of transition from an older to a newer theory of shadow. The old involves the mystery of shadow, shadow as emanation, the shadow of the Lord, or the shadow of St Peter healing the beggar in the fresco by Masaccio in the Brancacci Chapel in Florence, commented on by Stoichita in perhaps the best known book on the subject. In such moments, shadow acts as an intangible influence, or influence of something intangible, on the physical world. It has an allegorical function, and operates in a hierarchical grammar of allegory dominated by the semantic dimension of whatever is imaged. In the newer form, shadow is an expression of space, a geometrical formation, whose function is to give body to flat surfaces and to persuade us of two separate things: first, the existence of the object; second, the skill of the artist. The clash of these two models is especially clear in two panels by Fra Lippo Lippi, who completed the decoration of the Brancacci chapel after Masaccio's untimely demise. In the left panel of Lippi's dyptich of the *Annunciation* now in the Frick Collection in New York, the angel's shadow on the ground demonstrates his physical presence in the scene, emphasising the nature of the angelic, a messenger between worlds, capable of inhabiting both, and therefore of fully physical embodiment. In the right hand panel, we see the Virgin at the moment of conception, the Holy Spirit in the form of a dove murmuring in her ear. Here is the canonical passage in the Gospel of St Luke, Chapter 1 (KJV).

³⁴Then said Mary unto the angel, How shall this be, seeing I know not a man?

³⁵And the angel answered and said unto her, The Holy Ghost shall come upon thee, and the power of the Highest shall overshadow thee: therefore also that holy thing which shall be born of thee shall be called the Son of God.

Stoichita recommends a triple reading of the Greek *episkiazein* (*obumbrare* in Latin) as a) the magical power of shadow, as in Masaccio's St Peter b) shadowing as taking under one's wing for protection and c) the shadow as a mode of image-making, in a tradition which goes at least as far back as Plato's parable of the cave in the *Republic* (Stoichita 67-8). Gombrich (1995: 19) mentions that 'the Greek term for illusionistic painting was *skiagraphia*, shadow painting, though it is hard to decide whether the term implied the actual rendering of shadows or merely the use of light and shade for the purpose of modelling'. There may never have been a clear distinction between those meanings, especially in light of the well-known tale from Pliny about the origins of painting in the tracing of a profile cast on the wall by firelight. We should recall that Luke's Gospel was written in Greek, and he was of course the patron saint of painters, often portrayed taking a portrait of the Virgin Mary. Shadowing in the Gospel is not so much a metaphor for the act of love as it is an extrapolation from both the Graeco-Roman tradition of the shadow (and the reflection) as simulacral representation and from the Hebrew tradition according to which God made man 'in his own image'.

The mystical tradition had already begun to meet its more observational complement in the 15th century. By the time Leonardo set out to describe shadow in the *Notebooks*, the mystical had given way entirely to a balance between observation and craft:

Shadow is the obstruction of light. Shadows appear to me to be of supreme importance in perspective, because, without them opaque and solid bodies will be ill defined; that which is contained within their outlines and their boundaries themselves will be ill-understood unless they are shown against a background of a different tone from themselves. And therefore in my first proposition concerning shadow I state that every opaque body is surrounded and its whole surface enveloped in shadow

and light. . . . Besides this, shadows have in themselves various degrees of darkness, because they are caused by the absence of a variable amount of the luminous rays; and these I call Primary shadows because they are the first, and inseparable from the object to which they belong. . . . From these primary shadows there result certain shaded rays which are diffused through the atmosphere and these vary in character according to that of the primary shadows whence they are derived. I shall therefore call these shadows Derived shadows because they are produced by other shadows . . . Again these derived shadows, where they are intercepted by various objects, produce effects as various as the places where they are cast . . . And since all round the derived shadows, where the derived shadows are intercepted, there is always a space where the light falls and by reflected dispersion is thrown back towards its cause, it meets the original shadow and mingles with it and modifies it somewhat in its nature (Leonardo 1888; ch 111)

This newly scientific conception of shadow is notably geometric. Leonardo introduces it as an element of the art of perspective and, as in the case of Hoogstraten, shadow is prized for providing both volume and mass to depicted objects. In this respect, shadow is separable from and perhaps predates perspective as a means towards the construction of space. Leonardo's observational mode also informs the geometry analysed by Baxandall in his painstaking dissection of Enlightenment shadow. Baxandall discriminates between modes of shadow in relation to Leonardo's schematic from the Codex Urbinas Latinus:

The three sorts of shadow . . . are usually called cast shadow, attached shadow and shading respectively . . . In the case of the first sort of shadow. That which is caused by a solid intervening between a surface and the light source (as by a nose preventing light from reaching an upper lip) the term *projected* shadow will be used; and when a projected shadow is thrown on a differentiable surface, it may still surely be described as *cast*. In the case of the second sort of shadow, on surfaces which face away from the light (like the under part of the nose), the best term will be *self-shadow*, which is the term used in computer vision studies. As for shading, the word is much too generally current not to use, and if there is a danger of ambiguity, it can be qualified as *slant/tilt shading*, slant being angle on the vertical axis and tilt being angle on the horizontal axis (Baxandall 3-4).

This taxonomising of shadow is typical of the Enlightenment. Gombrich cites, in his frontispiece, the following passage from 1681:

“By **shadow** (*ombra*) is meant that which a body creates on itself, as for instance a sphere that has light on one part and gradually becomes half light and half dark, and that dark part is described as shadow (*penumbra*). **Half-shadow** (*mezz'ombra*) is called that area that is between light and the shadow through which the one passes to the other, as we have said, gradually diminishing little by little according to the roundness of the object. **Cast shadow** (*sbattimento*) is the shadow that is caused on the ground or elsewhere by the depicted object . . .” – After Filippo Baldinucci, *Vocabulario Toscana dell'Arte del Disegno*, Florence 1681. Cited in Gombrich 1995).

Baldinucci's explanation, like Leonardo's compounds two modes of shadow. Leonardo had written that "without them opaque and solid bodies will be ill defined; that which is contained within their outlines and their boundaries themselves will be ill-understood". There are two functions here: cast shadows places the object in its world; shading, or *mezz'ombra*, provides the artist with a means to render the moulding of surfaces as volume through an emulation of the differential fall of light on them. It provides texture, but also protuberances and dips: volume.

The subtleties opened up by the combination of observation with taxonomy are further explored in Leonardo's *Treatise on Painting*, where he notes that

Light too conspicuously cut off by shadows is exceedingly disapproved of by painters. Hence, to avoid such awkwardness when you depict bodies in open country, do not make your figures appear illuminated by the sun, but contrive a certain amount of mist or of transparent cloud to be placed between the object and the sun and thus – since the object is not harshly illuminated by the sun – the outlines of the shadows will not clash with the outlines of the lights” (Leonardo 1956; cited in Gombrich 1995: 20)

Such penumbral effects bring us to the colour of shadows. Returning to Leonardo's notebooks, and the continuation of his introduction to the topic of shadows, we come across one of the first mentions of shadow having colour other than the gray to which

Ariostotle (REF) had assigned it, and which worked so powerfully in late mediaeval and Northern renaissance *grisailles*:

I will investigate the many and various diversities of reflections resulting from these rays which will modify the original [shadow] by [imparting] some of the various colours from the different objects whence these reflected rays are derived. Again, the seventh Book will treat of the various distances that may exist between the spot where the reflected rays fall and that where they originate, and the various shades of colour which they will acquire in falling on opaque bodies (Leonardo 1888; ch 111)

Shadow colour adds a new quality to the uses of shadow in art. Attached shadow gives mass and texture; cast shadow gives volume and place; we can see these activities in two paintings separated by a scant 17 years and a few hundred kilometres (although also by the enmity of British and Spanish courts), Holbein's 1538 portrait of Christina of Denmark, which includes the shadow 'cast' by the picture frame, and Moroni's *Portrait of a Gentleman*, dated between 1555 and 1560, which combines mezz'ombra with cast shadow. It's clear that in both, shadow is quite simply grey, and serves to enhance the outline of the figure, softening the distinction between figure and ground while propelling the figure forward, and providing a sense of presence.

Shadow colour introduces a new understanding: an address to the specific illumination filling the space. Leonardo had been among those who noticed that shadows have their own colours. A particular example observed by Buffon and mentioned subsequently by others is the blue tint of shadows cast at dawn or sunset, an observation which would pass through von Guericke to Edward Land. Here is Leonardo's account of it from the *Treatise*:

'The shadows of things coming from the red of a setting sun near the horizon will always be blued; this happens because the surface of any opaque body has the colour of the body that lights it. Now, the white of the wall being altogether without colour, it takes the colour of its [illuminating] object – that is to say, of the sun and of the sky. And because towards evening the sun is a reddish colour and the sky appears blue, and because the parts of the wall where the shadow is are not open to the sun, since no luminous body has ever penetrated to the shadow of the body that it illuminates, so the [parts of the] wall the sun does not shine on at all

are open to the sky; the shadow projected on the white wall, being derived from the sky, will be of a blue colour, and the area surrounding the shadow being lit from the sun, whose colour is reddish, will share in this red colour' (cited in Baxandall).

It's notable that Leonardo's account is wholly physical, and close enough to the later scientific theses of Rayleigh scattering (bound by the observation that when light is scattered by its passage through the atmosphere, red and green wavelengths are more typically absorbed than blue) or Mie Theory (solutions to Maxwell's equations for the scattering of light of various wavelengths from variously sized spheres). At the same time, Leonardo's language remains bound into the geometry of projection, with no space as yet for later scientific quantisation and calculation. But before such arithmetical solutions of shadow and shadow colour could be formulated, alternative psychological theories were in circulation, based on either perceived contrast or the principle of colour constancy (according to which when a subject 'knows' the colour of an object, she corrects the perceived colour to match the known colour - presumed to be its colour in direct or diffused sunlight). These psychological explanations, already widely circulated in the 18th century, would be of great significance to the development of colour theory, especially in the famous 1931 meeting of the Commission Internationale de l'Eclairage, where the incompatible physical and psychological approaches found at last a working method to establishing colour norms. Baxandall comments 'The tension still exists: if one looks up 'Shadows, coloured' in modern handbooks on vision, some may refer briefly to Rayleigh atmospheric scattering, others just as briefly to colour constancy, but I have never yet found both. It would be to mix genres.' (Baxandall 1995: 117).

The genealogy of shadow colour ought, perhaps, to be a simple trajectory, but the taxonomy of observation and its geometrical regularisation would hit an unusual byway in the late 18th century through the work of Johann Kaspar Lavater. The idea that a person's face betrayed their character was scarcely new (Lavater himself credits Gianbattista della Porta and Sir Thomas Browne as predecessors). What was new, and what grabbed the popular imagination of the last years of the 18th century, was the technique of taking silhouettes. A literalisation of *skiagraphia*, the silhouette demanded a rigidly unmoving sitter and a deft artisan. but the results were a hit entertainment in an age of scientific demonstrations. More than that, they move in exactly the opposite direction to the subjectivist, psychological account of shadow that began to emerge in the same century.

Rather than engage in the subjectivity adumbrated in psychological accounts of shadow colour, Lavater derived subjectivity itself from the shadow profile. As he wrote in the *Essays on Physiognomy* of 1778

“I have collected more physiognomical knowledge from shades alone than from every other kind of portrait, have improved physiognomical sensation more by the sight of them, than by the contemplation of ever mutable nature.

Shades collect the distracted attention, confine it to an outline, and thus render the observation more simple, easy, and precise. The observation, consequently the comparison.

Physiognomy has no greater, more incontrovertible certainty of the truth of its object than that imparted by shade.’ (cited in Stoichita 1997: 157)

Referencing the idea that 'Few functions of cast shadow are more vital than the possibility of enhancing the impression of light' (Gombrich 1995: 42) and that 'Not only the shape but also the outer limits of the shadows and their colour can convey to us the character of the illuminating light' (Gombrich 1995: 47), Gombrich notes a further function of shadow: to adumbrate the existence of objects beyond the frame, citing Emanuel de Witte's *Interior of the Oude Kerk* from about 1660. de Witte's painting gives us a compendium of attached and cast shadows, penumbra and shadow colours, volume and weight, texture and moulding: a production of space in and off frame. All of these are sacrificed in Lavater's instrumentalisation of shadow.

Lavater notes the comparison as the second step from observation. This is still a taxonomic trajectory, but it takes a different direction to that pursued by Leonardo's heirs. In Lavater, the inward life – the soul embodied as shadow, as in the parable of Peter Schemihl's pact with the Devil, or indeed the Vampire's lack of a reflection – is brought to perfect exteriority. It might be seen as the beginning of behaviourism, a world without intentions (and to that extent without ethics) created by light (and to that extent wholly aesthetic, and thus too a key moment in the division between ethics and aesthetics. Lavater's silhouettes must be placed in the history of surveillance and related to photographic portraiture (especially that moment of stillness required by early plate photography hymned by Benjamin in the *Short History of Photography*), and to that extent placed in the history of discipline as a new regime of power. For the purposes of this enquiry, however, what is significant is their resolute flatness, a trait which opens them to

the purely planar transformations of shearing which delighted 19th century physiognomic eugenicists. This planar quality, the exclusion of moulding and depth, repurposes shadow as shallowness, in an exchange where the definitionally ephemeral shadow is fixed in time at the cost of its depth, texture and colour.

Lavater certainly presses for rule by norm, referencing his profile of the Belvedere Apollo as the perfect profile. But this norm is presented as scientific, as a knowledge rather than a judgement, and so a disavowal (*Verneinung*) of ethics or character as a question of autonomous intention. Its correlate is a spartan, neoclassicist (Apollonian) aesthetic reduced to outline and fill, something that would still haunt Mickey Mouse's ears 150 years later.

Lost in this process is the penumbra, and the actual shear of shadow cast on an unsmooth surface. In Lavater's apparatus, the perfection of projection is the loss of specificity (something that might be said of all four-square projection subsequently, especially where projection involves the use of tab curtains, blacked frames round cinema screens, and the anti-keystoning settings of contemporary digital projectors. This presumption of flatness and the plane should be distinguished from the *Wayang Kulit* shadow puppetry of Malaysia and Indonesia. In their stillness, abstraction and identificatory discipline, Lavater's silhouettes are as resolutely secular as those were divine. Even as mementos of the deceased, silhouettes belong to the secularisation of the afterlife. In *Wayang Kulit* the passage between flat and round is that between noumenal and phenomenal worlds: in Lavater there is only the phenomenal. As phenomenon, the profile provides a judgement which is no longer intuitive (or for that matter judgemental), a judgement ready to be automated. That we no longer believe in character types is incidental. This is the nascent moment of a far more credible credulity, belief in congenital destiny, whose most recent avatar is genetic necessity. Like Lavater's characterology, our genetic typology, as rigid and magical as astrology, relieves us of the unpleasant job of being free.

This is the place Lavater has in the history of shadow: more even than Schenihl's Devil, Lavater steals the shadow that otherwise proves our weight and volume, dematerialises it, makes us abstract, weightless, paper-thin and planar. Unlike photography, silhouettes do not permit of the accidents of light, the contingency of being in the world. These are shadows without mass or the memory of mass. Lavater's shadows are vital to the history of shadow, however, not only because of their articulation with the world of discipline, but

because they instigate shadows as pure surface, and as detachable from their objects. It is on this condition that shadow will have one of its key operations in digital technology, the construction of volume through layers.

That the mystical shadow can no longer be deployed in the era that follows both the geometricisation exercised by Leonardo and the disciplining operated by Lavater is clear from Holman Hunt's *Shadow of Death* of 1881: a painting which is wholly sentimental. Intended as spiritual, it is merely melodramatic (at least as far as the motif goes): stagey, and to that extent irresponsible. It is impossible to go backwards in history. Photography especially, and to some extent 20th century painting, return to the crispness and texture of shadow, make shadow play as atmosphere and omen, surrealism and naturalism. Many of these new techniques belong to the psychology of shadow, exteriorisations of inward states. The dialectic of psychological and physical optics remains in place, and its technology is still fundamentally geometric in the period of the historical avant-gardes. The exception is the Impressionists' discovery of shadow colour. In the words of Renoir, "No shadow is black. It always has a color. Nature knows only colors ... white and black are not colors." The theory of complementary colours made violet, the complement of sunlight's yellow, the natural for shadow (a colour which was also intensely new since Perkins' invention of aniline mauve, though they more typically used manganese and cobalt violet pigments). And yet even the Impressionists are caught in the dialectic which stems from Goethe's dispute with Newton: are colours out there, physical realities, or are they the impression of physical events on the eye and the mind that perceives them? One way or another (a theme to be pursued in forthcoming research), the idea of shadow colour was at once assimilated into the standard handbooks on painting and optics and yet half-forgotten in the mechanisation of image-making.

What happens in the late 1980s is exemplary (even though some of its genealogy can be traced back through the history of halftone, photolithography and electronic transmission). Thomas Knoll's decision, during 1987-8, to upgrade his 'Display' program from greyscale to full-on image editing software was the birth of Adobe Photoshop. Though the most recent releases incorporate some vector functions, Photoshop is basically a bitmap program, manipulating pixels in a raster array. Under the Filter menu, Photoshop includes a number of sub-routines which apply arithmetic rules ('convolutions') to designated areas of the image such as edges (described numerically as zones of significant difference between numerically-defined colours). The simplest way to understand its operation is to

build a new filter using Photoshop's Filter>Other>Custom command. This displays a 5x5 matrix of cells, the central cell of which represents the currently selected pixel and those surrounding it. Positive or negative integers entered in adjacent cells are used as multipliers of the cell's value, either its hexadecimal colour reference or its address, mapping the pixel to a new destination. Among these functions, nested in the Layers menu, is the Drop Shadow. This tool takes a shape (for example a line of type), displaces it, magnifies or diminishes it, and applies randomising noise to emulate penumbral effects. Like all Photoshop effects, Drop Shadow has a default configuration whose parameters can be manipulated by the user, and combined with other effects.

Characteristic of Photoshop is the use of layers. Here is where Lavater's detour in the history of shadow rejoins the mainstream. Layers deploy the depth illusions available for some considerable time in the theatre through the use of flats, and in cinema through matte painting. Layers emulate space by a similar manipulation to that first registered in 1914-15 by Bray Studios, Earl Hurd and Raoul Barré for separating background, midground and foreground in animation production. These simple devices, especially when rolled at different speeds to produce a primitive parallax effect, produced a simple cartoon of depth. This is the secret of Photoshop, and is integral to the layering of elements in digital composites.

The final battle of Pelennor Fields in *The Lord of the Rings: The Return of the King* provides a clear example of the problems this can produce, and the typical fixes used. Here the massive oliphaunts charge into a hurtling crowd of soldiers, the foreground extras, and in the background generated through Weta's proprietary *Massive* crowd-generating software. The live action sequence has been carefully matched to selected library footage in the digital cyclorama backdrops for the time of day. The sun's angle above the horizon has then been typed into the 3D software to produce the attached shadows on the undersides of the digital beasts. Far more problematic would be the cast shadows, especially as the animals are in motion over photographed physical locations. The solution here, as in many shots of the Ringwraith's horses, is to fox the ground by covering it in action: here soldiers, elsewhere the spray from rivers or dust of roads. In movies, parallax provides the sense of depth rather than cast shadow or, for that matter, perspective.

Such problems arise because of the arithmetic construction of shadow. Photoshop and the Adobe/Macromedia suite apply a global light to a specific image or sequence, and

maintains it through the workflow engines which are the suites strongest claim to industry domination. Both colour and direction are maintained across different layers, and through work processes that might lead from vector graphic to bitmap to compositing and output as finished high-definition sequence. This consistency helps verisimilitude, but rarely accommodates the influence of illumination on shadow colour. To gain shadow colour, it is more common to work through 3D graphics. Today the industry is dominated by the suite gathered during a 2006 buying spree aimed at broadening the range of offerings from Autodesk, world market leader in computer-aided design and manufacture (CAD/CAM) and architectural software. Adding industry leading 3D imaging software Maya, Softimage, 3ds Max and the Discreet suite of effects, editing and compositing as well as workflow tools, Autodesk's Montreal-based Media and Entertainment division is only challenged by the open source freeware Blender, also now widely used in Linux-based systems employed in the effects industry (Discreet's Inferno has recently also been migrated to Linux).

One of the crucial things to note about 3D imaging software is that, while there are industry leaders, there is no dominant product. Autodesk's acquisitions may have placed it extremely well to dominate, but there remains a crucial problem. Every film seems to throw up a specific problem and specific solutions. Every effects house seems ready to develop new plug-ins and algorithms to enhance the off-the-shelf products, and in many cases are able to either patent them, sell them on, or make them a house speciality (like Rhythm 'n' Hues' well-known fur algorithm). Local houses in Melbourne and Adelaide, for example, developed their own algorithms for spiderwebs and eyes when working on *Charlotte's Web*. A spectacular example is the 'grooming' system developed in-house at Weta for *King Kong*, where the scale of Kong is so large, and the number of shots (856) so great that the internal shadows of the fur needed to be built in. Not only does Kong's fur have clumps and knots, but the follicles themselves, grown individually during the render process, are not only matched to the overall geometry of the body but 'The shader also accounted for the absorption of light through the volume of the fur, which due to Kong's size has a significant effect, by modifying deep shadowmaps to include the effect of inter-hair light transport.' (Preston and Hioll 2006). The effects of internal reflections have been accommodated into 3D animation for many years, as have shading algorithms such as Phong shading (which however presumes a smoothly-varying, surface-normal vector).

Cast shadow however still remains a problem, somewhat more apparent in pure digital animation. In Pixar's *cars*, for example, in many scenes the light sources have been calculated in order to give a realistic tint to cast shadows under the bodies of the cars, with blue preponderating for the desert daytime sunlight. The animators also add extra shadow for the deeper shadow under the cars, for example where a tyre interrupts reflected light from the landscape. But (so far as my investigations have taken me to date), the common default is to apply gray shadow with no hue over colour-constant surfaces where the shadow falls, as in this interior shot from Pixar's *Up*. Here attached shadows and highlights are meticulously rendered, for example on the back of the head, in the curtains, and on the artefacts to the right of the open door. Yet the cast shadow of the central character is without tonal value. As an interim proposition, it seems that shadow colour is still impressionistic, and has to be added by hand or by additional plug-ins. Most of the available guides that mention shadow colour at all recommend home-made, bricolage remedies for a lack in the systems (although there appears to be a group working on the problem in Blender).

In the transition to digital media, there has been an unsurprisingly common move towards calculation, and to the kind of arithmetic procedures deployed in Photoshop filters. The continuing innovations and lack of standardisation on 3D animation seem to have precluded completing any such a project in 3D software. At the same time, the default shadow colour – grey – indicates that even in an era of increased complexity, cheap processing and memory, and fast rendering, shadow colour has not been developed to the extent that it was in the previous, geometric era. This may indeed be a problem with the late development of vector graphics, after a period in which bitmap appeared to rule the roost in digital imaging. It may also be a function of the sheer success of vector animation, whose very lack of verisimilitude, like that of older cartoon films, contributes to their allure. What is lost in the gradual arithmeticisation is the continuity of space, sacrificed to the layering and compositing required to build complex scenes. Shadow colour belongs to complex inter-relations in space, and while some of these (like reflections) are incorporated in programs like Maya, shadow colour would appear for now to be *too* complex. This in itself is not simply a challenge of computing muscle or even of finding the right fix. It concerns a reconceptualisation of space neither as the geometric given of a Kantian *a priori*, nor as the assemblage of discontinuous layers, but as an ongoing process of production as envisaged, for urban geography, by Lefebvre (1991). The current weakness of shadow colour in pre-packaged programs has encouraged bricoleurs in the

industry,. But their solutions are still grounded in the unresolved dialectic of physical and psychological colour. Lozano-Hemmer's installation indicates in its detour from this history something of what remains to be achieved in this area of digital light: a socialised production of space as a complex network of agents which do not occupy space but generate it through their interactions. The separation of physical and psychological 'genres' of explication and technique rests on a separation between human actors and non-human objects or laws. The production of space which would be required for a fully functioning shadow colour space implicitly requires breaking down the bias against crediting agency to non-human actors, specifically in the production of space. In the age of quantum light, this is surely not too hard technically. But it requires a reorientation of deep cultural biases that may be too deep for a quick fix.

REFERENCES

- Baxandall, Michael (1995), Shadows and Enlightenment, Yale University Press, New Haven.
- Gombrich, E.H. (1995), Shadows: The Depiction of Cast Shadows in Western Art, A companion volume to an exhibition at the National Gallery, National Gallery Publications, London; Yale University Press, New Haven
- Lefebvre, Henri (1991), The Production of Space, trans Donald Nicholson-Smith, Blackwell, Oxford.
- Leonardo da Vinci (1888), The Notebooks of Leonardo Da Vinci Volume 1, Translated by Jean Paul Richter, Project Gutenberg: <http://www.gutenberg.org/etext/5000>
- Leonardo da Vinci (1956), Treatise on Painting, ed A Philip McMahon, Princeton University Press, Princeton, 70
- Preston, Martin and Martin Hill (2006), 'Grooming, animating & rendering fur for "King Kong"', ACM SIGGRAPH 2006 Sketches, ACM, New York.
- Stoichita, Victor I (1997), A Short History of the Shadow, Reaktion Books, London.