The Material Image: Artists' Approaches to Reproducing Texture in Art

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Abstract: Since the introduction of computers, there has been a desire to improve the appearance of computer-generated objects in virtual spaces and to display the objects within complex scenes exactly as they appear in reality. This is a straightforward process for artists who through the medium of paint or silver halide are able to directly observe from nature and interpret and capture the world in a highly convincing way. However for computer-generated images, the process is more complex, computers have no capability to compare whether the rendering looks right or wrong – only humans can make the final subjective decision.

The evolving question is: what are the elements of paintings and drawings produced by artists that capture the qualities, texture, grain, reflection, translucency and absorption of a material, that through the application of coloured brush marks, demonstrate a convincing likeness of the material qualities of e.g. wood, metal, glass and fabric?

This paper considers the relationship between texture, objects and artists' approaches to reproducing texture in art. However texture is problematic as our visual system is able to discriminate the difference between natural and patterned texture, and incorrectly rendered surfaces can hinder understanding. Furthermore to render surfaces with no discernable pattern structure that comprises unlimited variations can result, as demonstrated by the computer-generated rendering, in exceptionally large file sizes. The paper explores the relationship between imaging, artists' approaches to reproducing representations of the attributes of material qualities, the fluid dynamics of a painterly mark, and 2.5D relief in printing. The objective is not to reproduce existing paintings or prints, but to build the surface using a deposition of pigments, paints and inks that explores the relationship between image and surface.

Keywords: Artworks, Texture, Material Reproduction, 2.5D Printing, Material Qualities and Characteristics, Vector

Introduction

Today the field of colour is becoming increasingly more technical and remote from traditional methods of applying colour in the physical world. The way an artist mixes and applies colour is fundamentally different to the digital reproduction of colour and coloured images. An artist's approach to colour painting and printing is concerned with the physical mixing of pigments that are applied as layers of colour, whereas the digital reproduction of colour is reliant on computational colour modelling to provide accurate numerical data for four-colour halftone[1] reproduction. Certainly, many contemporary artists are working with a digital colour palette and are now becoming cognisant in an increasingly technical environment that demands more understanding of different colour spaces, characterisation of printer hardware and paper, and an array of file formats.

The process of colour measurement, colour matching, conversion and reproduction of a colour patch is well known and used for a wide range of commercial and industrial applications. (Judd, 1975; Hunt, 1983; Sharma, 2003) However, smooth and flat colour rarely occurs in the real-world, and by introducing roughness or texture to a colour, then the appearance of a colour and its reflectance values becomes much more complex to measure and to match. For example, a smooth, coloured surface is fairly straightforward to measure under a uniform illumination, but a textile that is woven or is knitted, or a piece of polished wood or quartz marble may be more challenging. These materials may contain many micro-elements, that may be viewed under raking light or complex illumination, will reveal many different angles of reflection and will prove to be more difficult to accurately measure, model and reproduce. This paper attempts to

[1] Halftoning describes a printed image that is made up of a series of small squares and dots, which vary according to the intensity of the tone. The conventional method of halftone screening is one that uses a regular pattern of dots in straight rows or AM (amplitude modulation) screening. The dots are placed at a fixed frequency, with fewer or more dots corresponding to the required level of grey.

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delve deeper beyond *just* colour measurement to consider the perceptual textural attributes underpinning the making of an image.

Texture can be described as the minute structural details that can be perceptually distinguished from one surface property to another. One could consider texture as multisensory, we may only need to look at a surface to gain a quick understanding of its textural properties, but we may need to touch a surface, whilst hearing the sound that is made to reinforce our understanding. *How* we touch a surface may provide further sensory information, such as the vibration made by scratching nails along sandpaper. (Klatsky, 2010). But for the purposes of this investigation, this paper will concentrate on the visual perception of texture, that is generated both through the physical geometry of a painted, printed, or drawn surface, and its relation to the pictorial cues provided through representation. The three main characteristics that have been identified as useful in determining the qualities of a surface texture are: value, repetition and edges, which will be explored later in the paper.

This paper aims to address and compare three sides of a textural coin:

- what are the essential characteristics of real-life texture, and how can these qualities be transcribed into a synthetic world;
- the artist's understanding of materials and textural qualities, and their ability to transcribe their percept into two dimensions e.g. painting and drawing;
- how can physical artworks be created that incorporate both analogue (paint, ink, graphite) and digital (vector) be created that could be described as containing textural or 2.5D qualities? what qualities are lost in translation?

This research is motivated by the physical deposition of viscous inks and paints, by painting and rendering programmes (Ferwarda, 2012) and the need to leverage meaningful interaction between the software, the colour printed output and viscous properties of the medium. The objective is to create a surface topology that incorporates both digital (vectoral paths, computer coding, digital rig) and analogue (drawing tools, brushes and pens, paint and ink). The evolving question is whether images could be created with the benefit of printed texture and during the process of this refinement, what qualities have been lost along the way? This question - what qualities are lost - is certainly at the forefront of the enquiry, and we may begin to answer by comparing an original artwork and it reproduction e.g., a favourite painting in a gallery and its post card reproduction. The reproduction may show a huge range of inaccuracies. Apart from the difference in reduced colour appearance, the reproduction might also appear flat and lacking in textural information, whereby on comparison, the gallery artwork will reveal a rich surface: full of nuances of surface such as texture, brushstrokes and gloss/matt differential. Inspect any painting, drawing or traditional print, and texture is discernable, albeit on a micro scale. Texture in paintings, traditional prints and drawings is generated through the physical relief of brushes, charcoal, pencils and palette knives, or printed surfaces through building and overprinting multiple layers of colour. In artworks, where paint is over-layered onto canvas or paper, the surface has a multidimensional quality the varying translucency and opacity of the marks can be seen, as can the gloss and matte differential between oil on canvas or the fluid dynamics of pigment and watercolour on paper.

Perception of the Textural Image

The field of object perception is well documented both in the sciences and the arts. (Pappas, 2013; Marr 1982; Elkins, 1996; Ramachandran, 2012) Objects, symbols of objects, even highly abstracted, naïve or badly drawn objects can be interpreted as the object it is meant to represent. (Pappas, 2013) Artists have been describing the world through pictorial form for thousands of years, and furthermore, as visitors to galleries or looking through art-books, we are highly tuned to converting flat artworks such as paintings, drawings and photographs into three-dimensional objects in space. (Melcher and Cavanagh, 2010; Gombrich, 1959; Gibson, 1971) Likewise artists are also able to convey the nuances of the surface qualities of an object. They have long been aware of the psychological aspects of the juxtaposition of colour by exploiting optical and visual effects to convey the intrinsic textural qualities of a material. Artists have demonstrated their mastery of texture by juxtaposing velvet with fur, satin alongside stiff silver embroidery, or the dynamic range of reflective surfaces such as pearls, glass and gold.[2] (Bayer, 2004)

The primary question when looking at the relationship between the object and surface is: does this texture look convincing to me? Edward Adelson (2001) highlights the difference between things and stuff, and in order to make objects look convincing, the stuff of things requires closer attention. This does not necessarily mean that more information (or computer power) is required, but a better study of the relationship of things and stuff – between the intrinsic and organic relationship of material and texture.

Since the introduction of computers there has been an interest in the digital modelling of materials for synthesizing realistic images, whereby the colours and the tonal range are computer generated as a numerical model, (Sayim, 2011) which is stored in the computer as an objective description. Surface effects have evolved from limited algorithms to describe limited reflective, smooth surfaces (Phong, 1975) in the 70s, to contemporary approaches that can describe more complex textural rendering such as wood grain and leather. (Filip, 2009) Recent research has investigated volumetric models for accurate modelling of woven fabrics. (Zhao 2012) The objective is to render objects in a way that the human visual system looking at the same scene would perceive it, and can be compared to the artist's approaches to Trompe l'Oeil painting. (Hochberg, 1979; Hollman, 2004) The impact of illumination and inter-reflections are essential features of an accurate and convincing rendering. (Gibson, 1971) However, where objects are viewed or rotated in a virtual space, the material visual properties will also need to change in relation to the illumination and viewing variations. It is necessary therefore to capture all the reflectance of the materials in as wide range of light and camera position combinations as possible. (Filip, 2009)

The digital, or indeed any, rendering of realistic texture is problematic, as our visual system is able to discriminate the difference between natural texture and pattern; incorrectly rendered surfaces can hinder understanding and enjoyment. Natural textures contain a complex geometry, and in order for the overall appearance to be convincing and not perceived as a repeat pattern, there must be a balance of regularity and anisometric synthesis. (Lefebvre, 2006; Hawkins, 1970) A natural texture appears homogeneous but remains random – each element is similar but remains unique. Therefore each of the individual elements is recognizably similar but may differ, for example: in size, colour, distortion, spatial frequency, orientation, or location to the other. Furthermore to render surfaces with no discernable pattern structure that comprises unlimited variations, as demonstrated by the computer-generated rendering, can result in exceptionally large file sizes. (Snider, 1995) All these variables require an incredible amount of processing and methods are being sought to reduce resolution through down-sampling, and based on the photographic methods of antialiasing. (Fenlon, 2014)

The complexity in the creation of a natural textural render (both in virtual and as physical objects) is essentially due to the enormous range of components that are required to incorporate all the nuances of a texture, such as: colour, fibre, grain, reflectance, specularity, weave, hardness, softness, glossiness, fluidity; and as demonstrated in the previous list, the range of descriptive adjectives, cultural and specialist terms that extend these more subtle characteristics of a texture. Furthermore, these multi-variables of textures tend to be stored as a visual taxonomy in the human memory, whereby subtle variations of textures and surfaces can be easily identified and differentiated by our visual memory. In a real world scenario, planed wood can be quickly

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[2] A highly useful resource of world wide art collections and archives, which includes some high resolution images of popular artworks. http://www.google.com/culturalinstitute

distinguished from chipboard or paper (grain, surface, flexibility, colour) and animal fur from human hair (direction, fall, colour, smoothness, curl).

Furthermore, as humans we use highly complex and varied terms to describe the things we see and touch, which are based on our background, age, education and cultural influences. Based on specialist knowledge, a textile designer would quickly be able to differentiate the difference between cotton, poly-cotton, calico, hessian, linen, silk, habutai, organza or chiffon. And through the medium of paint, graphite or silver halide, artists are able to directly observe from nature, interpret and capture the world in a highly convincing way. However in digital technologies, the reproduction of the nuances of texture is a harder task, that firstly, in order to translate between subjective and objective, to extrapolate numerical data from natural objects and present data in a realistic way is still a challenge. Secondly, computers have no capability to compare whether a textural rendering looks right or wrong. Only humans can make the final subjective decision (Adelson, 2001). Thirdly, it is important to have useful data, for example, cameras are able to capture large amounts of pixel information, but if the quality of information is noisy, lacking in detail or definition then the data not useful. Although highly sophisticated mathematical models have been developed to map and model surface qualities of materials, there remains, regions of ambiguity, adjective and comparison, and significant areas for further investigation.

Dürer's Rhinoceros as Metaphor

In 1515, Durer made a drawing based on a description of rhinoceros that had been conveyed to Lisbon…

> ... from India to the great and powerful King Emanuel of Portugal at Lisbon, a live animal called a rhinoceros. His form is here represented. It has the colour of a speckled tortoise and it is covered with thick scales. It is like an elephant in size, but lower on its legs and almost invulnerable. It is also said that the rhinoceros is fast, lively and cunning.

Dürer, living in Nuremberg had never seen a rhinoceros, but appropriated the characteristics from other animals that were pieced together to capture the qualities of his beast, and managed to draw a highly convincing likeness. Dürer transcribed his drawing into a woodblock print. The woodblock process enabled four to five thousand prints to be made, and therefore the image was widely dispersed. This powerful image has become so firmly implanted in our minds, that even today, Dürer's print remains the most go-to image representative of a rhinoceros, even for those who have seen a real rhinoceros, and know that the real animal does not have scales or two horns. (McGregor, 2012)

The metaphor of Durer's rhinoceros can be compared to the current and emerging area of interest in the accurate reproduction and application of texture in additive layer manufacturing (ALM, 2.5D and 3D printing). From a craftsperson or artist's perspective, there is a fundamental lack in the relationship and balance between the tacit knowledge of the maker, their interaction with the digital tools and machines and industrial-based materials (eg. nylon, resins). It could be argued that these materials neither contribute to a textural aesthetic, or even extend material understanding. Furthermore, the user has become reliant only on computer software, and is removed from an interactive engagement with the technology, that by constraining the user to strict machine parameters (set out by the manufacturer), will tend to yield very limited results, that are recognisable as the product of a particular machanical process.

Texture Analysis

Texture is a visual attribute that enables us to distinguish the differences between materials (substances or substance out of which a thing is or is made), identify the structure and shape of objects, and discriminate edges in a complex pictorial scene. In order to gain an understanding of creating a verisimilitude of materials we can study lighting techniques, drawing and painting techniques used by artists (Bayer, 2004; Hollman, 2004; Jordan, 1995; Constable, 2007) alongside scientists working on human vision and texture perception. In order to identify appropriate methods for texture reproduction the three main characteristics that have been identified as useful in determining the qualities of a surface texture are: value, repetition and edges. (Landy, 1996; Klatzky, 2010) The following section includes examples by artists who have explored or exploited these qualities in their work.

Value

Value *or tone* provides important information in determining spatial relationships in a picture through tone and/or colour. It can be used to identify boundaries between objects to infer surface properties, even though they may be very subtle or contain the least amount of detail. Although the print by Joe Tilson (figure 1) lacks all the detailed information on the left side of the image, thus reducing it to a block-like appearance, it still retains its spatial and essential tonal values.

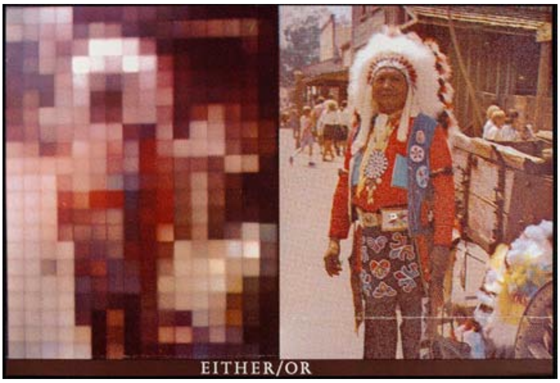

Figure 1: Joe Tilson (born 1928) *N - Nightletter*, from the portfolio A-Z Box... fragments of an oneiric alphabet (1969-1970) Screenprint. Reproduced with permission from DACS

As exampled in the painting by Caravaggio (1571–1610), *Basket of Fruit* (c.1599) in which the fruit are piled loosely on top of each other (http://www.museomilano.it/caravaggio-canestro-di-frutta) even the smallest amount of value can be discriminated. As a study in light and dark (chiaroscuro) the black grapes seem to fuse together but through local contrast are still discernable as individual objects. Albers described these small differences as simultaneous contrast, (Albers, 1963) and is amplified by our visual perception. (figure 8) Value may also provide cues as to its distance relative to other objects, by changing the overall lightness or darkness. This was also understood by Leonardo da Vinci, who describes the use of perspective and depth of field by modulating or diminishing the colour.

Value or tone can be expressed by changing the regularity or thickness of the line as demonstrated by Hendrick Goltzius (1558–1617) who was possibly the first to express tone and surface qualities through an engraved line, and as illustrated in figure 3, by intermixing engraved lines of different thicknesses and varying the modulation of lines to suggest the physical structure and movement of different types of materials. (Hind, 1963)

Figure 3: Hendrick Goltzius (1558–1617) *The Standard Bearer* (1587) Engraving.
Right: detail of the folds of the flag. Reproduced with permission from The British Museum.
Ref number 1853,1008.87AN49184001

The tradition of engraving and etching follows a particular syntax (Ivins, 1969) or language to describe the surface structure that ranges from equally spaced lines to describe smooth surfaces to thickening or diminishing of lines to suggest surface modulations. Halftoning is a well-known and used method of converting a grey scale image into a series of dots relative to the tonal values in the image, that when printed, creates the appearance of a continuous tone image. (Burch, 1983)

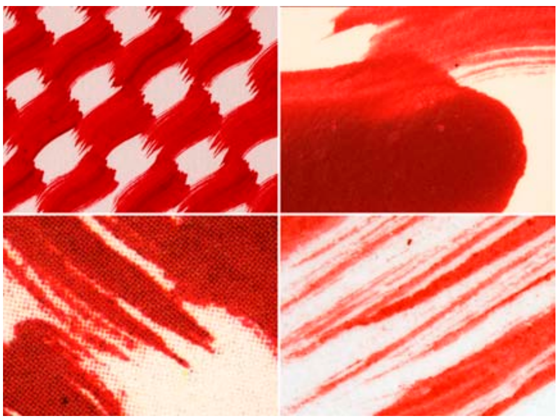

Figure 4: Cadmium red (TL) uniform brush strokes, (TR) brush overloaded with paint, (BR) dry brush, (BL) halftone (TR, BR and BL) at 40x magnification (author's own image)

A full colour image is created by making a colour separation of each colour channel, and then each channel is converted into a grey-scale image. When reprinted using the four process colours will optically mix to appear as a full colour image. On inspection of a print under magnification the dots are still discernable. Compare the same image that is printed, for example, by photocopier, inkjet or offset lithography and the clustering of the dots will appear to be very different; often resulting in very different reproductions. To create a halftone reproduction of the textural and surface qualities of a material also relies on the optical mixture of halftoning. Darker areas of a texture are implied through the use of dense areas of ink or clustering of dots to suggest shadow. White, pale colours or highlights in colour halftoning are achieved by the absence of dots or ink, but to obtain a similar colour in traditional painting, a pale colour is achieved by mixing a hue with white, or applying a thick impasto of white to indicate a highlight. Figure 4 illustrates the difference between a brush stroke, the density of a colour that can be obtained by overloading paint, and how the brush stoke appears under magnification.

Repetition

Repetition or pattern can be described as containing three characteristics:

- where local 'order' is repeated over a region which is large in comparison to the order's size,
- the order consists in the non-random arrangement of elementary parts,
- and the parts are roughly uniform entities having approximately the same dimensions everywhere within the textured region. (Hawkins, 1970)

Patterns also provide three-dimensional information relating to the topology of a shape. Where patterns appear to recede or become smaller or denser assists in reinforcing depth cues, as illustrated in figure 5, Vincent Van Gogh's *Olive Grove* is an interesting example of all these elements. Van Gogh (1853-1890) here has used the same repeated element, but has modulated the depth of field by changing the size, the direction and the colour of the element. This is particularly explicit in the diagonal brushstrokes that describe the receding and undulating mound at the foot of the trees.
http://www.vangoghmuseum.nl/en/collection/s0045V1962

Figure 5: Vincent Van Gogh (1853-1890) *Olive Grove* (1889) Oil on Canvas. Van Gogh Museum, Amsterdam (reproduced with permission Vincent van Gogh Foundation)

Likewise, Diego Velázquez (1599-1660) demonstrated a sophisticated understanding of the appearance and surface characteristics of materials including human skin, fur, metals and textiles. In the painting of St Philip of Spain his highly gestural approach to brushwork, when viewed close up, appears abstract and impressionistic but also appears to coalesce as embroidered silver thread on velvet at a distance, "The degree of understanding of the optical act of viewing had never before been so spectacularly demonstrated". (Keith, 2006) One hypothesis is that he used long handled paintbrushes to create the overall painting, and a short brush to add the highlights and detail. (von Sonnenburg, 1971) http://www.nationalgallery.org.uk/paintings/diego-velazquez-philip-iv-of-spain-in-brown-and-silver

Edges

Edges could be considered as more ambiguous. Although objects in the real world are not defined by an outline, or by contour lines, lines are often used to depict three-dimensional shapes and to define the contours of a surface. Lines are important to the brain as even the simplest of lines can effectively describe an object, its position in space or convey the essence of a material. The paintings by Wayne Thiebaud are interesting examples to such an approach. (Sheets, 2010) He uses lines in a range of ways. He uses lines to define and separate individual elements as exampled in *Three Machines* (1963. Oil on canvas. Fine Arts Museum of San Francisco). Each of the gum-balls is outlined by a colour of complementary contrast, thus increasing the vibrancy of their appearance. The lines both define the outer contour of the balls and increase the spatial relationship of the coloured spheres as they are packed behind, in front, above or below in the confines of the gum ball dome. He has added a dot of white to emphasize their smoothness and the direction of illumination.

In the painting *River Intersection* (2010), Thiebaud uses contour lines as if made by a tractor ploughing the field; that section the picture plane and to create a sense of perspective. Whilst the landscape is not necessarily optically or coloured correctly the viewer can gain a sense of the type of day, the projected shadows, the shadows are interesting in as much that he has generated the painting at different times of the day and therefore the shadows are not consistently pointing in the same direction. Thiebaud uses outlines to define the outer contour of the sections of the fields and increase the spatial relationship of the coloured spaces, where local contrast and simultaneous contrast is used.

The perception of edges across homogenous regions can also be influenced by small variations in value (figure 8). As demonstrated in the enlargement of a leaf lying on top of another leaf, the overall tonal value of the leaves are the same, but where there is a shadow, the left leaf is perceived to be lying on top of the right.

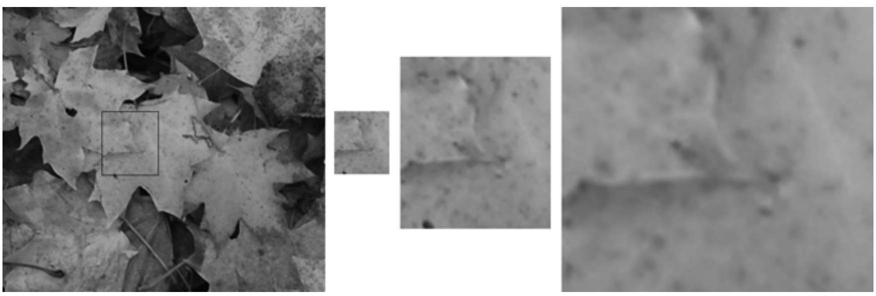

Figure 8: section of two leaves magnified to show similarities of value and that only discreet changes are required to perceive differences (author's own image)

As a contrast to the definite use of an outline, Impressionist artists were accomplished at a loose handling of paint and accented brushstrokes, whereby edges of objects and scenes were implied and not defined. This was brought about by brush strokes used as repeatable elements such as dots, staccato strokes and stipples. Also their interest in scientific colour theories using complementary colour resulted in a shimmering appearance and a reduction in sharpness of detail and texture. (Reutersvärd, 1952)

Printing the Image

Inkjet printing has evolved as a process that is capable of printing flat areas of colour, alongside text, blends of colour, photographic images. In the emerging 2.5D and 3D print market, there is now a requirement to develop methods that can reproduce textures that have the look and feel of, for example, brushstrokes of old master paintings, or create realistic embellishments on photographs. The conflict between texture and image is more apparent where there are contrasts,

edge contours, or attempts are made to distinguish relief from a flat picture plane. The appearance of false shadows and edges tends to amplify these problems.
An artist's approach to creating an image using paint on an iPad and drawing on paper can be loosely divided into digital and analogue methods. By digital methods, we often use terms such as: graphical user interface, tablet, pixels, colour picker tools, imaging, software, vector, raster; and analogue approaches to image making might include: pigments, brushes, fluid dynamics of paint, charcoal, graphite, paper, canvas, materials, texture, embossing, relief. Each approach contains a rich vocabulary of description. In the digital domain, terms are borrowed from photography, painting and craft (burn, dodge, paint, draw, cut, paste) where the digital creator is still emulating the tools of the analogue but through a screen. Whilst painting software such as Sketch Book Pro for iPad, Brushes by Taptrix inc. simulate the appearance of drawn marks and brush strokes, paper and canvas textures, oil or watercolour, these examples highlight opportunities for manipulating virtual paint but do not bridge the gap between virtual and physical output. Similarly, Tangipaint is an interesting touch-screen paint mixing application, developed at RIT that creates the appearance of gloss, wetness and the texture of paint. (Ferwerda, 2012) By *painting* on touch-screen devices or drawing tablets the user can scroll to select colours and brushes and manipulate paint. The assumption is that images remain screen-based or are shared between mobile platforms and again does not provide the file format that can drive a printer directly.

In our search for an identification of what are the basic constituents to identify, classify and reproduce texture, (Marr, 1980) differentiates between image and representation, and the use of what he describes as *primitives* to describe an object's shape. There are two primary classes of shape primitive: surface based (2D) and volumetric (3D) volumetric primitives involve the spatial distribution of a shape and vectors to describe its dimensions, along with shading and texture gradients.

The concept of the texton was presented by Julesz (1981) as a way of describing the individual structural characteristics of a texture. He identified a list of image features including: size, orientation line terminations and line crossings. A brushstroke texton method has also been explored, which creates a representation of the different brushworks in a painting. This approach could be considered by art historians as way of identifying and authenticating artworks through the comparison of brushstrokes. (van der Maaten, 2009; 2010) A voxel is an evolution from a texton, which could be compared to a three-dimensional pixel. (Leung, 2001) But in this context, it could contain the raw materials from which more sophisticated fabricated and controllable products could be obtained. "control over material composition of physical objects opens the door to the next stage, control over the behaviour of physical products'. (Lipson, 2013)

A contemporary digital version is the vector or .SVG (Scalable Vector Graphics) that provides a set of instructions to a drive computer numerically controlled path for lathes plotters and printers. In software programmes, a vector path is a series of elements that describes a set of lines, curves, arcs, and a combination of all to form closed shapes. A path can be *stroked* to obtain different thickness or colours, or used as input for other elements such as pressure, gradients in height, and blends to include opacity and translucency. A vector-based drawing philosophy is significant to gaining an understanding of alternative approaches that breaks away from pixels (digital, screen resolution) and halftones (analogue, print resolution).

Conclusions and Applications

In a previous paper the author considered how by observing the brush strokes of painters, (Parraman, 2012; 2013) the images are generated through the use of lines, modulation of similar strokes and a repetitive over layering of paint. Inspired by the meticulous painting methods by artists such as Van Gogh and Seurat, the objective for the experiment is to create a vector-driven painting machine that applies a brush loaded with paint to paper in a methodical and mechanical way. The difference is that although the vector marks (digital) can be created in the same way, the resulting painted brush strokes (analogue) are not. Based on the placement of the brush on the paper and the flow of paint, that each painted brush stroke is similar but not exactly the same, thus creating a non-uniform but harmonious effect across the paper surface.

A test chart of vector-lines was created in Inkscape where each component can be modified, enlarged, rotated. Other information such as gradients can also be assigned. The test sheet is used to compare the character and behaviour of paints, tools and marks at different flow rates and different methods of application.

The objective is to work towards the application of colour through surface deposition, by which an image is not transferred onto a pre-textured surface, but where texture and colour are integral to the mark, that like a brush, delineates the contours in the image. By re-addressing these historical methods and the ways images were painted, the potential implications for 21st century digital technologies could assist in the development of new rendering methods that incorporate vector and analogue approaches through the over-layering of different colour, pigments and decorative paints.

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