# CPEGs: the aesthetics of digital signal processing in pictorial carpet making practice


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### Abstract

The practice of pictorial carpet making aims to reproduce figurative images in fibrous materials. For contemporary pictorial carpet practice, the range of colour is infinite however the available physical resources in the form of suitable yarn can be problematic. Pictorial carpet-making requires quantising colour into discrete values to build chromatic relationships. In this paper we explore a new 3D carpet previsualisation methodology that leverages digital signal processing approaches to aid in the consolidation of chromatic relationships in the carpet making process.



## Keywords

carpet, pixel, shader, tapestry, jpeg, lossy, tableau, yarnlut


## Introduction

In this paper we will discuss how the characteristics of the JPEG algorithm can provide insights into the variance in chromatic shifts between spectral and physical gamuts. This paper considers how the digital camera system interacts with this process and the ways that the human visual system can be deceived by projected light.

In instances where projections are employed to translate the image to the backing material, the colour is transduced through the RGB gamut and then undergoes additional value shifts as projected light. This introduces further variance to the chromatic relationships and amplifies contrasting tonal characteristics that are less pronounced in the original digital image. Projection is a vital step for many arts practitioners, in the process of translating scale and blocking out the tonal zones; however just as in painting it can be a crutch and lead to many issues in coordinating tonal values.

## Contemporary Carpet Making

In carpet each tuft is defined and follows a gridlike structure. Colour in carpet operates in absolute values which create additional issues in reproducing smooth gradients. By nature the carpet yarn provokes its own set of material nuances whilst interacting with ambient light. Manual carpet making is typically performed with the aid of a tufting gun. A particular advantage of working with a tufting gun is the possibility of utilising multiple colour values in dichromatic and trichromatic combinations of yarn.

A common approach to contemporary pictorial carpet making is to project the digital image to be reproduced onto a loom, where the carpet is tufted. Much as the camera obscura was used in traditional figurative painting, this enables the artist to 'trace' over the projection with a tufting gun. Each application of the tufting gun requires a choice of yarn colours, which will be applied to a contiguous set of loom grid points via a short single continuous motion of the gun.

Our method of mapping the colour introduces a custom digital image filter (implemented as a graphics 'shader') that quantises colours to a fixed set of values based on a sample set of 24 colours. Each pixel has the capacity to be monochromatic, dichromatic, or trichromatic, expressing multiple colours per tuft with up to three possible strands of yarn. The image is mapped to a 3D surface and extruded to account for depth, clumping, and density.

The rest of the paper is structured in the following manner: we discuss how colour is perceived from the camera's perspective, then the metaphorical bit depth of carpet is introduced. An overview of our sample collection methods, image processing pipeline, and carpet pixel shader are covered under the moniker of Yarnluts. The paper concludes with a discussion about the implications of lossy compression in carpet making previsualisation.

## Colour from a camera's perspective

"Color is the visual perception or interpretation of light" [1]. The camera sees and interprets the chromatic information in the optical path through a tri-stimulus system, interpreting hue value and chroma in three channels.

"A CMOS sensor converts the incoming light into three channels (RGB) using a colour filter array (CFA). The most common CFA is the shown Bayer pattern: a green square means that the green color is allowed for this pixel, similarly for the red and blue squares" [1]. The camera software then performs an interpolation method to determine the chromatic relationship between pixels.

"Each pixel captures only one of the three colors, and an interpolation (aka demosaicing) method implemented in hardware is used to estimate the other two"[1].

"Image demosaicing is a problem of interpolating full-resolution color images from so-called color-filter-array (CFA) samples" [2].

This is the fundamental operation where the algorithmic techniques of the camera's software interprets the incoming light. Demosaicing methods include bilinear interpolation, nearest-neighbour interpolation, and more sophisticated algorithms involving edge detection and statistical modelling. The resulting information is recorded as raw uncompressed image data and organised in a raster file format. This is arguably the only stage where the image may be complete however to view the image the data has to be processed.

The raw data is divided into a lattice or grid structure to then apply compression techniques such as the Block-based Discrete Cosine Transform (DCT) used in JPEG compression algorithms. "The DCT can be used to convert the signal (spatial information) into numeric data ("frequency" or "spectral" information) so that the image's information exists in a quantitative form that can be manipulated for compression" [3]. At this stage the blocks of pixels may become more pronounced in the image especially in the gradients and solid colours.

## Metaphorical carpet bit depth

We have been referring to the 'bit-depth' of carpet colouration, which might at first glance seem strange given the physical nature of yarn. However as Cramer [5] points out, 'digital' should not be conflated with 'electronic' or 'computational'. Rather the defining characteristic of digitality is discreteness or quantisation. In digital colour applications, bit-depth refers to the number of discrete colour levels available, expressed as the base-2-logarithm of this number; pertinent because of the binary numeric scheme typically employed to represent them.

A central point of this paper is that carpet makers are restricted in the number of yarns they can practically employ, thus leading to a discrete number of colours possible to use in the carpet. In line with the general tone of this paper, where we are drawing an analogy between digital processing and physical manifestations of discrete colour, and seconding the term bit-depth to apply to the number of yarns available. So, for example, a carpet created with 8 different coloured yarns would have a bit-depth of 3.

Traditional carpets typically have 3-8 different tones, sometimes more, so the bit depth varies between two bits in simple geometric designs and up to three or four bits in more complex ornamental rugs.

## Yarnluts carpet shader

To reproduce the chromatic relationships of a digital image in carpet there are three determinant factors that govern the resulting image

- the hues of yarn
- the scale and height of the tuft
- the configuration of chromatic information

In this paper we are working with the sample size of 24 colours. These samples have uniform specularity and were purchased from an upholstery supplies wholesaler. Each sample weighs between 1.5-4 kilograms and is wrapped around a cardboard tube. These yarn samples were documented with a down-shooter camera setup lit by two panel lights on 90 degree angles. The rolls of yarn vary in dimension and the ambient occlusion of the yarn wrapped over itself creates subtle variation in colour. The perceived colour of yarn changes heavily depending on lighting and orientation.

## Carpet Pixels

Tufts and more traditionally knots are the primary unit of carpet. In traditional weaving knots are woven in horizontal rows and vertically packed with a downward compression. This is in some way consistent with tufting, as vertical rows are more ergonomic. The tufting gun can be used to 'draw' diagonal and horizontal lines, however this can result in unintentional clumping and tension. The tufting gun performs best in short bursts of less than 100 mm. The pneumatic tufting gun is capable of mechanically weaving 40-48 tufts per 100 mm. Each tuft is between 2-3 mm in length, which depends on the number and gauge of yarn used.

## Colour Configuration

In digital signal processing literature there is an abundance of peer-reviewed research around hue reduction and algorithmic methods for optimising colour. However in carpet making there is a prevalence of "manual and experience-based methods for reducing the size and number of hues for making a hand-woven carpet tableau map"[4]. We believe the digital signal processing pipeline can provide insights transferable to color gamut reduction in manual carpet making.

We suggest that image compression algorithms can play an interesting role in carpet making. Through a combined investigation of digital image compression and practice-led carpet making methodology, there is an argument that can be made about the utility of the JPEG not only as an image format but also as a medium of translation and transience.

The verticality and tiling of the colour information in a JPEG is in direct correlation with the ergonomic demands of the tufting gun. The context of the JPEG technological development and historical position predispose it for this research, as it is already there in the imagery.

As carpet is assembled in a gridlike structure as well, this operation helps to accentuate the difference in chromatic values. Lossy compression can greatly enhance the fidelity of translation between digital imagery and carpet. The JPEG compression algorithms themselves greatly contribute to reducing colour depth in smooth gradients and additional aid in flattening solid colours. Aliasing and other digital noise introduced in the compression process can be reproduced in yarn. The specularity, glossiness and contrasting colours of the fibres all play a role in reconstituting the digital image.

## The Carpet Pixel Shader

In order to assist with previsualisation, we created a custom image filter that both assists in yarn colour selection, and attempts to emulate the resultant carpet reproduction of the given source image using this yarn mapping. By using this image filter to derive the yarn selections for each point on the loom, we obviate the need for colour identification through projection onto the loom, and the attendant difficulties of this approach as described earlier.

We created the image filter as a custom ‘shader’ using the OpenGL glsl shading language. The benefit of this approach is that the image filter can be used in a number of different applications. We have implemented it in two; firstly in a standalone web application that allows for the uploading of an image, the selection of a palette of yarn colours, and renders the image into a carpet previsualisation using the custom shader in WebGL. The vertex can have a combination of up to three yarn colours, as the tufting gun can be configured to hold up to three yarns as previously discussed.

The job of the vertex shader is to find the combination of yarns from the given palette that best matches the colour of the sampled image at that point. The yarn colours are fed into the shader program as uniforms, and for each vertex the shader performs a brute force search of all combinations of three yarns (possibly duplicated) that additively combine colour to most closely match the sampled colour. There are a couple of arguable assumptions here: firstly that additive blending is the appropriate way of calculating the ‘combined colour’ of several co-tufted yarns, and secondly that the distance measure used (Euclidean distance in RGB space) is perceptually meaningful. Exploration of these assumptions is an interesting topic for further research, however for the time being we are running with them. The brute force search algorithm is rather sub-optimal, and does indeed strain the system when using a reasonable number of yarns.

The fragment shader then takes the chosen yarn colours for each tufting point, and applies them to render the actual pixels on the screen. Generally each tufting point (i.e. each vertex in the grid) will correspond to a larger number of screen pixels, for example a tufting point might be covered by an 8x8 array of screen pixels. In order to emulate the visual effect of having multiple yarns co-tufted, the fragment shader simply randomly chooses from the chosen yarn colours for each screen pixel in the fragment.

The Carpet Pixel Shader web application is accessible on https://carpetpixel.offig.com.

## CPEGs

The post-internet aesthetics and patterns of creative output have attenuated further toward the metaphorical over the corporeal. The memification of painting serves as a potent example of this.

“So, if one is to take the history of painting as a meme spreading from mind to mind through its history—from cave paintings to Piero della Francesca to Thomas Gainsborough to Nancy Spero and beyond—each iteration in the history of the meme mutating itself in response to its own context—then what would it mean to extend the painting meme into the context of digital computer networks? That is, assuming that painting did not, in fact, die sometime in the early 1980s, what would it mean to respond to the continually evolving painting meme in the context of ubiquitous computing in 2010? How would the painting meme be translated when a painting is still an object, but an object dispersed through the network as a mutable digital photograph, as well? This is not to say that all relevant painting must take this question of the network into consideration, but that it could be a pressing and fruitful intellectual question for at least some painters” [6].

This can also be said of pictorial carpets, however textile production anachronistically straddles everything post-digital and prehistoric; From the jacquard’s loom in the industrial revolution and the codification of patterns in carpet songs over millennia. With textiles there is an implied consonance between technology and weaving systems that goes beyond the boundaries of painting. Weaving technology was a lynchpin in the development of computer technology and code. The existence of digital signal processing is intrinsically linked to early industrial weaving technology as it was co-opted for the first general purpose computing machine, the analytic engine.

The “tableau vivant” or living picture was nothing new in light of cave painting, however the expansion of perspective enabled Renaissance art to communicate more sophisticated concepts through higher fidelity. Fidelity strengthens the relationship between the signified and symbol.

This argument may also be considered as another example of retro nostalgia and yet again another “rerun of 19th-century Arts and Crafts movement, with its programme of handmade production as a means of resistance to encroaching industrialisation” as Cramer writes in [5]. However in contemporary creative research, this methodology is potent for the amplification of colour coherence in carpet making.

Through rendering the patterns and variations of the JPEG as meaningful and informative to the carpet map we could endearingly consider the CPEG as a form of ‘slow newspaper’. C as in carpet, PEG as in abbreviation of the photographic experts group format, validating the Carpet Pictorial Experts Group format.

Figure 1. 3D render of a CPEG image processing

## Conclusion

We have presented an argument promoting the use of concepts and techniques from digital image processing, particularly JPEG compression, in the physical making of pictorial carpets. The benefits of JPEG like compression are (i) quantised colour schemes that do not vary too fast spatially; affording practical tufting (ii) a bias toward verticality of colour similarity, which again concords well with the ergonomics and physics of the tufting process. We have suggested a previsualisation methodology for yarn selection and colour configuration that does not only rely on projection to translate colour mapping. Our colour configuration methods work to tighten the colour relationships at the previsualisation stage to give the artist some pertinent information to expand the creative process while working with a minimal palette of colours.

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