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Exploring a Parameterized Portrait Painting Space

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Abstract
We overview our interdisciplinary work building parameterized knowledge domains and their authoring tools that allow for expression systems which move through a space of painterly portraiture. With new computational systems it is possible to conceptually dance, compose and paint in higher level conceptual spaces. We are interested in building art systems that support exploring these spaces and in particular report on our software-based artistic toolkit and resulting experiments using parameter spaces in face based new media portraiture. This system allows us to parameterize the open cognitive and vision-based methodology that human artists have intuitively evolved over centuries into a domain toolkit to explore aesthetic realizations and interdisciplinary questions about the act of portrait painting as well as the general creative process. These experiments and questions can be explored by traditional and new media artists, art historians, cognitive scientists and other scholars.

1 Introduction

Portrait artists and painters in general have over centuries developed a little understood, intuitive and open methodology that exploits cognitive mechanisms in the human perception and visual system. Compared with the original live sitter or the sitter's photograph, the portrait artist is able to filter and manipulate using what cognitive scientists only recently have begun to understand about our visual and perception system including shape and edge detection, centre of vision focusing and eye movement as well as colour temperature relational space. Our research, by first collecting (through interviews and reference data) a 'soft' qualitative knowledge space of how portrait painters achieve their craft, converts that soft data into a parameterized computer model which sits on the rigor of vision, image processing and facial knowledge. This computer model is the basis for our XML based interactive knowledge toolkit that has a two fold interdisciplinary goal. First it is able to generate a correlated space of painterly rendered portraits from input photographs in a large style set which has applications in computer based rendering, often called Non Photorealistic rendering (NPR), for games and multimedia and second it can be used as a toolkit to explore interdisciplinary questions about the act of portrait painting by traditional and new media artists, art historians, cognitive scientists and other scholars. For the later area, it can begin to bridge these areas and show how artistic knowledge can lead to additional cognitive and human mind discoveries as well as understand a deeply creative, intuitive and human process of visual art making.

Non Photorealistic Rendering (NPR) is a computer graphics technique which creates imagery with a wide variety of expressive styles inspired by painting, drawing, technical illustration, and cartoons. This is in contrast to typical computer graphics, which focuses on photorealism. NPR already has applications in video games, movies, architectural and technical illustration, animation and rising fields such as computational photography. NPR also has applications in learning and medicine (e.g. communication systems for autistic children) where filtering out unnecessary detail is important.

Many current NPR techniques rely on computer imaging approaches (e.g. edge detection, image segmentation) that model at the physical level such as blobs, strokes and lines. While also using some of these techniques, we take the novel approach of parameterizing a cognitive knowledge space of how a human painter paints – i.e. their open methodology to the process. For instance, unlike most NPR techniques, an artist holds a semantic representation of the object to be rendered (e.g. a face for a portrait, an emotional emphasis, a notion of foreground / background, a value and palette plan, etc.). In general, artistic methodology attempts the following: from the photograph or live sitter, the painting must simplify, compose and leave out what's irrelevant, emphasizing what's important. Since human painters have knowledge of the source imagery, we are limiting this approach to portraiture and therefore take advantage of portrait and facial knowledge in the NPR process, as well as portraiture's strong foreground versus background distinction. We believe this portrait painting knowledge approach when fully realized has two intertwining and interdisciplinary benefits. The first benefit is creating a novel type of NPR system that within its domain (portraiture but with benefits to still life and figurative work) may produce both a wider range of results and improved or more natural results compared to current techniques. The second possible benefit, which is the main thrust of this paper, is that portrait artists over thousands of years have somewhat unconsciously evolved a 'painting methodology' exploiting specific human vision and cognitive functions, which, if presented in a quantitative way, can shed light on psychological research in human vision and perception or at least validate them via another method.

2 Related Work

Within NPR research, a number of painterly rendering techniques were developed in the early 1990s, starting with Haeberli's (1990) pioneering work, which introduced painting with an ordered collection of strokes described by size, shape, colour and orientation. Litwinowicz (1997) created a fully automated algorithm based on Haeberli's earlier work producing paintings by using short linear paint strokes tangent to Sobel edge gradients. Relying on Haeberli's work as a base, many approaches appeared that used local image processing techniques in an attempt to achieve relevant high level content semantics to better control stroke/placement/colour choices. Hertzmann (1998, 2002, 2003) advanced the field by using a multi-pass system of coarse-to-fine curved b-spline strokes aligned to a layered course-to-fine image difference grid with multiple styles. This was inspired by his observation that artists begin a painting with large broad strokes and then refine the process with smaller strokes to create detail. Our system is inspired by his work and the general procedure of using artist knowledge to dictate parameters. For instance, we have moved away from a multi-pass course-to-fine grid for stroke placement choices and toward tonal masses based on lighting and drawing types. We are also developing a colour system that moves away from colour sampling with perturbations to a system which uses source tone to indirect into a semantic colour temperature model.

More global-oriented computer vision techniques to model scene semantics have attempted to both automate the higher level process and improve aesthetics. Gooch et. al (2002) first proposed segmenting the image into homogeneous greyscale regions leading to a significant reduction in the number of brush strokes. Segmentation was also used by Decarlo and Santella (2002) who presented a salience extension of guiding the painting process by eye movement, emphasizing the areas the user thinks are important. Hertzmann and others (Hays & Essa, 2004) used the variation of low level parameters such as stroke length to create different painterly styles. Gooch, as well as Collomosse and Hall (2002), relied on several human vision techniques. du Buf, Rodrigues, et. al (2006) used human vision techniques to better tie visual perception theories to NPR and painterly rendering. Our system relies heavily on hierarchical parameters which build up higher constructs from low level components based on portrait painter methodology.

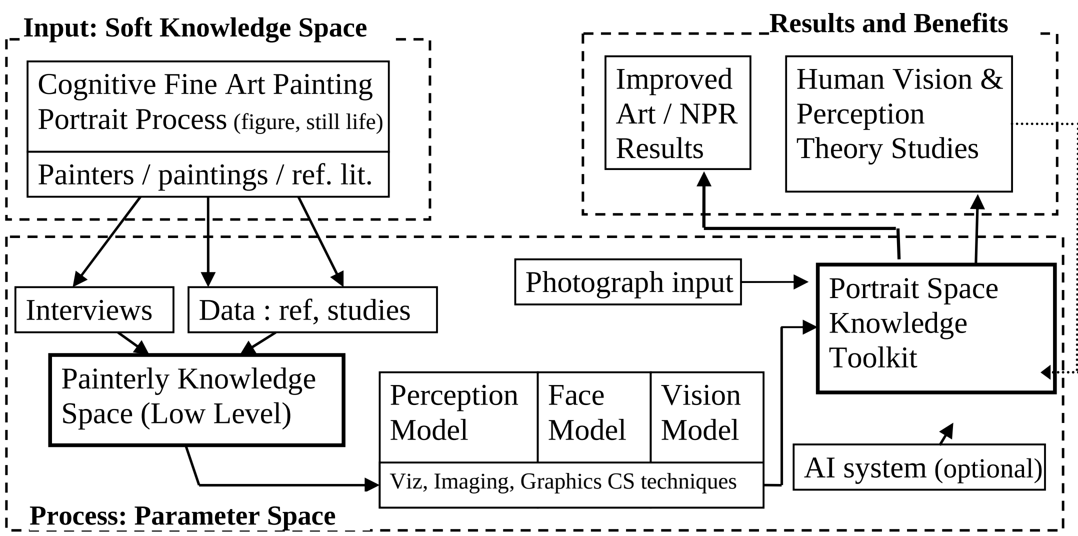

Figure 1. Proposed process chart.

3 Process Plan

Our research system uses a parameterized approach to approximate a knowledge domain for painterly rendering of portraits. The knowledge domain uses fuzzy knowledge rules gained from interviews with oil portrait painters, data from the traditional 'portrait painter process' combined with human vision techniques and semantic models of the face and upper torso. By knowledge domain we mean that the system attempts to act on the same semantic level a human painter might function at, such as: human vision techniques, facial planes and expression, tonal masses, and colour temperature control. It also relies on an historical, open methodology that artists have created and passed down to each other. This qualitative knowledge is parameterized into an n-dimensional space of low level rules which can be accessed at different semantic levels. Non-professional photographic imagery of people's heads is used as input. Figure 1 shows the process starting at the top left, which can be summarized as collecting a knowledge space of the painterly process (qualitative at this point – lower left) from artists interviews, reference materials and user studies, then using known computer science and cognitive science models and methods, parameterize the knowledge (bottom middle) into the NPR system (lower left) which can be used for 1) better/wider NPR results as well as 2) clues/data into human vision/perception theory which can be mapped back into the system.

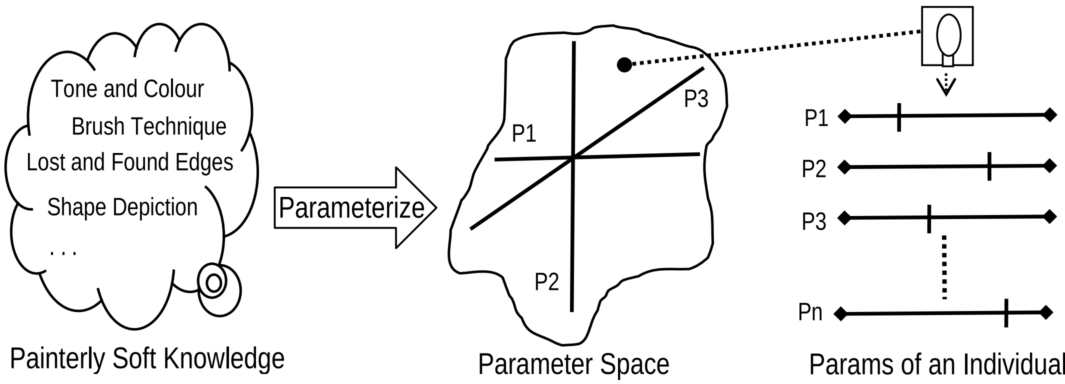

Figure 2. Parameterization Process: From soft knowledge to a space of millions of individual paintings, a parameter space (middle) defines a set of factors (params) whose values determine the characteristics of a system (dimensions of the space). With one individual (a painting) being a point in that space.

4 Painterly Knowledge Domain

Our first task has been to collect and quantify human painterly knowledge. With this knowledge we can begin to create both low level components that match known portrait painter techniques as well as build initial higher level, more adaptive semantic techniques which are built up from the lower level parameters. Multi-dimensional and hierarchical parameter spaces using knowledge domains have been used successfully in several areas including generative systems and facial animation. Our portrait painter research comes out of work we have done with multidimensional parameter spaces for virtual facial systems (Arya & DiPaola, 2007) as well as with animal simulation systems using artificial intelligence techniques (DiPaola et al., 2007). The basis of this approach is to create a low level set of parameters that are object-oriented, encapsulated and mathematically rigorous. These can be thought of as letters in a specialized alphabet which form the basis for words and phrases (high level components). The key to our low level parameters, as with real letters, is their rigorousness and universality - any high level component must be derived from them without the need for new letters to be created as we progress. These letters then become low level dimensions (e.g. axes) in a large knowledge space which can be accessed through higher level constructs which are solely comprised of the lower level parameters often with logical, spatial and temporal attributes. For example, in facial animation, low level muscle parameters can be built up into a more semantic 'smile' parameter and 'smile' with other parameters and temporal considerations can be built up into 'joyousness'. In practise, our low level parameters are grouped into functional types: 1) parameter constants like brush size or colour weighting, 2) method parameters such as ClosestColourPalette which uses a method where all brush colour choices for a given pass or area use an indirection into a second palette based on the closest colour and 3) process method parameter which guide the process flow of the other parameters types (i.e., do this before that). To begin this process we first need to parameterize a soft knowledge space of portrait painter methodology which we outline in this section and then with this knowledge space begin to build low level constructs which we discuss in the following section.

Deriving portrait methodology knowledge from interviews and reference materials with working artists on their artistic process (as well as art experts) is obviously fraught with ambiguities, seemingly ad hoc methods, differing opinions, and techniques that have no current software based analogy. As well, many in the art world are somewhat uncomfortable overly dissecting an aesthetic pursuit like portrait painting. With these challenges in mind, the goal was to create a toolkit research system that can be iteratively updated and refined based on information and user studies from the NPR, art criticism and cognitive science sectors. We hope a system that attempts to quantify the process in a parameterized way can serve as a tool in both science and art discussions including respecting and informing the human art making endeavour by trying to model the process. The following is an excerpt from our preliminary data of artist reference materials and artist interviews, a more comprehensive version appears in the author‘s early paper on the subject (DiPaola, 2007).

4.1 Tonal

The artist Max Meldrum (Colahan, 1919) in 1919 argued that painting was 'the science of optical analysis by means of which the artist, in carefully perceiving and analyzing tone and tonal relationships, could produce an exact appearance of the thing seen'. Tone was the most important component of the art of painting, next came proportion, 'the superficial area occupied by one tone', and then colour, the least important component.

The tonal value (tone) is the relative lightness or darkness of an object. Artists squint when they look at the portrait sitter to see more in tones than colours. They also adaptively squint to see more in general masses, allowing artists to decide the size of mass they are interested in tone sampling at the moment. At the fine or stroke level, final colour is generally derived from a 'sampled' tonal value. This ‘tone first approach' allows an artist to be more creative in their colour choice without sacrificing the portrait integrity.

An artist tries to limit the overall number of values in painting. In portraiture (and other styles including still life and figurative) values can be categorized into particular "types" where the first 3 are the most important:

- Body tone (or light) – in the light source; in direct light (usually warm colours).
- Halftone – where the light begins to turn; in between light and shadow.
- Body shadow – away from the light source; darkest area (usually cool colours).
- Other Types: Cast shadows, Reflections, and Highlights.

One commonly used approach in portrait painting is to first paint the gross head masses in 3 divisions of value – body tone, halftone and shadow. Within these gross areas fit degrees of finer tonal gradation (light to dark) which benefit from the semantic information of what gross tone area they are in.

A painting must have a domain value, either it's light, or its medium, or it's dark. For example, a small sketch might be dominated by a light value, an impressionist landscape is dominated by a medium value and a Rembrandt portrait is dominated by a dark value. With 3 values: dark, mid and light, one should be dominant, the other two together typically make up less than half of the first; none being of equal amount of the others. This 'rule' is often referred to as Unequal Dominate Value.

4.2 Colour

The tonal value points to what colour to pick within the other rules of portrait colour, the most important of which is colour temperature. Temperature refers to the relative warmth or coolness of any given colour. Warm colours and cool colours work harmoniously both globally and within regions of a painting. The foremost concern when picking a colour is getting the value correct. A typical process would be to determine the colour of the light on the area of your subject, say the body tone area. When the light areas are going to be warm

tones, generally speaking the shadows will be cool. So warm lights produce cool shadows and cool lights produce warm shadows.
The rule of unequal balance dictates that both light and cool temperatures cannot be shown equally. Usually within a portrait the warm light is dominant over the cool in shadows. Alongside a dominant value, most successful paintings have a dominant colour.
Most painters use the classic 3 primary colour system around a colour wheel. More recently many artists have adopted the Munsell Colour Notation system's 5 "principal" colours (red, yellow, green, blue and purple) which are spaced equally around a colour wheel. Artists typically make a decision about palette or colour harmony for a given painting before they start.

Here is a summary of how an artist can use colour temperature: 1) a painting should have a dominant colour that is readily evident, 2) complementary colour (from across the colour wheel) may be introduced, occupying much smaller space at full intensity, or greater area if greyed, 3) discord colours (equidistant on the colour wheel from the dominant hue and from each other) should be added sparingly in approximately equal amounts. Discords bridge and add visual excitement.

4.3 Shapes, Edges and Centre of Interest

Shapes and composition can be more important than subject. Artists link shapes to create pattern and thereby composition. Shapes are related to edges. Edges occur wherever shapes meet. By softening or hardening edges or making them disappear entirely, the artist strengthens the illusion of form and gives a painting dramatic flow - this is known as Lost and Found Edges. By losing an edge we allow it to merge with an adjacent shadow, creating a link between objects, which is a powerful tool for design. For instance, a subject can emerge from a strongly textured background, yet remain one with it, with the help of edges softened or entirely lost and shadow cores. Edges can control the viewer's eye movement over the canvas, since eyes always move to sharp edges and coast softly over soft edges. On a lost edge the viewer finds comfort in seeking out the place where it is found again. Sharp edges are at or in the centre of interest. An edge plan can create a story for the painting.

A chosen centre of interest in a portrait, say a mouth smirk or intense eye gaze, can draw the viewer to the desired personality of the sitter. An artist creates and draws the viewer towards the painting's centre of interest through the edge quality or detail in the portrait. The sharpest edges are at the centre of interest, less sharp edges move the viewer's eyes across the canvas toward the centre of interest and the softest edges are placed where the artist wants the viewer's eye to glide over.

4.4 Photography

There are several problems with portrait painting based on photographs including depth of field, value clumping, and colour distortion. Depth of field from photographs does not provide a centre of interest focus, since everything is in focus or the camera focuses in unnatural vertical planes. This means an artist must create the centre of interest. Photos also give false edge readings making edges too sharp. Cameras also darken the shadows and lighten the bright areas causing value clumping. Colour and perspective distortions are also common in photographs. From the photograph to the painting an artist attempts to simplify, by leaving out the irrelevant and emphasizing the important. Photographs distort the tonal range, known as value clumping making values on either end of the scale compressed. Artists extend the middle value by extend out areas that look dark in value, as well as extending lighter areas to range to darker in value.

4.5 Brush Strokes

The conditions that dictate the placement, size, shape and direction of a particular brush stroke is less verbalized by artists. There are however many sometimes techniques artists pick from. Artists often think about the way the facial surface or plane is orientated and paint in colour and strokes to suggest the surface itself. Often they stroke the paint on in the same direction as the plane. One technique is to pull or push the stroke in the direction of the plane. Strokes put down in the same direction become monotonous, so they are broken with strokes in opposing directions which it is said brings energy to a painting.

So in summary, balance and variety seem to be the key. Stroke to match the shape, and then complement it with a stroke in the opposite direction. Never completely finish edges. Always overlap rather than putting objects in a row. Use stroke direction with edges to move views to the centre of interest.

5 Knowledge Based Implementation

Our early research methodology, as shown in Fig. 1, has been to gather and systematically convert qualitative painterly knowledge into a quantitative parameterized software toolkit (figure 2). Low level parameters can then be iteratively built-up into more semantic high level components.

To exploit tone and colour portrait knowledge, the system uses a multi-layer stroke analyzer/renderer which perceives and lays strokes down in large masses first, progressively using smaller stokes and more detailed analysis. This multi-pass tonal shape based approach approximates how painters squint at first to read large tonal masses and progressively add greater levels of detail over exposed paint from the layer before. Rather than use progressive difference grid techniques to move through a source image, the system progressively iterates over tonal masses, beginning with major tonal areas of the face: body tone, half-tone and shadow by calculating a 'gross tone map' (figure 3B). Then exploits working in limited tonal spaces. These working maps are recalculated per level of detail and are affected by other value plan parameters. A value plan is used which can rescale and re-centre the tonal space of source masses. Unequal dominant and sub-dominant value parameters also can rescale how the system analyzes/uses the source image. This is an example where painterly knowledge rules can supersede the information from the source sitter image (the sitter photograph) by filtering, emphasizing/de-emphasizing, and scaling input information as well as by other rule based means.

Figure 3.   Initial Image (A),   Tone Map (B),   Object/Focus Map (C).   .

The system has several low level colour method parameter routines that indirect into a colour temperature system via tonal value information at stroke time. Since many artists work in a known palette space, our current high level colour components create a pre-constructed palette by sampling the source photograph(s) as a pre-process along with other image analysis or by choosing historical portrait palettes from any given artwork. This pre-step image analysis determines input attributes like dominant value and dominant colour, both overall and locally for the body tone, half tone and shadow areas as well as a colour temperature plan and a lost edges (i.e. tonal contrast) plan. These input attributes are used at stroke analysis time by the knowledge system to indirect into a unique but constructed palette for the final painting. Currently that colour palette indirection can happen via many different method parameters at a per image, per pass, per region or per stroke level. These methods use different artist and perception oriented remapping techniques that we have gleaned from our qualitative methodology analysis. For instance, one palette called FullRangeValuePalette(), uses the top functional regions (body tone, shadow, …) the stroke pointer is currently in to remap the input value weighed by all the values in the region to a specific warm or cool palette much as artists do with a tone first, then colour temperature choosing technique in a given blob area. With this method we have been able to use any number of historical colour palettes separated into body tone, shadow, clothes, background and hair sub-palettes which we than can map any input photograph region by region based on weighed constant parameters such as value or hue.

Figure 4. Controlling the parameters interactively, allows the toolkit to generate several or 100s of different painterly portrait scenarios in the specified multi-dimensions as shown by these four images.

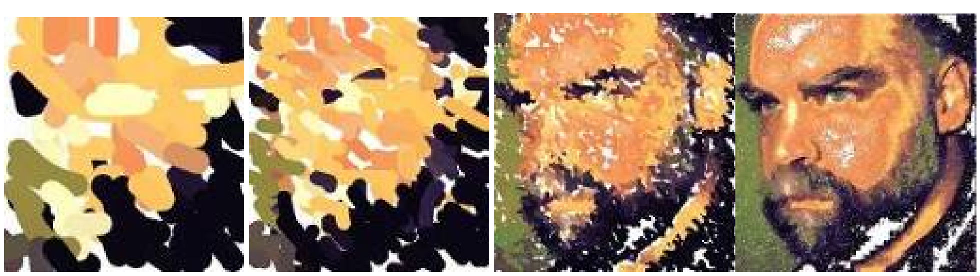

Figure 5. The example set taken from a run of 100s, shows moving through a one parameter (above - brush size), then other examples (cropped) of many paths through the portrait space from the same input.

Figure 6. Another example set taken from a run of 100s, shows moving through one parameter (left), then others from fig. 3 input, the pastel and the wet oil output only have a handful of XML parameter differences including different palette and the pastel uses matte 1C for a eyes/lips centre of interest (note sharpness).

6 Conclusion

We have described our initial work on a novel and interactive painterly portrait space toolkit which can explore a cognitive portrait painter knowledge base and present results. These results use non-professional photographs (e.g. figure 3A), an XML and input files as input, automatically producing output with a wide range of traditional and experimental (even animated) styles (figures 4, 5, 6) by changing a subset of the variables. An artist or scholar has the ability to control different axis of the parameter space (the cognitive portrait space) which can generate one, several or thousands of correlated portrait images smoothly ranged in the given multi-dimensions. Figures 4, 5, 6 show example images, cropped from the high resolution originals, from larger image sets (100s or 1000s) iterated in different dimensions. This allows media artists, art historians, designers and scientists to experiment in portrait space. As of this writing, cognitive scientists are using this system together with eye tracking experiments to evaluate theories related to whether Rembrandt intuited human central visioning and exploited this knowledge to significantly and specifically influence the viewer's eye path through his late portraits. This interdisciplinary research effort involves art historians, digital media arts and vision scientists. A different effort is underway to use genetic programming techniques to allow users to move through a large search space of painterly portraits created by this system to aesthetically play with the idea of moving through or dancing within a conceptual fine art painterly space.

The system uses fuzzy knowledge rules gained from interviews with portrait painters, as well as traditional reference information. The knowledge data is parameterized into an n-dimensional space of low level rules that use constant, method and process parameter types, which can be accessed at different semantic levels. We have described how this toolkit is scripted using XML, allowing for experimentation and the creation of high level constructs such as described in the previous paragraph. Our ongoing goal is to build up high level constructs using additional artistic vision and perception techniques that support the portrait painter knowledge, allowing for an interdisciplinary system which has research benefits for NPR as well as new media art, art theory and cognitive science.

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