ColourVis:
Exploring Colour Usage in Paintings Over Time

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Figure 1: *ColourVis representation of paintings by Vincent van Gogh.*

Abstract
The colour palette of painters over history has been of interest to many, including: art historians, archeologists, and art lovers. Colour usage in art changes from culture to culture and season to season and is often thought of as reflecting or inspiring mood and ambience. We present ColourVis: a visualization that supports exploration of colour usage in digital images. In particular, we use as a case study European art over the last six centuries. Visualizing this relatively unexplored area offers insights into such questions as: How blue was Picasso's blue period?; How do realist painters' colour choices compare to that of surrealist painters; or How has the usage of colours changed over time? Through ColourVis we offer an exploration and comparison tool for individual paintings, groups of paintings and trends in colour usage over time.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Information Visualization]: Picture/Image Generation—

1. Introduction

In ColourVis we explore the visualization of colour as used in paintings and images. ColourVis graphically represents which colours and how much of each are used in single image and provides a graphical way to compare the colour usage of two or more paintings or images. Information about how colour has been used in paintings has been the focus of many scholarly studies [Gag90], historical records [Bir65], and literary criticisms [Ril96]. Colour usage in paintings is an ongoing area of interest for art historians and archae-

ologists but depicting how colour usage has changed over time still remains a challenge. ColourVis aims to address this problem by graphically displaying trends and patterns in colour usage of paintings, artists, over time, over genres and across spectrums.

With ColourVis we can analyze any set of scanned images, such as paintings or advertisements, extracting the colour information from these images pixel by pixel. ColourVis presents this information for single images using our own custom histogram visualizations and, for ex-

ploration of trends in a series of images, colour information is visualized with a variation of a stacked line graph visualization. We created both of these visualizations to give the viewer a sense of the colours, and the amount of each of these colours, that make up either an image, or a series of images. ColourVis offers a new way to extend our understanding of colour usage in images; for example, it can offer a unique perspective on a selection of historically relevant paintings.

2. Related Work

Colour is a fascinating and diverse topic that has received attention from a wide variety of research areas including science, art, and history. Colour observation is a key attribute of human vision and a primary way in which humans understand our world due to the fact that humans are physiologically wired for colour and colour perception [Gre73]. While both digital and non-digital colour representation have been previously explored in academic literature, colour and colour usage remains a fascinating topic in need of further exploration.

In the field of information visualization colour has historically been used as one of the primary visual variables through which difference in data can be distinguished and is considered as one of the fundamental building blocks of visualizations today [Ber83]. One typical use of colour is in the labelling or categorizing of information, as in legends for maps in order to facilitate the understanding of more complex visualizations [Sto03, Bre94]. When using colour as a label in visualizations there are many perceptual factors to consider. These factors include: distinctness, unique hues, contrast with background, colour blindness, number, field size, and conventions [War04]. While colour has an important role in information visualization we see rich opportunities for new research into how the use of colour itself in digital images can be visualized and how colour information can be represented visually.

In order to explore colour usage over time we drew inspiration from existing visualizations that focus on visualizing information chronologically. Our prototype design was informed by works such as ThemeRiver, a visualization that attempts to visualize the changes in data over time [HHWN02]; the Video Traces Project, which visualizes video history in order to gain an understanding of activity [NGCG07]; and Dubinko et al. who attempted to understand the evolution of tagging of Flickr images over time [DKM*07].

2.1. The Use and Analysis of Colour in Science

Scientists have long been interested in understanding colour. When depicting colour scientifically there are, generally, two types of colouring: true-colouring and false-colouring. An example of true-colouring is as follows: in an image of a blue ocean, the ocean appears to be the same colour as it would in the real world and, likewise, an image of a red brick of a house would appear to be the same red as it would in real life. False-colouring differs from true-colouring in that false-colour imagery alters the colour of the subject matter to appear as a different colour than it would normally appear to the human eye. One of the most iconic examples of false-colour imagery are images produced by astronomers using satellite technology, such as the Hubble Space Telescope. In false-colour satellite imagery, light colours that are imperceptible to the human eye are altered in order to be perceived by humans in an understandable and visually appealing manner. Scientists also commonly observe trends in colour change and colour shifts in order to measure things such as the speed and distance of celestial objects, and for diagnosing medical conditions using medical imagery.

Scientific investigations of colour have also focused on using technologies, such as x-rays and other scanning technologies, to more closely examine the qualities and technical properties of pigments colours used in paintings [KDDL*06]. Due to the historical significance of some painting, analyzing pigment from painting in an unobtrusive and minimally impactful way has been a focus of research for many art historians. Examples of these types of investigations include the development of a minimally invasive process using x-ray fluorescence spectrometry to produce a gentle sampling technique in historical paintings and manuscripts [KvBM00] and viewing paint colours painted under other layers of painting in the works of Vincent van Gogh [DJVDS*08]

Exploring colour in paintings has also been examined by archaeologists and historians. Archaeological researchers are interested in things like the processes used to create certain colours used in historical paintings; for example, understanding how certain shades of blue and purple were created. Some of this curiosity stems from the elaborate or expensive process of creating certain pigments. Archaeologists have even attempted to replicate the historically correct methods of processing raw ingredients required to make rare pigments colours such as Royal Purple [MM90, MM87].

2.2. Colour Analysis in Visualization and Art

Most closely related to our work are Buxton's pie chart visualizations of Vincent van Gogh paintings that represent the colour usage in van Gogh's paintings [Bux10]. In these visualizations, similar colours from van Gogh's paintings have been aggregated and are represented by a single colour in order to simplify the visualization and make it more readable [Bux10] (see Fig. 2). These pie chart visualizations represent various van Gogh paintings in five distinct colour regions or less. Rigau et al. also explored the evolution of the colour palette and composition of van Gogh's style [RFSW10] by introducing measures to better understand the changes in van Gogh's painting style over his career.
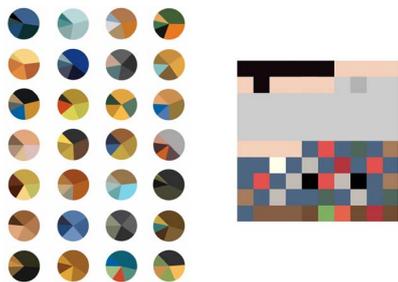
Figure 2: *Left: various pie charts representing a series of van Gogh's paintings by Arthur Buxton. Right: a visualization of the colours worn by Jacobo Zanella over a period of one day. Reprinted by permission of the artists.*

Besides in paintings, colour usage has an important impact in our everyday life and we constantly make colour-related choices. Visualizing these everyday choices regarding colour can lead to interesting insights about one's life. Artist Jacobo Zanella, for instance, has visualized the daily colour palette of the clothing he wore over the course of each day in 2010. In Zanella's work rectangles are used to depict not only which colours were worn but also, as shown by each rectangle's area, what quantity of each colour was worn (see Fig. 2) [Zan10].

There also exist a large number of software tools designed to help designers and artists analysis, choose, compare, and generate colours based around themes and patterns. Examples include Adobe Software's Kuler, which is an online colour choosing application; they also include photo editing applications such as Photoshop^{TM}or Gimp which can aid in the visualizing of images by displaying histograms of the colours present in images.

Both academics and artists have explored colour usage and patterns in images and yet, to our knowledge, a system that allows for the visualization of colour usage in a series of images has yet to be undertaken. With ColourVis, we explore this area of visualizing colour usage and changes in paintings and other images.

3. ColourVis Information Visualization

ColourVis explores the pixel by pixel colour usage in images. In ColourVis we use the HSB (Hue, Saturation, Brightness) colour system. Although the concept of the HSB colour system is well known, we reiterate the definitions here for the convenience of the reader since these factors are fundamental to ColourVis. Hue is the colour range from red to violet; saturation is amount of hue present and ranges from full intensity to transparent; and brightness is the degree of darkness or lightness of the particular colour. To describe ColourVis we will start explaining how the colour usage in a single image is visualized. Then we will discuss how visual comparisons can be made with two or more images. To illustrate this discussion we use an image set of European

paintings obtained from Freebase.com database [Fre10]. In total this dataset contains approximately 1,300 paintings by European painters created during the time period of 1475–2000 AD.

3.1. Visualizing Colour Usage in One Image

One way of visualizing colour usage in one image is to measure the hue of each pixel and count how many pixels of a given hue were actually used. From this analysis, a hue usage histogram can be created. For the next series of images we will use the painting "Fishing in Spring, the Pont de Clichy" by Vincent van Gogh (see Fig. 3) as a sample image and discuss some colour visualization possibilities. Fig. 4 shows a simple hue histogram for our sample painting. Note how, though this is an accurate representation of hues present, it does not relate well to the actual colours in the painting, which combine hue with saturation and brightness. Taking this histogram and replacing the pure hue pixels with the actual pixel colour that is in the painting creates a much more compatible visual result (see Fig. 5). However, the variations of dark and light colours make the actual colour ranges hard to read. This histogram can be sorted according to saturation (see Fig. 6) or brightness (see Fig. 7). Both groupings help readability, but the gradient produced while sorting by brightness appears to be more readable. However, neither of these histograms leads to a completely simple gradation because variations in colour are caused by both saturation and brightness.

These histograms all indicate frequency distribution of colours in the van Gogh painting. Based upon the histograms' shape, they can indicate over-arching trends in colour usage such as symmetry or degree of skew of colour distribution. However, a simple question that might be of interest for further analysis, such as "Does this painting contain more blue than green?" cannot readily be answered and must be deduced by visually assessing the area of blue in the histogram and comparing it to the area of green in the histogram. It is well know that judging comparative size of areas of irregular shapes is a difficult task that is not often done successfully when trying to form judgements by eye [Tuf91, War04]. If all the colours were grouped, according to how we are accustomed to recognizing them, gathering the blues, greens, yellows, etc. together, the histogram could become a simple readable bar graph (see Fig. 8). However, exactly how to group them is a complex issue.

One possible solution for grouping colours is to use named colour spaces. Studies have been run asking people what name they would use for a set of colours [PC89, War04]. There are some colours that were consistently named the same by most people. Post et al. [PC89] attempted to determine how participants named colours shown to them on CRT displays and found that only six colours were named by participants with high reliability: blue, green, yellow, orange, pink, purple. Research literature also sug-

gests that the naming and banding of colours may be affected by the language and culture of participants [Con55, HO72, KR03, RDD00, RDDS05]. Also, the named areas in the colour gamut are small with large areas in-between them where, for instance, some people would call a given colour blue and others would call it green.

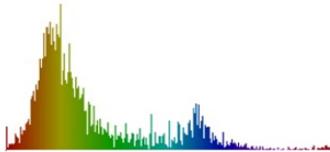**Figure 3:** *"Fishing in Spring, the Pont de Clichy" by Vincent van Gogh.*
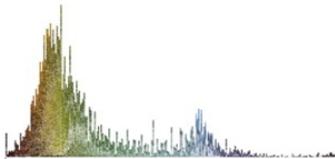

Figure 4: *Simple hue histogram of Fig. 3.*

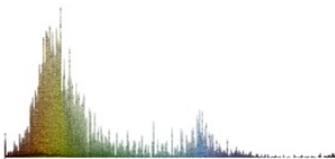**Figure 5:** *Unsorted actual pixel colour hue histogram of Fig. 3.*

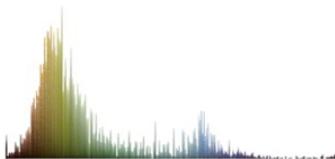**Figure 6:** *Actual pixel colour hue histogram sorted by saturation of Fig. 3.*

Figure 7: *Actual pixel colour hue histogram sorted by brightness of Fig. 3.*

These indeterminate spaces in-between colours make for indistinct bins. We therefore choose to revert to painterly colour divisions: we categorized colours by the painterly primaries: red, yellow, and blue colours; and the painterly secondaries: orange, green, and purple. These six colour categories also contain red, green, blue (the three primary colours making up the trichromatic human colour vision [RW88]). Even then, the dividing line between these colours was a topic of much discussion.

In response to this potential for culture and lingual bias when representing the six colour categories we decided to provide configurable colour categories. ColourVis colour categories are configurable in category amount and hue. People can specify the number of colour categories and adjust the range of hues; both the start and stop point of any bin are settable. These customizations can be adjusted in a configuration file.
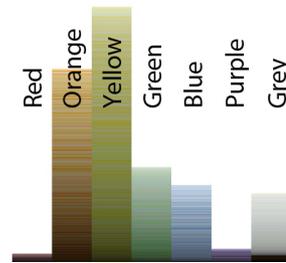

Figure 8: *Labeled linear banded histogram representations of Fig. 3.*

As a default, six colour categories seemed to be a reasonable number because a study has shown that five-colour target identification provided little difficulty for participants while seven-colour target identification has been found to be significantly more difficult for participants [Hea96].

Note that the ColourVis actually consists of seven colour (see Fig. 8) categories with an additional grey scale category. While the pixels represented in the greyscale category do register as having hue, their saturation is so low that the hue is not perceived. If these were included in the colour categories they would show up as lines of black, white and grey. As with the simple histogram, these binned colour bar charts can be sorted by either brightness or saturation. The images in the rest of this paper are sorted by brightness.

From Fig. 8 one can see how van Gogh made more frequently use of lightly saturated colours in this particular painting. Notice how the binned colours support the comparison of the amount of blue colour (mostly the water and sky) to the green colour (representing foliage and the boats) in the painting. We are able to observe from the size of the banded histogram bars an approximation of how much of the natural scenery in the painting is in the orange range compared to green in colour.

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3.2. Visualizing and Comparing Two Images

We extend ColourVis functionality to support colour usage comparisons across two or more images. While it is possible to do comparisons across images by generating the necessary set of histograms and then switching back and forth between histograms of individual images (see Fig. 9) this procedure increases the cognitive load on the observer [CS91]. ColourVis addresses this challenge through a specially tailored implementation of a stacked line graph that enables the comparison of colour usage in multiple images [BW08]. We note that there exists similarities between this approach and the technique of parallel coordinates, a visualization technique used to plot individual data elements across many dimensions [ID90]. Our stacked line graph visualization can therefore be thought of as an unique implementation of a stacked parallel coordinate visualization.
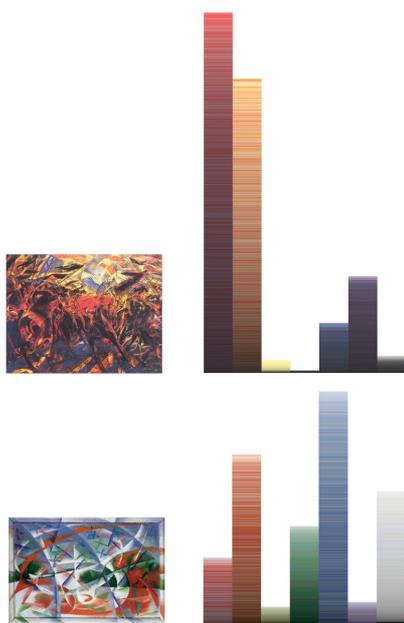

Figure 9: *Linear histograms representations of "The Funeral of the Anarchist Galli" by Carlo Carrà (top) and "Speed+Sound" by Giacomo Balla (bottom).*

To compare two or more paintings in ColourVis, we first stack our single painting bar graph, starting with red and moving through orange, yellow, green, blue and purple to end with the low saturation greys at the top. One could simply juxtapose these two (or more) stacked bar graphs. However, to emphasize changes and trends we draw triangles between the respective colour bins to create a stacked line graph.

Fig. 10 shows a ColourVis stacked line graph for the same two paintings shown in Fig. 9. The same six colour categorizations are used. More specifically, we compare paintings from the futurism time period using our stacked line
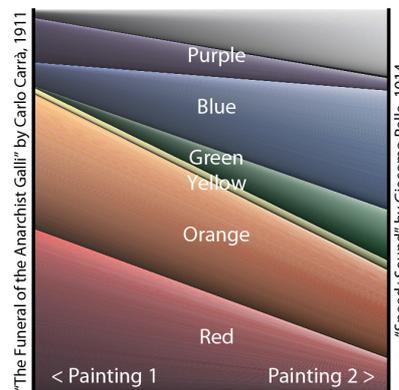

Figure 10: *Labeled stacked line graph representation of "Speed+Sound" by Giacomo Balla 1911 and "The Funeral of the Anarchist Galli" by Carlo Carrà 1914.*

graph implementation in Fig. 10. The outer vertical edges of Fig. 10 each represent a painting. The left column shows the colour usage in the painting "The Funeral of the Anarchist Galli" by Carlo Carrà and the right column shows the utilization of colour in the painting "Speed+Sound" by Giacomo Balla. For each painting the colour bins of their linear histogram are stacked one on top of each other according to the hue range pattern. In a given colour bin the pixels are rendered using HSB as they are in the painting and are also sorted by brightness. This results in a stacked bar graph for one painting. Given two paintings, as in Fig. 10, the exact colours in each stacked bar differ. The hue colours are then blended between the left and the right image's stacked bar using a linear interpolation between the colours on the left and right.

In Fig. 10 we can observe the differences in the paintings by Carrà and Balla; in particular considering the different utilizations of the colours red, blue and green. The visualization also shows that both paintings use a similar amount of yellow paint which would be difficult to observe by just visually comparing the paintings themselves or by analyzing the ColourVis histograms created for these paintings (see Fig. 10).

3.3. Visualizing and Comparing Collections of Images

ColourVis stacked line graphs can be extended to compare entire series or collections of paintings to enable, for instance, comparisons between paintings across time periods, over the career of an artist, or across genres of paintings. Furthermore, ColourVis can combine groups of paintings into a singular vertical stacked bar graph, and by using this complied group ColourVis can then create a stacked line graph to compare this combined grouping with other paintings or other groupings of paintings. Thus, entire collections of work can be compared with one another.

Fig. 11 presents six paintings by Picasso created from

1902–1937. Picasso is well known for his distinctive periods of painting, including his blue period (1901–1904) and his rose period (1904–1906) [Ste84]. In Fig. 11 both the blue and rose period can be observed in Picasso's work. His blue period consisted of paintings rendered in shades of blue and blue-green and this can be seen in large amount of blue and green colours used in 1902 painting in Fig. 11. By 1905 (see Fig. 11) we can see a decrease in Picasso's use of blue and green colours in favour of a large amount of orange colouring and in this visualizations' second painting from 1905 we see a large amount of purple/red/pink colours during his transition phase to the rose period.
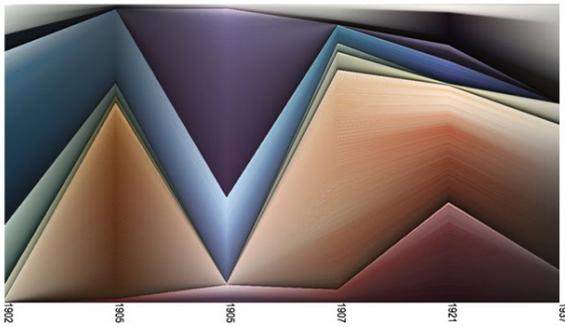

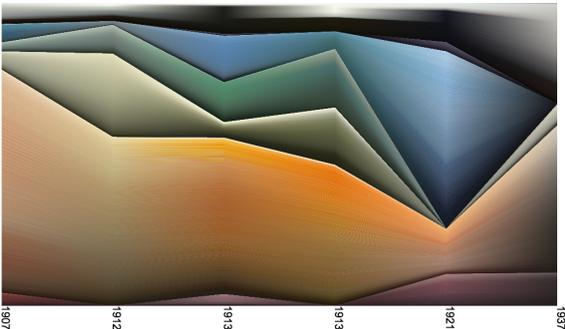**Figure 11:** *Picasso paintings visualized using ColourVis.*

Figure 12: *Representation of 30 years of paintings from the cubism movement.*

We can also use ColourVis to observe entire genres, movements, or time periods in paintings (see Fig. 12). Further, ColourVis can be used to group collections of paintings into singular vertical points. In Fig. 13 paintings from realism (31 paintings) and surrealism (13 paintings) are compared in a normalized aggregated form. We see a decrease in the usage of red colours, a consistent use of greens and yellow, and an increase of oranges from the realism into the surrealism time period. We can also observe that purple colours were not as prevalent during these time periods. Understanding these changes in colour usage by visually examining hundreds of paintings from both time periods would be a large undertaking but by representing them in aggregated

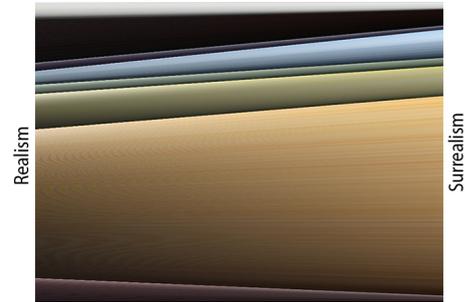form using ColourVis these patterns become much more apparent.

Figure 13: *ColourVis representation of Realism and Surrealism painting movements.*
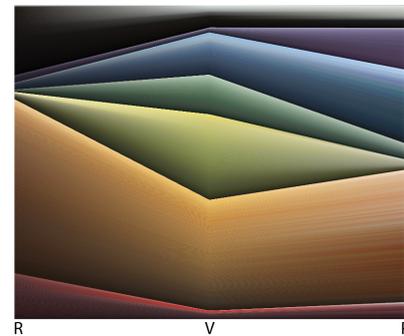

Figure 14: *Comparison of the Rembrandt Harmenszoon van Rijn / Vincent van Gogh / Pablo Picasso painting collections.*

In Fig. 14 we compare the collected works of Rembrandt (34 paintings), van Gogh (56 paintings), and Picasso (7 paintings). Here we see Rembrandt's fondness of oranges and reds, Van Gogh's greater use of greens and yellows compared to the other two artists, and Picasso's noted choices of blues and purples. At a quick glance ColourVis allows for a viewer to gain a global understanding of colour usage of these three well know artist without having to manually compare their vast collected works.

ColourVis allows for both a depth and breadth understanding of colour use across time, artists, and genres. ColourVis representations can be viewed along with the original paintings in order to gain a better understanding of the art, the artists' creation process, and larger views on art movements and trends across time.

4. Applying ColourVis to Magazine Covers

While our first set of examples of ColourVis only include paintings, ColourVis can be applied to any digital image. In the following examples we have applied ColourVis to present the "People" and the "New Yorker" magazine covers from the period of April 2010 to March

2011. To view these magazine covers please visit: a) People Magazine: http://www.people.com/people/archive/ b) New Yorker Magazine: http://www.newyorker.com/magazine/covers/2010.
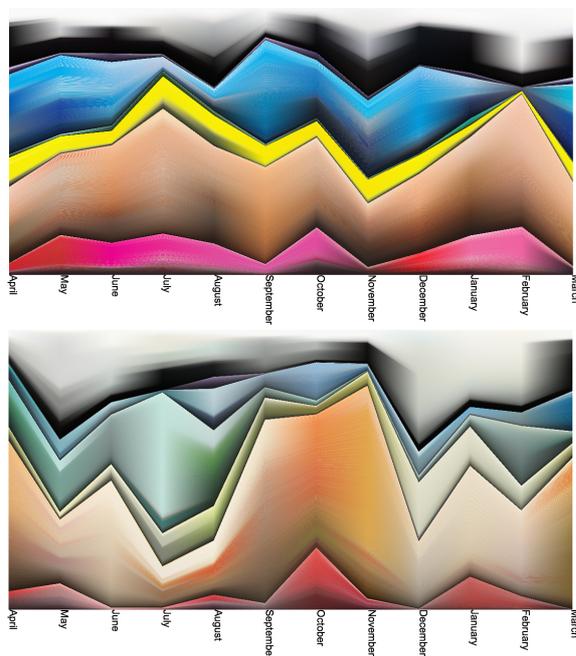

Figure 15: *ColourVis representation of "People" (top) and "New Yorker" (bottom) magazine covers from April 2010 to March 2011.*

In Fig. 15 we can observe the prominent use of bright primary colours (reds and blues) used in the "People" magazine cover images contrasted with the more muted tonal colours used in the "New Yorker" magazine cover images. Also visible from the stacked line graph representation are the bright yellow subtitles employed by "People" magazine covers. In contrast, the "New Yorker" magazine does not use consistently bright colour titles in their cover images but alternates between black and white titles. We can observe relative consistency in the colour choices for "People" magazine cover images, while the colour choices of the "New Yorker" magazine fluctuate more frequently. We can also clearly see the fluctuation of bright blue and bright pink colours used on the covers of "People" magazine; and we can see a trend forming, from July to March, where months of high pink usage result in lower levels of blue usage and vice versa.

An aggregation of the April 2010–March 2011 covers of "People" and the "New Yorker" magazine (see Fig. 16) reveals that "People" magazine uses a larger amount of blue and red colour in their covers than the "New Yorker" magazine. In contrast, the "New Yorker" magazine covers show more green colours than the "People" magazine covers. The visualization also reveals that the six colour categories are

Figure 16: *ColourVis overview representation of "People" (left) and "New Yorker" (right) magazine covers from April 2010 - March 2011.*

more evenly distributed in covers of the "New Yorker" magazine than in the "People" magazine covers.

5. Conclusions and Future Work

ColourVis visually supports the exploration of colour usage in individual or multiple digital images through the use of histograms, bar charts and stacked line graphs. Using ColourVis particular trends over time or by artists can be made visible. With ColourVis we contribute:

- the design and exploration of customizable banded histogram used to represent colour,
- the design and exploration of a customizable stacked line graph visualization,
- a colour abstraction the supports the comparison of two or more paintings,
- a novel way to track the change of painter's colour usage over a career and/or painting genre or across time.

ColourVis has the potential to further promote discussions around colour usage in images by visually representing trends and patterns in the colour usage of images, paintings, artists, and over time/genre spectrums not previously understood or explored.

ColourVis is just the first step towards examining colour usage in images. There is considerable opportunity for further exploration into additional scenarios where the analysis of colour is important and into how experts in different fields such as art history, design, or advertisement would experience the opportunity to make use of such tools.

This project has brought to light some of the challenges of depicting colours with named colour space and how these colour values range using the hue colour spectrum. ColourVis offers a customizable solution to alleviate issues related to labelling colour which could be adopted and extended by future systems. Other future work may include exploring other data sets using this application, enabling direct manipulating of parameters inside the visualization for

customization purposes, and moving the application to the web so that it can be accessed by the public more easily.

6. Acknowledgements

References

[Ber83] BERTIN J.: Semiology of graphics: diagrams, networks, maps. 2

[Bir65] BIRREN F.: *History of color in painting*. John Wiley & Sons, 1965. 1

[Bre94] BREWER C.: Color use guidelines for mapping and visualization. *Visualization in modern cartography 2* (1994), 123–148. 2

[Bux10] BUXTON A.: Van gogh visualisation, November 2010. http://arthurbuxton.blogspot.com/2010/11/van-gogh-visualisation.html (Retrieved 2011-04-26). 2

[BW08] BYRON L., WATTENBERG M.: Stacked graphs–geometry & aesthetics. | *IEEE Transactions on Visualization and Computer Graphics* (2008), 1245–1252. 5

[Con55] CONKLIN H.: Hanunoo color categories. *Southwestern Journal of Anthropology* (1955), 339–344. 4

[CS91] CHANDLER P., SWELLER J.: Cognitive load theory and the format of instruction. *Cognition and instruction 8*, 4 (1991), 293–332. 5

[DJVDS*08] DIK J., JANSSENS K., VAN DER SNICKT G., VAN DER LOEFF L., RICKERS K., COTTE M.: Visualization of a lost painting by Vincent van Gogh using synchrotron radiation based X-ray fluorescence elemental mapping. *Analytical chemistry 80*, 16 (2008), 6436–6442. 2

[DKM*07] DUBINKO M., KUMAR R., MAGNANI J., NOVAK J., RAGHAVAN P., TOMKINS A.: Visualizing tags over time. *ACM Transactions on the Web (TWEB) 1*, 2 (2007), 7–es. 2

[Fre10] FREEBASE.COM: Freebase, April 2010. http://www.freebase.com/ (Retrieved 2011-04-27). 3

[Gag90] GAGE J.: Color in Western Art: An Issue? *The Art Bulletin 72*, 4 (1990), 518–541. 1

[Gre73] GREGORY R.: *Eye and brain: The psychology of seeing.*. McGraw-Hill, 1973. 2

[Hea96] HEALEY C.: Choosing effective colours for data visualization. In *Visualization'96. Proceedings.* (1996), IEEE, pp. 263–270. 4

[HHWN02] HAVRE S., HETZLER E., WHITNEY P., NOWELL L.: Themeriver: Visualizing thematic changes in large document collections. *IEEE transactions on visualization and computer graphics* (2002), 9–20. 2

[HO72] HEIDER E., OLIVIER D.: The structure of the color space in naming and memory for two languages* 1. *Cognitive Psychology 3*, 2 (1972), 337–354. 4

[ID90] INSELBERG A., DIMSDALE B.: Parallel coordinates: a tool for visualizing multi-dimensional geometry. In *Proceedings of the 1st conference on Visualization'90* (1990), IEEE Computer Society Press, pp. 361–378. 5

[KDDL*06] KRUG K., DIK J., DEN LEEUW M., WHITSON A., TORTORA J., COAN P., NEMOZ C., BRAVIN A.: Visualization of pigment distributions in paintings using synchrotron k-edge imaging. *Applied Physics A: Materials Science & Processing 83*, 2 (2006), 247–251. 2

[KR03] KAY P., REGIER T.: Resolving the question of color naming universals. *Proceedings of the National Academy of Sciences of the United States of America 100*, 15 (2003), 9085. 4

[KvBM00] KLOCKENKAMPER R., VON BOHLEN A., MOENS L.: Analysis of pigments and inks on oil paintings and historical manuscripts using total reflection x-ray fluorescence spectrometry. *X-Ray Spectrum 29* (2000), 119–129. 2

[MM87] MICHEL R., MCGOVERN P.: The chemical processing of Royal Purple dye: ancient descriptions as elucidated by modern science. *Archeomaterials 1*, 2 (1987), 135–143. 2

[MM90] MCGOVERN P., MICHEL R.: Royal purple dye: the chemical reconstruction of the ancient mediterranean industry. *Accounts of Chemical Research 23*, 5 (1990), 152–158. 2

[NGCG07] NUNES M., GREENBERG S., CARPENDALE S., GUTWIN C.: What did I miss? Visualizing the past through video traces. *ECSCW 2007* (2007), 1–20. 2

[PC89] POST D., CALHOUN C.: An evaluation of methods for producing desired colors on CRT monitors. *Color Research & Application 14*, 4 (1989), 172–186. 3

[RDD00] ROBERSON D., DAVIES I., DAVIDOFF J.: Color categories are not universal: Replications and new evidence from a stone-age culture. *Journal of Experimental Psychology: General 129*, 3 (2000), 369. 4

[RDDS05] ROBERSON D., DAVIDOFF J., DAVIES I., SHAPIRO L.: Color categories: Evidence for the cultural relativity hypothesis. *Cognitive Psychology 50*, 4 (2005), 378–411. 4

[RFSW10] RIGAU J., FEIXAS M., SBERT M., WALLRAVEN C.: Toward auvers period: Evolution of van gogh's style. The Eurographics Association, Computational Aesthetics in Graphics, Visualization, and Imaging, 2010. 2

[Ril96] RILEY C.: *Color codes: modern theories of color in philosophy, painting and architecture, literature, music, and psychology*. Univ Pr of New England, 1996. 1

[RW88] ROORDA A., WILLIAMS D.: The arrangement of the three cone classes in the living human eye. *Acoust. Soc. Am 83* (1988), 1102–1116. 4

[Ste84] STEIN G.: *Picasso*. Dover Pubns, 1984. 6

[Sto03] STONE M.: *A field guide to digital color*. AK Peters, Ltd., 2003. 2

[Tuf91] TUFTE E.: Envisioning information. *Optometry & Vision Science 68*, 4 (1991), 322. 3

[War04] WARE C.: *Information visualization: perception for design*. Morgan Kaufmann, 2004. 2, 3

[Zan10] ZANELLA J.: My daily color palette 2010, December 2010. http://www.flickr.com/photos/jaco/sets/72157623126461021/ (Retrieved 2011-04-27). 3