

User preferences in colour enhancement for unsupervised printing methods

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ABSTRACT

In order to obtain a good quality image in preparation for inkjet printing, the process of adjusting images can be a time consuming and a costly procedure. In this paper, we consider the use of an unsupervised colour enhancement method as part of the automatic pre-processors for printing. Other unsupervised colour enhancement methods are utilised and compared: Retinex, RSR, ACE, Histogram Equalisation, Auto Levels. Test images are subjected to all of the enhancement methods, which are then printed. Users are asked compare each of the sampled images. In all cases, the results are dependent on the image. Thus, we have selected a range of test images: photographs of scenes, reproduction of prints, paintings and drawings.

Some of the tested methods are parameter dependent. We do not intend to consider fine tuning for each of the techniques, rather to consider an average parameter set for each one and then test if this approach can aid the decision process of fine tuning.

Three user groups are employed: the general user, commercial photographer expert and fine artist. Groups are asked to make a blind evaluation of a range of images (the original and the colour enhanced by the different methods); these are randomly placed. All images are printed on the same printer using the same settings. Users are asked to identify their preferred print in relation to lightness, tonal range, colour range, quality of detail and overall subjective preference.

Keywords: Colour, Enhancement methods, Image quality, Print, Art

1. INTRODUCTION

Requirements for digital image capture and reproduction range from the high end fine art printing to more general image printing of digital photographs and scans. Speed, volume, convenience may be the cited requirements, but this may be in exchange for a reduction in image and print quality. This research attempts to investigate a range of image enhancement methods that may aid the user to obtain the maximum potential of their scanned or photographed images prior to printing, or in preparation for applied print methods, or further image manipulation by the artist.

1.1 Overview of users and approaches

Methods for taking photographs, has significantly evolved over the last few years, as has the quantity of images taken. Furthermore, methods of storage, approaches in viewing and printing of photographs has also changed. There has established a genus of amateur photographer, who take photographs using a range of digital capture devices and utilise the Internet as a means of networking, sharing images and exchanging methods of working; images are viewed, however, a large proportion are rarely printed. A similar photographer group are those who upload and share digital albums such as *Flickr* or *Snapfish* via the Internet [1], who might not require images to be printed, but friends and family might access the album remotely to download and print. There is also evolving, the casual or spontaneous photographer, who use camera phones to make snapshots. It is likely that all these groups will need to process a quantity of images, which will include processing at a faster and possibly at an auto level in order to improve or enhance image quality prior to uploading.

In 1997, digital cameras hit the mass market and between 1997 and 2006, 300 million cameras were sold [2]. It is estimated that by 2008, 213 billion photos will have been taken [3], however less than 40% of the images taken are ever

printed. Although the amount of cameras was estimated to increase, the amount purchased is now on the decline; moving from double figures last year to a drop of around 7% from now until 2010 [4]. A contributing factor is the improvement to phone cameras, and in 2006, phones such as the Nokia N73, with an inbuilt 3.2 megapixel camera and Carl Zeiss optics, is outselling digital cameras by 4:1. However, it is rare that phone images are printed, but as phones can wirelessly connect to online albums, there is the option to save images and, as more camera phones are purchased, then camera manufacturers are having to focus on other services, such as storing, sharing and printing. Moreover, as handheld devices evolve as the sole device for a multiple of activities: music, email, film, still images [5], then there is also a much greater potential market for image printing.

The problem of how to manage, archive and access digital images stored on a hard drive is being partly addressed on the Internet by either sharing through the uploading of self edited albums, which are then laser printed and bound as a traditional photo album [6]. Here we return to the traditional format of printed images on paper, but possibly, as users might combine old scanned photographs along with digitally captured images, there is a need therefore for well balanced images and a consistency of image quality across the album. There is also an increasing impetus and requirement to create digital archives of, for example, artefacts, prints, artworks [7]. These are image heavy digital archives, web based sites that display or sell artworks, on line galleries and exhibitions, museums and archive libraries that require image and colour accuracy and to balance image quality with processing workflow.

A digital imaging and closed loop printing system, which is designed for the mass-market general and home photographer [8] is now well established and utilised. Closed printing loops have become a standardised printing approach employed by a variety of major manufacturers by which a camera connects directly to a printer, either through a camera/printer dock, or via a cable or memory card, resulting in coloured prints within the minute. These portable printer/camera systems remove the need for a computer, as the software, printer driver and profiles are built into the system; devices are calibrated to give quality, and in theory, well balanced images. For those wanting to correct or enhance images before printing there is a limited imaging software unsupervised application bundled with the printer. For more sophisticated requirements, a manual correction into the printing pipeline is required.

For digital darkroom artists working outside the direct camera to printer system, who might be scanning documents, creating composite images from a variety of source files, or digitally generating images that exist only on a computer, these non mainstream approaches therefore require alternative fine tuning. In most cases, the artist is unlikely to print an image straight from the camera and will require many days or weeks of reworking and retouching. This reworking is often inclusive of printing as well, proofing and editing of images is undertaken during the printing process [9] [10]. Furthermore, for the artist, the quality of the source image is of primary importance. How an image is captured or scanned is necessary to provide a good quality digital canvas on which the artist can work and therefore the quality of the capture devices are fundamental.

1.2 Previous test results

An earlier test project [11] sampled thirteen images, and included textured or collaged artworks, digitally generated or manipulated artworks, printed black and white artworks, commercial cmyk prints, newspaper images, scanned artwork, colour photographs, black and white photographs. Sampled images, using a range of ACE parameters, were printed and presented for comparison. Although there were some failures, the tests demonstrated that overall, users preferred the ACE filtered images to the original. In this test, users preferred the results of black and white images, but less so for colour. The black and white images benefited from an enhancement in tonal range and increase in detail. In some cases, the changes to colour images proved to be unsatisfactory, this might have been due to some images having a particular chromatic dominance, and after sampling, the colour was significantly changed so as to have no resemblance to the original. It was decided that, based on initial tests, further investigations for refining methods for enhancing images were required.

1.3 Rationale for choosing the images

Based on the previous test results, the images for this test therefore have been reserved to colour images, but in this instance using a range of capturing devices, images, with the objective for a range of end user requirements. As user reasons for digital capture have more far reaching objectives: documentation, collection of images for recording, uploading to Internet, dissemination of images, prints and artworks through the internet, recording of events and preparing images in preparation for printing eg. wedding or holiday albums, the process of selecting images therefore reflects these requirements. Moreover, snaps or spontaneous images by phone may be captured in an environment that is under low or artificial lighting conditions.

The intention is to consider a range of photographic conditions and reasons for image capture, such as documentation of artworks and artefacts that are poorly lit (possibly due to museum or conservation issues), conditions where flash photography is prohibited or unsuitable, scenes taken in artificial light conditions, de-saturated scenes, photography of flat artworks, objects taken against a white background and underwater photographs are sampled.

An initial set of thirty images were sampled. From these thirty, ten were chosen for printing, which was due to the other images showing similar characteristics.

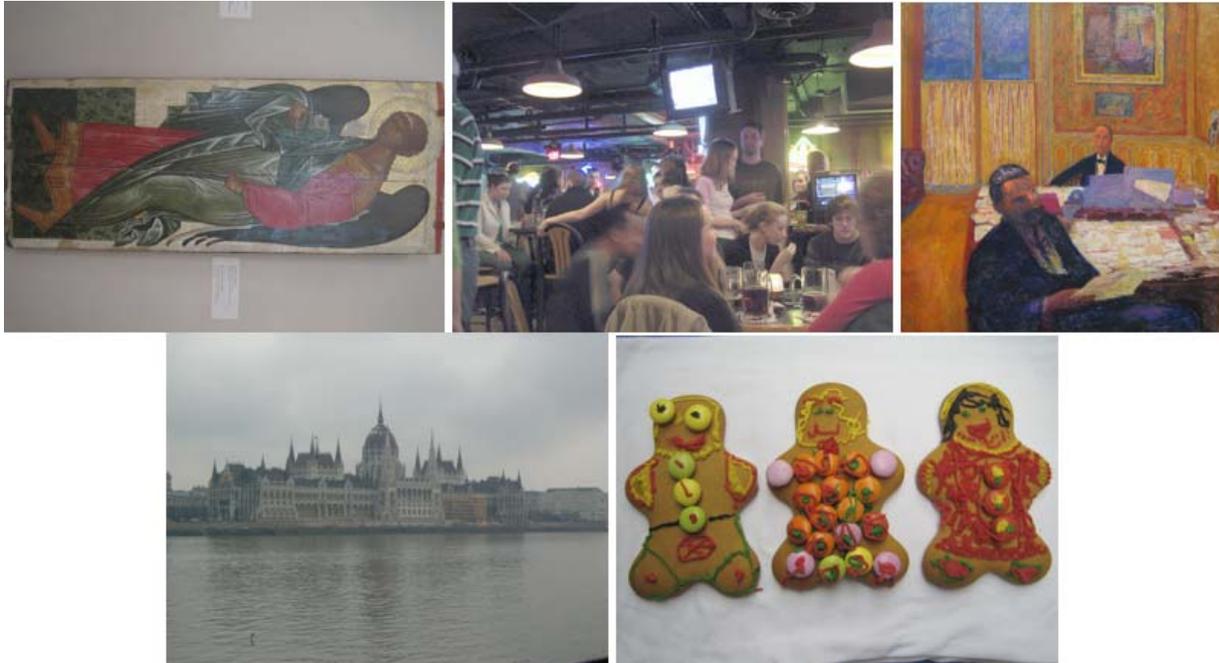


Fig.1. Examples of images to be sampled

2. DESCRIPTION OF COLOUR ENHANCEMENT METHODS

Two categories of image enhancement methods are utilised. The first are classic global enhancement methods that are included in Photoshop: histogram equalisation, auto levels. This global approach maps every pixel using the same value. The second is a spatial image enhancement approach, which is inspired by human visual system characteristics and share local colour correction characteristics. This method makes a pixel by pixel comparison to re-compute the pixels based on the context of the scene. Examples are Retinex in all its various implementations of ACE. A description of the methods used in this test are included here.

2.3 Histogram equalisation and curves

In commercial software applications, such as Photoshop, there are a range of tools for the fine-tuning of an image. Therefore, improving the dynamic range of an image can be undertaken using the histogram in Levels by changing the input and output levels; or through Curves by adjusting any point on a 0-255 tonal scale; or by assigning target values to the highlight and shadow pixels using either the Levels of Curves. Photoshop automatic tools process the image on a global level, therefore making an assessment of an image by building a histogram, and applying corrections to the whole image. As demonstrated in figure 2, by stretching the black and white points, a brighter image is obtained. In the lower image, the histogram shows peaks in the black and white and nothing in between. However, using auto levels to an image that has high contrast no improvement is made to the mid tones (Figure 2).

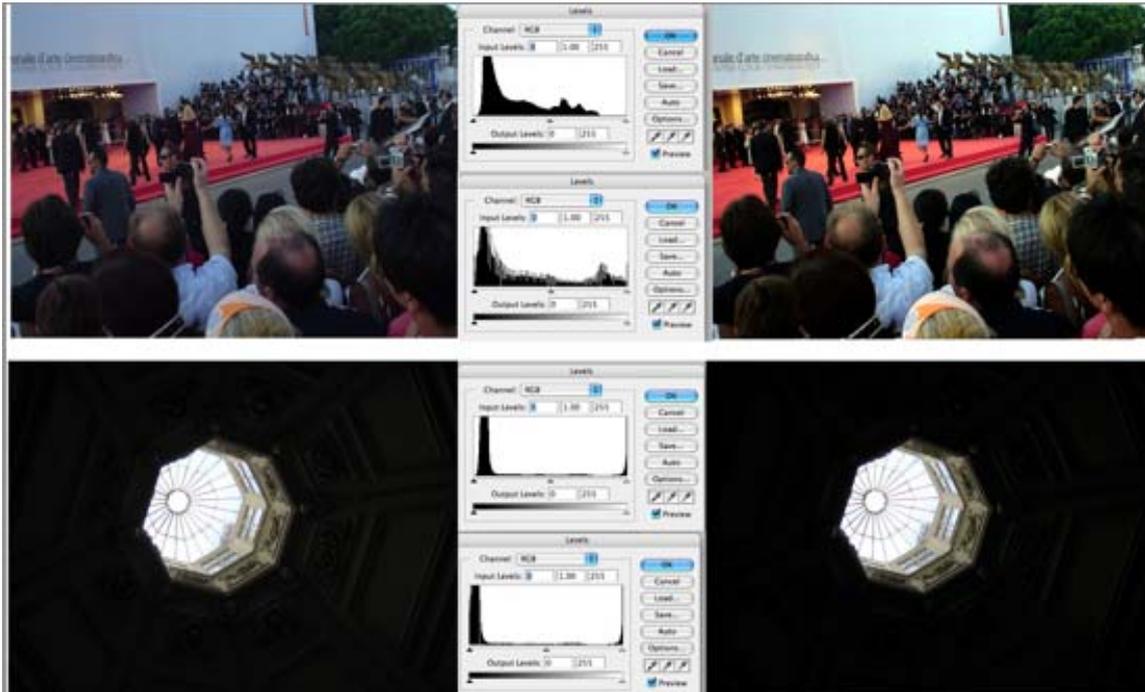


Fig. 2. Levels are useful for correcting images that are slightly imbalanced (top), unlike the image below, which benefits from other tuning parameters (see Figure 5)

2.3.1 Auto levels

Auto Levels defines the lightest and darkest pixels in each colour channel as white and black and then stretches the in-between pixel values proportionately. Because Auto Levels adjusts each colour channel individually, it may remove or introduce colour casts.

2.3.2 Auto colour

Takes an average distribution from the darkest, midtone to the lightest areas of an image, by neutralising the midtones and clipping the white and black pixels. This can be undertaken in Curves on a more precise level by assigning up to 14 points on a curve, or by using the auto levels. Because each channel is adjusted individually, the algorithm may remove or introduce colour casts.

2.1 Retinex

Based on the human colour perception system, the term is a composite of 'retina' and 'cortex'. The retinex algorithm, mimicking human vision, performs the effect of colour constancy, and is described by Edwin Land in 1971 [12] [13], which enables a viewer to perceive an object colour as similar, under different illuminations. It performs a local filtering effect according to the way it scans the input image, this basic implementation uses a random path for this purpose.

2.2 RSR

Random Spray Retinex, (RSR) is a new implementation of the original Retinex model [12], which has been inspired from the results of the mathematical analysis of Retinex performed in [14], the results are presented in [15]. In this implementation, locality is performed by random sprays of a target point rather than random paths.

2.4 The ACE model

ACE is an algorithm for unsupervised enhancement of digital images. The implementation of ACE follows the scheme as shown in figure 3: the first stage (chromatic spatial adaptation) is responsible for colour correction and the second stage (dynamic tone reproduction scaling) configures the output range, and implements accurate tone mapping.

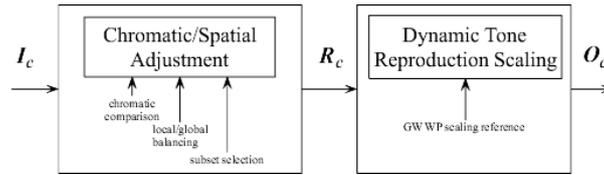


Fig.3. ACE basic scheme

In figure 3, I is the input image, R is an intermediate result and O is the output image; subscript c denotes the chromatic channel. A more detailed description of the algorithm can be found in [16] and [17].



Fig. 4. Image sampled using Auto Colour command in Photoshop (top left) and Retinex (top right), hand correction using curves (bottom left), ACE Slope 5 (bottom right)

The above figure 4 demonstrates a range of sampling. A plaster ceiling (Hampton Court Palace, London), the only light source being the domed sky light, is photographed. The original can be seen in figure 2. Here are four sampled images: on the left processed through the auto colour command in Photoshop and on the right is sampled using the Retinex algorithm. The domed skylight and surrounding panelling appear lighter, but the details of the plasterwork are more obvious. However, based on user preferences, even though there is more visual information after sampling. This is discussed in Section 4.

3. METHODOLOGY

3.1 Parameters for ACE, RSR and Retinex

The global set of parameters, are used for the test, and are shown in the following tables, with explanations for each of these parameters. Photoshop levels are not included here, as these commands have been explained in section 2.3.

Table 1. ACE Parameters

Parameter	Parameter range(s)
Subset selection	Sub-sampled at a sub-factor of LL2
Chromatic comparison	SL5 SL20 Sign
Distance	0.01

Subset selection affects mainly the speed of the computation and is not investigated in this paper.

Chromatic comparison adjusts the contrast. The higher the slope the greater the contrast and the filtering effect, therefore among the tested values, Sign produces the greatest contrast and SL5 the least [16][17]. This is the most important parameter on which the users can base their selection.

Distance affects slightly the saturation. It has a very mild effect and is not investigated in this paper. The pre-set value is used.

Scaling affects the way black tones are mapped.

WP+GW option uses the estimated mean grey value and maps it in the middle value of dynamic range, with this option part of the darker tones can be missed or compressed.

Table 2. Retinex Parameters

Parameter	Parameter range(s)
Sub sampling factor	4
Number of random paths	20
Type of path	Brownian

Table 3. RSR Parameters

Parameter	Parameter range(s)
Number of spray per pixel	5
Number of point per spray	500
Type of spray	Random

3.2 Print set-up

All the images, as exemplified in figure 6, are arranged eight sampled images to an A3 sheet in a random order. Each image is numbered at the top right hand corner of the sheet. The number of the sample appears at the bottom left hand corner of each sample (from 1-8). There is no indication on the printed sheets of the parameter ranges. Based on previous print test experiments, optimum output and printer settings are determined. All images are printed at an image file resolution of 200dpi using the same printer profiles and paper: PostScript colour management, with perceptual rendering intent, and using an HP Photosmart Pro B9180 printer onto HP Premium Gloss Photo paper. Using the HP printer dialogue box, the paper profile, rendering quality are also the same: HP Premium Plus Photo, and normal quality and printed using the Adobe RGB colour option.

3.3 Questionnaire

Users were asked examine ten A3 sized sheets, containing eight sample variations of the same image on each page. Users were asked to consider the questions and select the sample that best answered each question.

1) Which image seems more natural?

- 2) Which is the closest to your personal preference?
- 3) Which offers the most details?
- 4) Which has the widest tonal range?
- 5) And which is the tonal range most preferred?

The background of the user was also taken into account:

What is your age? What is your sex? Do you have a colour deficiency? Do you wear glasses? If so are you long sighted, short sighted, have an astigmatism?

And, the user's background experience: technical/scientific, commercial photographer/printer, fine artist, general/hobby/domestic photographer

4. RESULTS

4.1 Anticipated responses from the tests

When undertaking psychophysical experiments, there are expectations by the tester as to what might be the outcomes; hopefully a positive response. The following section attempts to provide some indication of the preferences, prior to calculating the results. Two printed sheets are discussed here in relation to the first two questions: 1) Which image seems more natural? and, 2) Which is the closest to your personal preference? The first question assumes that even though the scene is poorly lit the most natural image might be of a quality that is close to the assumed conditions in which the image is taken: a photograph taken inside a church is more than likely to have low light levels. However, on a practical level, gaining more visual information, and based on an image that is more pleasing, then the assumption would be to choose an image that is not based on the brightest such as sampled version (a), but the anticipation is that user preferences would be more inclined more to a median brightness and colour quality, such as versions (b). Or, personal preferences may be based on a more subjective criteria to create a mood or atmosphere, that is not based on the brightest, most colourful, or showing the most amount of information.

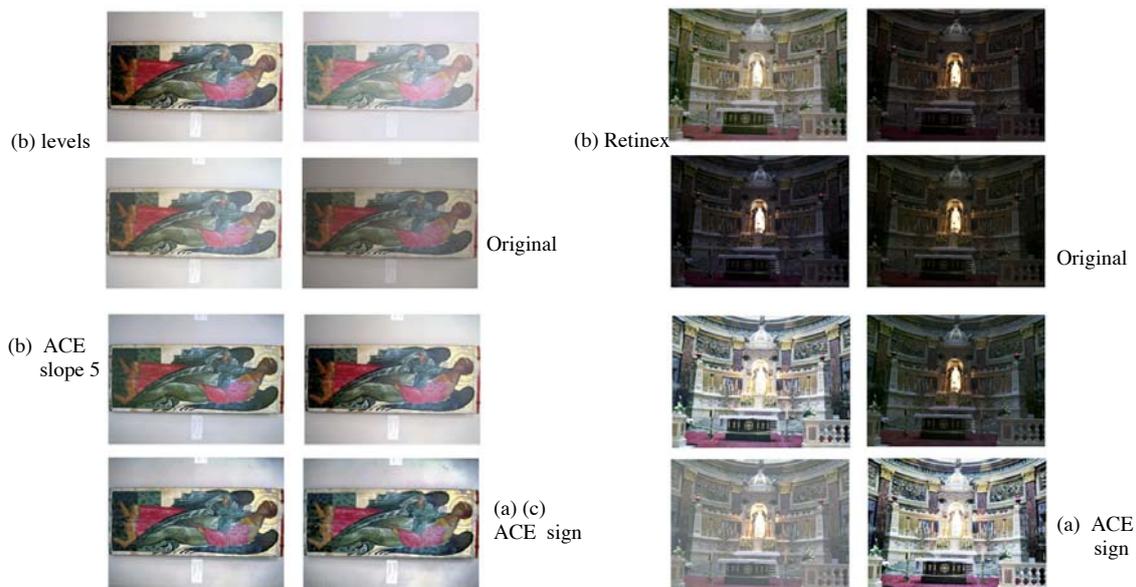


Fig. 5. Examples of two printed sheets, 8 sampled images are placed in a random order.

The figures show two images taken under different lighting conditions. The first “Angel”, is a painting on a wood panel, which is displayed in a museum where flash photography is not permitted and therefore the original appears de-saturated and dull. Similarly, inside “Church”, where flash is disallowed, the only light source is the illuminated figure and the surrounding environment is in darkness. Gold is a colour that is particularly difficult to reproduce and print, and so the balance or brightness of gold in relation to the rest of the image might be considered as: too bright, overpowering, too

dull, not convincing as gold. The red might also be an aspect that is subject to comparison: the red tunic of the figure, the red line along the top of the painting; the red of the carpet around the altar, the red lights on either side of the altar. Does the red in both the images stand out as dull, balanced or too bright? Lastly, large flat areas of chromatic dominance, which contains little information is problematic: for example, where art works are photographed against a white background or where the light source is uneven, might results in pooling or halos of light. This is particularly obvious in (c).

4.2 Results

The following tables show the total responses from 24 users. In table 4, the columns, Original SL5, SL20 SIGN, RSR, Retinex, Auto levels, Auto Colour, show the total number user preferences

Table 4. Total number of user preferences

	Original	ACE slope 5	ACE slope 20	ACE sign	RSR	Retinex	Auto levels	Auto colour
Total	56	95	151	182	171	52	232	261

This is separated into the two categories of image enhancement methods: global (Auto Levels, Auto Colour) and spatial (SL5, SL20 SIGN, RSR, Retinex).

Table 5. Totals according to global and spatial image enhancements

	Global (Auto Levels, Auto Colour)	Spatial (SL5, SL20 SIGN, RSR, Retinex).
Total	493	651

In order to further refine user preferences according to image, the following tables show the preferences according to image. Small images are included to illustrate the type of image, tonal and colour content.

Table 6. “Underwater”

Question	Most preferred	
1) Which image seems more natural?	auto levels	
2) Which is the closest to your personal preference?	auto levels	
3) Which offers the most details?	rsr	
4) Which has the widest tonal range?	auto levels and rsr	
5) And which is the tonal range most preferred?	auto levels and rsr	

Table 7. “Oil Painting”

Question	Most preferred	
1) Which image seems more natural?	auto levels	
2) Which is the closest to your personal preference?	auto levels	
3) Which offers the most details?	auto levels and ace sign	
4) Which has the widest tonal range?	auto levels	
5) And which is the tonal range most preferred?	auto levels	

Table 8. "Skylight"

Question	Most preferred	
1) Which image seems more natural?	auto colour	
2) Which is the closest to your personal preference?	ace sign and rsr	
3) Which offers the most details?	ace sign	
4) Which has the widest tonal range?	ace sign	
5) And which is the tonal range most preferred?	ace sign	

Table 9. "Drawing"

Question	Most preferred	
1) Which image seems more natural?	rsr	
2) Which is the closest to your personal preference?	rsr	
3) Which offers the most details?	auto levels	
4) Which has the widest tonal range?	auto levels	
5) And which is the tonal range most preferred?	rsr	

Table 10. "Gingerbread"

Question	Most preferred	
1) Which image seems more natural?	auto colour	
2) Which is the closest to your personal preference?	rsr	
3) Which offers the most details?	rsr	
4) Which has the widest tonal range?	auto levels and auto colour	
5) And which is the tonal range most preferred?	rsr	

Table 11. Church

Question	Most preferred	
1) Which image seems more natural?	auto colour and retinex	
2) Which is the closest to your personal preference?	retinex	
3) Which offers the most details?	ace slope 20 and ace sign	
4) Which has the widest tonal range?	ace sign	
5) And which is the tonal range most preferred?	retinex	

Table 12. Club

Question	Most preferred	
1) Which image seems more natural?	auto colour	
2) Which is the closest to your personal preference?	auto colour	
3) Which offers the most details?	ace sign	
4) Which has the widest tonal range?	ace slope 20	
5) And which is the tonal range most preferred?	auto colour	

Fig.13 “Angel”

Question	Most preferred	
1) Which image seems more natural?	ace slope 5	
2) Which is the closest to your personal preference?	ace slope 5	
3) Which offers the most details?	ace sign	
4) Which has the widest tonal range?	ace slope 20, ace sign and auto colour	
5) And which is the tonal range most preferred?	ace sign	

Table 14. “St. Petersburg”

Question	Most preferred	
1) Which image seems more natural?	ace slope 5	
2) Which is the closest to your personal preference?	ace slope 20	
3) Which offers the most details?	ace slope 20	
4) Which has the widest tonal range?	ace slope 20	
5) And which is the tonal range most preferred?	ace sign	

Table 15. “Venice Film”

Question	Most preferred	
1) Which image seems more natural?	auto colour	
2) Which is the closest to your personal preference?	auto colour	
3) Which offers the most details?	auto colour	
4) Which has the widest tonal range?	auto colour	
5) And which is the tonal range most preferred?	auto colour	

5. CONCLUSION

Although there are a large total number of preferences for auto colour and auto level methods of image enhancement, when viewing the figures on an overall basis, there is a greater preference for spatial methods of image enhancement. By refining the responses according to image, we begin to gain a better understanding as to which image enhancement methods are better for particular photographic conditions. In this context, there is more of an even spread of user preferences including RSR and ACE. This is also illustrated in the two test examples as explored in 4.1 (figure 5) and corresponding tables 11 and 13 for which ACE and Retinex, as well as Auto colour methods are preferred. Moreover, these preferences are also cross checked according to the background of the user to ascertain whether preferences differ according to technical, hobby, commercial photographer or fine artist. The data shows similar responses: samples were selected according to that which appears to be the most natural, has the widest tonal range, and has a greater amount of detail. However, as exemplified in “Club”, “Church” and “Oil Painting” users selected samples that were not necessarily the brightest or the most colourful, unlike the most preferred sample in “Angel”, which is the brightest, contains the most contrast and shows the most amount of gold.

Results therefore demonstrate that there is a spread of preferences, according to the type of image being considered, with a greater positive response to spatial methods of image enhancement.

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