The Effects of Light Intensity on Tracing Digital Image into Vector Image

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Abstract

This paper aims to study the effects of light intensity on the digital image production, and therefore the accurate reproduction of details when tracing this digital image to the vector image.

The paper used experimental and analytical methods to study the light intensity as the independent variable through the dependent variables "lens aperture, sensitivity speed (ISO)" and shutter speed. Next, the digital images obtained from the experiments were auto traced to vector images. Then, the results were measured and analyzed.

While the results were identical to the hypotheses related to lens aperture and sensitivity speed (ISO) experiments, **t**he shutter speed experiment results did not match the hypothesis: there is no change in the details of the vector image created through the variables shutter speed in the digital image. Therefore, using fast shutter speeds is recommended to increase the accuracy of the vector image details produced through the digital image.

Keywords

light intensity; Image trace; digital image; vector image; photography.

ملخص البحث:

هذا البحث يهدف إلى دراسة تأثير تغير شدة الإضاءة على الصورة الرقمية المستخدمة لإنتاج صورة متجهة. وذلك لتحسين جودة تفاصيل الصورة المتجهة الناتجة عبر عمليات إعادة الرسم إلكترونيا (Image Trace) للصورة الرقمية.

ولتحقيق هذا الهدف فقد استخدم البحث المنهج التجريبى لدراسة أثر تغيير شدة الإضاءة كمتغير مستقل، من خلال المتغيرات التابعة (فتحة العدسة، سرعة الحساسية ISO، وسرعة الغالق)، ثم تحويل الصورة الرقمية الناتجة إلى صورة متجهة عبر إعادة رسم الصورة إلكترونيا مع ثبات إعداداتها، وقياس النتائج وتحليلها.

وكانت نتائج البحث مطابقة للفروض في حالة زيادة تفاصيل الصور المتجهة الناتجة من الصور الرقمية التى تم زيادة ضيق فتحة العدسة بها، أو زيادة سرعة حساسيتها.

إلا أنها خالفت الفرض بثبات نسبة تفاصيل الصور المتجهة الناتجة من الصور الرقمية التى تم تغيير سرعة الغالق بها، حيث كانت هناك زيادة في تفاصيل الصورة الناتجة تبعا لزيادة سرعة الغالق.

لذا فإنه يوصى بإستخدام فتحات عدسة ضيقة، مع سرعات حساسية بطيئة، مع سرعات غالق عالية، لزيادة دقة تفاصيل الصورة المتجهة المنتجة عبرعمليات إعادة الرسم إلكترونيا للصورة الرقمية.

DOI: 10.12816/0044835

Introduction

Many cases require converting (tracing) the digital image into a vector image, such as technical drawing, logo design, clip art, backgrounds of graphic designs, abstract designs, and digital painting. Furthermore, it requires the ability to produce a small file size and enlargement without the pixelization in the digital image (raster) because they are based on geometric shapes or drawn with simple curves.

But, to control a successful conversion from raster to a vector image, there are many factors that should be adjusted, like the intensity of light, colors, contrast, definition, dynamic range, and resolution. This paper will focus on the intensity of light sources to produce a digital image that could improve the image tracing process.

Considering that photography is the method of creating an image by converting variables of light intensity or other electromagnetic radiation reflected from subjects to variable densities of electric signals in the image sensor or silver halides in photographic film. The variables of light intensity reflected from the subjects are based on the amount of light intensity have fallen on them. The levels of light reflectance change according to the colors, tones, textures, and angle of the light fall to the objects. So, to produce a correct exposure digital image means that the densities of the image match the densities in landscape lighting, as they appear to the human eye.

But, increasing the light intensity is compensated by exposure factors, such as lens aperture, shutter speed, or ISO. Therefore, despite the increasing light intensity, the resulting image remains with the appropriate densities to what appear to the human eye. Exposure factors also have the ability to change some densities at the expense of other densities, which may help to improve the vector image production and more path details. In addition, the other possibilities have direct effects on the vector image production, such as motion blur, which is controlled by shutter speed or depth of field, which is controlled by lens aperture.

This paper hypothesizes to improve converting the digital image into a vector image through increasing light intensity will influence the fine details production in the digital image, and therefore when converting the digital image to a vector image, by decreasing diameter of lens aperture and sensitivity speed (ISO). However, there is no change in the details of the vector image created through the variables shutter speed in the digital image.

The experiments were designed to study the light intensity as the independent variable through the dependent variables "lens aperture, sensitivity speed (ISO)" and shutter speed. Next, the digital images obtained from the experiments were auto traced to vector images. Then, the results were measured and analyzed, by considering the lengths of the paths as an indication of the details magnitude produced in the vector image. The number of anchor points used as a reference for the accuracy of details and the number of colors used as a reference for the color reproduction accuracy.

1. Vector Image

The vector image consists of objects that built from lines, anchor points, and vectors, through employ mathematical equations that contain the points positions, outline, directions, and color information. Vector image called also object oriented image, or vector graphics. Vector graphics are resolution independent, which means that they can be freely moved or modified while not losing detail or clarity; they retain crisp edges when enlarged. Thus, the appearance of a vector image doesn't change when it is moved, resized, or reshaped [1].

The vector image created through software designed to form this complex, object oriented image, defined by lines formed through anchor points positions, line lengths, curves, and color value.

Considering vector images have both magnitude, in the meaning of size or quantity, and orientation. Which they are produced as a graphics using a method called 'directed line segments,' which means that the line length is providing the size of the vector representation and the vector's direction.

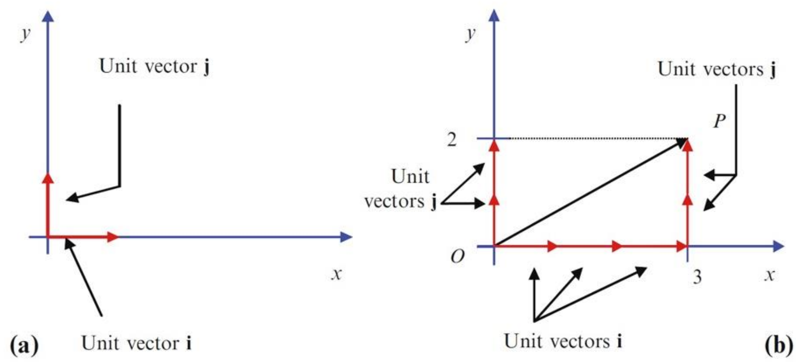

Figure 1 vector in 2-D space

Vector arbitrary in two-dimensional space may define using a pair of perpendicular units vectors. This unit vector, sometimes called normalized vector, is a standard vector space for one unit in length. One vector directed in parallel with the x-axis and the other vectors guided in conjunction with the y-axis, which shown in Figure (1a). The former usually allocated the ‘i’ symbol and the latter the ‘j’ symbol. Considering the vector ‘OP’ which explained in Figure (1b), the former may be driven from ‘O’ to ‘P’ through moving three units over the x-axis and moving two units over the y-axis. ‘That looks like set three cases of the vector ‘i’ and two cases of the vector ‘j’ end to end. Thus, we can create the vector ‘OP’ as: **OP** = 3**i** + 2**j’** [2].

The Bézier curve is defined as “a parametric curve that is a polynomial function depending on the points amount used to define the curve”[3]. This process implements control points and creates an approximating curve. This curve is already attracted to the interior points, does not pass over them; it is as if the points trying to drag the curve to them magnetically. Each point effected in the direction of the curve by pulling it toward itself, and that impact is most powerful when the curve becomes too close to the point.

Figure (2) presents some samples of cubic Bézier curves. For example, a curve is defined by four points and is a cubic polynomial. It is worth noting here is that one has a bump and another one has a loop. The fact that the curve doesn't pass through the points implies that the points are not rigid in its place and can be moved. This makes it easy to edit, modify, and reshape the curve, which is the famous reason for its popularity. The curve can also be modified by adding or deleting points [3].

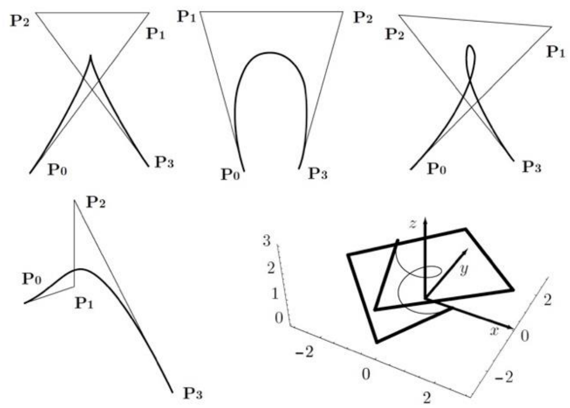

Figure 2 Four examples of cubic Bézier curves

2. Advantages of a vector image

There are many differences between raster and vector image. The first main difference is the image structure, while the raster image is composed of pixels (shortcut for picture element) organized within a grid and defined by the location and color value of each pixel in the grid [1]. The vector image is represented using paths-geometric areas defined by points, lines, curves, and shapes [4].

The second difference is scalability. While the raster image is resolution-dependent, which means it provides photo-realistic that need to variations of mixed color, it is hard scalable neither increasing the size. The result of increasing all single pixels in raster image making lines and forms represented rough and thick, much like the stairs shape. While in case of reducing the raster image size it is also being distorted because the pixels are removed to decrease the image size [5]. The ideal size of the image depends on its complexity, the amount of visual information, and the viewing distance [6]. But, the vector image is resolution-independent, which means the image can be resized without losing detail or clarity. The quality stays the same with crisp edges no matter what image size is used [7].

The third difference is the functional suitability, while the raster image is the best format for low- resolution monitors. It is used in digital photography, video, and web pages. The vector image is the best format for high- resolution printing and pre-press applications; it is also used in render-ing 2D or 3D computer animation [4].

The fourth difference is color depth, while the raster color image consists of a huge number of colors required to reproduce the original scene accurately [8]. Every pixel in a raster image is the same size and contains a single color value stored as a 24-bit color depth (16 million colors) [4]. A vector image has a lower color depth because fewer total variations of color are used, and therefore the file sizes of vector images are small [7].

The fifth difference is file size, while the raster image file is enormous in size because of a large amount of data, including the location and color value of each pixel in the image structure [8]. So, the high resolution (dpi) and more colors should produce bigger raster image file sizes. The vector image has a small file size, which does not take up a lot of storage space because it contains only mathematical description of the lines, anchor points and curves which shaped the objects [5].

3. Vectorization (Image Tracing)

Vectorization (raster-to-vector conversion), also known as image tracing, is the process of inputting a digital (raster) image and transforming it into a vector image representation. The raster-to-vector conversion extracts all objects from the raster image and represents them with middle lines or contours lines. The middle lines expressed as coordinates and vectors joining their component points. The characteristics of the components can also be added.

In automatic, computerized raster-to-vector conversions, the raster image passes through some defined stages to reach the required target representation in the vector form. These stages are “noise reduction, image contouring or thinning, feature extraction, object approximation, and formation of a vector representation” [9].

No tracing process is perfect in the absolute sense of producing photo-realistic vector images, and all vectors are not created to be equal. There are many issues that should be considered before raster-to-vector conversion to obtain a photo-realistic vector image.

One of the most common problems in photo-realistic vector tracing is the low quality of the raster image. Even if the image looks ready to convert, there may be problems that aren't immediately visible [10]. There are many different image tracing software that have many preferences that influence the results like lines at any angle, curved lines, and several line weights (thick and thin for objects or dimension lines).

A different issue is the number of colors in the image pixels. Even with images created as black-and-white drawings, it may consist of many shades of gray pixels. Some line-drawing methods use anti-aliasing pixels; that means the pixels are completely covered by the black line, but the pixels only partially covered will be gray. If the original image is scanned from paper, there is a similar result; the edge pixels will be gray.

The result of most tracing software consists of cubic Bézier curves. A region boundary approximates with several curve segments. To keep a curve smooth, the joints of two curves are compelled so the tangents match [11], but because of control points affecting the curve, this can be a disadvantage when designing smooth shapes with the Bézier curves [12].

Image tracing software, such as Adobe Image Trace, eligible to create a complex vector graphics from raster images as input. They basic operation idea is by segmenting an input raster image into zones of solid or varying color and appropriate polygons on these primitives. Although these tools are producing impressive results in uniform regions, the segmentation usually generates a huge number of primitives in smooth regions.

"The ArDeco (Automatic Region Detection and Conversion) system allows vectorization of more complex gradients using existing linear or radial gradient primitives. It is based on a segmentation of the input image into regions of varying color, and an estimate of color variations within each region with linear or quadratic gradients. The resulting primitives are fully compatible with the SVG standard, but the approximation tends to produce sharp color transitions between segmented regions" [13]. To avoid these limitations which adopted by the SVG format, Adobe Image Trace, and other software (Inkscape, and CorelDraw), a simple solution by re-blur the image when vector primitives have rasterized.

Recently, a gradient meshes have been introduced to address these cases through expanding users permissions to define colors shades on the quad mesh vertices, then interpolating these shades over the mesh surfaces [14].

4. Methods

Considering, light intensity in photography refers to illuminance or illumination, which measured the brightness of illuminated surface by lux. Lux is the quantity of visible light emitted by a source incident on a surface [15]. So, to produce a photographic image with correct exposure (produce acceptable shadow and highlight detail in the image), the light intensity (illumination) should measure and then adjust the exposure factors: lens aperture, shutter speed, and ISO sensitivity, depending on the measured light intensity. Taking into consideration the reciprocity law, which is the logical relationship between the length of exposure time and the intensity of light, it states that an increase in one is balanced by a decrease in the other [16].

To study the effect of light intensity on the digital image and converting it to the vector image, there three experiments were designed to investigate this effect by changing the lens aperture, sensitivity speed ISO, and shutter speed. So, the light intensity is the independent variable in each experiment with fixing all the exposure factors as controlled variables except for the one under test as the dependent variables. Then, the produced digital images were auto-traced to vector images by using the Image Trace function through defined settings. These procedures were followed to study the effect of each factor on the produced vector images.

The experiments (4.1) and (4.2) are designed to examine the hypothesis: to improve converting the digital image into a vector image through increasing light intensity will influence the fine details production in the digital image, and therefore when converting the digital image to a vector image, by decreasing diameter of lens aperture and sensitivity speed (ISO). Because of the produced details growth in vector image in the experiment (4.1), is depending on the sharpness of details in the digital image, which is a result of using deeper depth of field (decreasing diameter of lens aperture). And the produced details growth in vector image in the experiment (4.2), is depending on the increase of noise production in the digital image, resulting from increased ISO.

The experiment (4.3) is designed to examine the hypothesis: there is no change in the details of the vector image created through the variables shutter speed in the digital image. Because of the various shutter speed affects on the moving objects only to control the effect of motion blur, this has no effect on stationary objects.

Consequently, all experiments were performed by photographing a set of three-dimensional fixed objects that were selected based on the diversity of colors and the magnitude of fine details, indicated in Figure (3). With fixing of the camera type, position and the using of the normal lens.

Figure 3 the experiments sample image

Four continuous high-luminance LED lighting sources, Godox SL-200W used to illuminate the scene, everyone offers 12000 LUX at 1 meter (100% output), with dimmer switches to adjust light intensity range from 10% to 100%, as well as the use of a removable barrier from the white cloth to increase the range of light that could produce.

Also, light meter SEKONIC L-478D-U used to measure the light intensity by LUX in addition to exposure factors.

Table 1 The averages of light intensity measurements

No	Minimum Illumination (LUX)	Maximum Illumination (LUX)	Lens Aperture	Average Illumination (LUX)
1	800	1000	2	900
2	1000	1600	2.4	1300
3	1600	2000	2.8	1800
4	2000	3000	3.2	2500
5	3000	4200	4	3600
6	4200	6000	4.8	5100
7	6000	8300	5.6	7150
8	8400	12000	6.7	10200
9	12000	17000	8	14500
10	18000	24000	9.5	21000
11	25000	35000	11	30000
12	36000	49000	13	42500
13	50000	70000	16	60000
14	70000	94000	19	82000

To determine the light intensity suitable for each exposure, so that there is no tolerance proportion in the selection, to ensure the objectivity of the results. The minimum and maximum limits of light intensity were measured for each exposure in the range of 1/2 lens aperture, as indicated in Table (1). And then calculated averages for these measurements and recorded them, to adjust the light intensity values in experiments to these averages values. Exposure experiments were also performed through full-lens aperture (2. 2.8, 4, 5.6, 8, 11, 16) rather than half the aperture, to ensure the transition of experiments through luminance multipliers only, as usual in photography.

The objects in experiments photographed by using Canon 5D Mark III DSLR with normal lens EF50mm f/1.4, the resolution has 22.3 MP (5760 X 3840), Full-Frame CMOS image sensor, image type 14-bit RAW (CR2 Canon original), and used 5500K white balance.

After transferring the RAW images to MacBook Pro 2.9 GHz quad-core Intel Core i7, they opened them using Adobe Photoshop CC 2017 software, with choice "As Shot" to avoid modifications in all images. They are then saved in TIFF format, which could be imported in the Adobe Illustrator CC 2017 software to auto trace them to vector images by using Image Trace function through defined settings, as follows: Mode: Color, Palette: Full Tone, Colors: 100%, Paths: 100%, Corners: 100%, Noise: 1 pixel, Method: Abutting (Creates cutout paths), Options: Snap Curves to Line.

After the vector image had formed, the vector objects metadata saved as a text file through the document info panel. The objects information file explained the data of all objects especially for this study, like paths number, the number of anchor points, paths length, compound paths, and the number of generated colors. But the relevant information for vector image measurements in this paper are the lengths of the paths as an indication of the details magnitude produced in the vector image, the number of anchor points used as a reference for the accuracy of details and the number of colors used as a reference for the color reproduction accuracy.

4.1. The effect of variable light intensity through variable lens aperture

Table 2 Experiment 4.1 conditions

No	Illumination	Lens Aperture	Shutter Speed	ISO
1	900	2	90	100
2	1800	2.8	90	100
3	3600	4	90	100
4	7100	5.6	90	100
5	14500	8	90	100
6	30000	11	90	100
7	60000	16	90	100

The experiment 4.1 was designed and implemented to study the effect of variable light intensity through variable lens aperture on digital images production, and therefore tracing this images to vector images. The exposure factors of shutter speed and ISO were controlled variables, and the lens aperture was changed according to a variable light intensity to obtain the "correct exposure" of digital images.

According to the predetermined standards in Table (1), a seven-digital image was produced with light intensity multiples as indicated in Table (2). Table (2) also describes the conditions of each image captured in the experiment.

The RAW images were transferred to the computer, opened using Adobe Photoshop CC 2017 software, saved in a TIFF format, and imported into Adobe Illustrator CC 2017 software in order to trace them to vector images. The vector images were saved in the .ai format, and the vector objects' data were saved as txt files.

4.2. The effect of variables light intensity through variables ISO

The experiment 4.2 was designed and implemented to study the effect of variable light intensity through variable image sensor sensitivity speed (ISO) on digital images production, and therefore tracing this images to vector images. The exposure factors of shutter speed and lens aperture were controlled variables, and the ISO speed was changed according to a variable light intensity to obtain the "correct exposure" of digital images.

Table 3 Experiment 4.2 conditions

No	Illumination	Lens Aperture	Shutter Speed	ISO
1	900	8	750	12800
2	1800	8	750	6400
3	3600	8	750	3200
4	7100	8	750	1600
5	14500	8	750	800
6	30000	8	750	400
7	60000	8	750	200

According to the predetermined standards in Table (1), seven digital images were produced through light intensity multiples as indicated in Table (3), which explained the conditions of each image captured in the experiment. Then, the same procedures were followed as in experiment 4.1.

4.3. The effect of variables light intensity through variables Shutter Speed

The experiment 4.3 was designed and implemented to study the effect of variable light intensity through variable shutter speed on digital images production, and therefore tracing this images to vector images. The exposure factors of ISO speed and lens aperture were controlled variables, and the shutter speed was changed according to a variable light intensity to obtain the "correct exposure" of digital images.

Table 4 Experiment 4.3 conditions

No	Illumination	Lens Aperture	Shutter Speed	ISO
1	900	8	6	100
2	1800	8	10	100
3	3600	8	20	100
4	7100	8	45	100
5	14500	8	90	100
6	30000	8	180	100
7	60000	8	350	100

According to the predetermined standards in Table (1), seven digital images were produced through light intensity multiples as indicated in Table (4), which explained the conditions of each image captured in the experiment. Then, followed the same procedures as in experiments 4.1. And 4.2.

Results and Discussion

The results of the experiment (4.1), which studied the effect of variables' light intensity through variables lens aperture on digital images traced to vector images are indicated in Table (5). It shows that there is a steady increase in the number of anchor points, the length of paths, and the number of colors depending on the lens aperture reduction.

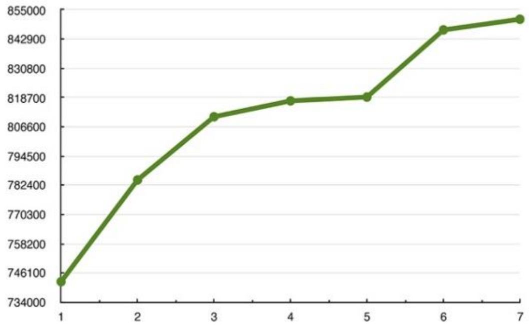

Figure 4 The relation between lens aperture and the number of anchor points in experiment 4.1

Table 5 The analysis of experiment 4.1

No	Lens Aperture	Anchor points	Paths Length mm	Colors
1	2	742528	342077.06	10688
2	2.8	784593	354254.88	11504
3	4	810728	362377.414	12959
4	5.6	817289	363760.289	14688
5	8	818869	364061.546	16556
6	11	846632	380134.272	16909
7	16	851048	387840.648	16990

The graph in figure (4) shows the effect of the variation in the lens aperture on the number of anchor points in the vector images. The graph in figure (5) shows the effect of the variation in the lens aperture on the length of paths in the vector images. The graph in figure (6) shows the effect of the variation in the lens aperture on the number of colors in the vector images.

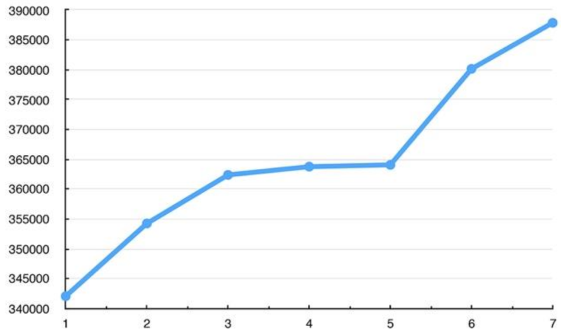

Figure 6 The relation between lens aperture and the length of paths in experiment 4.1

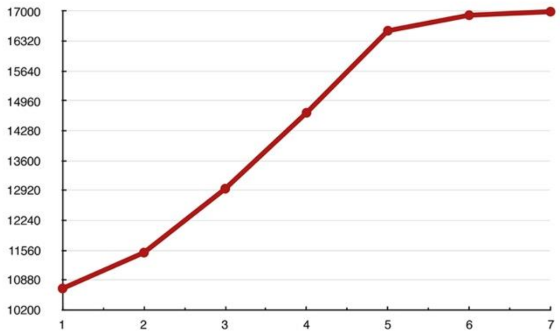

Figure 6 The relation between lens aperture and the number of colors in experiment 4.1

The results of the experiment (4.1) match the hypothesis: There is an increase in the details of the vector image produced through the diameter of lens aperture reduction (increase aperture number) in the digital image. These results are due to the additional effect of lens aperture diameter reduction, which is the depth of the field, that affects in increasing the zone of sharpening objects through the depth of the digital image and thus improves the details accuracy of the produced vector image.

Table 6 The analysis of experiment 4.2

No	ISO	Anchor points	Paths Length mm	Colors
1	12800	1135239	466299.122	27942
2	6400	1034532	435340.221	21445
3	3200	956282	404496.78	19744
4	1600	912402	393572.71	18825
5	800	880772	385409.064	17931
6	400	874168	383048.798	17323
7	200	863083	377863.977	16970

The results of the experiment (4.2), which studied the effect of variables' light intensity through variation of sensitivity speed (ISO) on digital images traced to vector images, are shown in Table (6).
An increase in ISO led to a steady increase in the number of anchor points (Figure (7)), the length of paths (Figure (8)), and the number of colors (Figure (9)) in the vector image.

The results of the experiment (4.2) support the hypothesis: There is an increase in the details of the vector image produced by an increase of ISO in the digital image. However, these results are due to the additional effect that increased ISO has on increasing image noise.

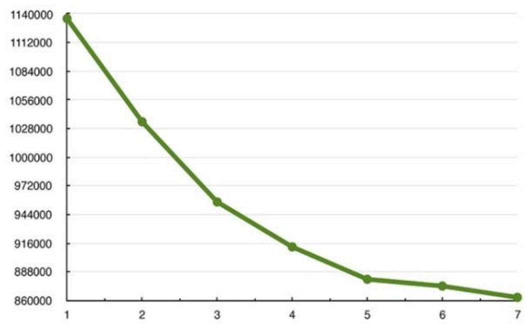

Figure 7 The relation between ISO and the number of anchor points in experiment 4.2

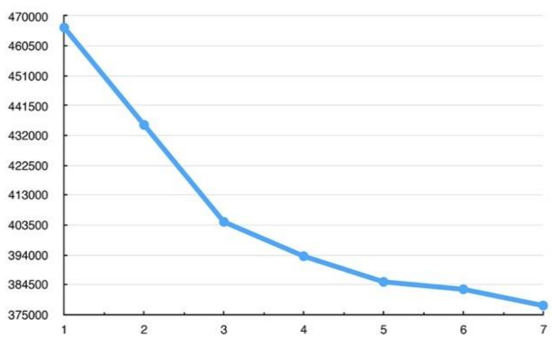

Figure 9 The relation between ISO and the length of paths in experiment 4.2

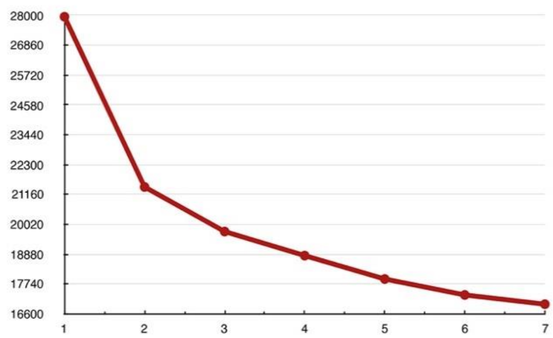

Figure 9 The relation between ISO and the number of colors in experiment 4.2

Noise are small random dots that may appear on the image that are not objects, which are caused due to an interference of electronic signals in the image sensor, and thus increase unwanted details in the final vector image. Then, to increase the accuracy of the details of the paths produced in the vector image, there is a need to use slower sensitivity speeds (ISO)

Table 7 The analysis of experiment 4.3

As for the results of the experiment (4.3), which studied the effect of variables' light intensity through the variables' shutter speed on digital images traced to vector images, there are no side effects, as the depth of the field like in the experience (4.1) or the noise as in the experience (4.2). The side effect of the shutter speed is, in the case of photographing moving objects, by controlling the effect of motion blur or freezing the image of the objects. However, it has no side effect on the image of the fixed objects, and therefore, the experiment (4.3) should match the hypothesis: There is no change in the details of the vector image produced through the variable shutter speed in the digital image, but, the results of the experiment (4.3) contradict this hypothesis. Where the results were shown, as indicated in Table (7), there is a steady increase in the number of anchor points, the length of paths and the number of colors depending on the acceleration of shutter speed.

The graph in figure (10) shows the effect of the variable shutter speed on the number of anchor points in the vector images. The graph in figure (11) shows the effect of the variable shutter speed on the length of paths in the vector images. The graph in figure (12) shows the effect of the variable shutter speed on the number of colors in the vector images.

No	Shutter Speed	Anchor points	Paths Length mm	Colors
1	6	762416	347291.772	12595
2	10	786527	351515.607	13699
3	20	802561	360193.27	14241
4	45	811831	362788.188	15389
5	90	825947	368198.321	16388
6	180	844047	375287.963	17078
7	350	863755	387861.177	17235

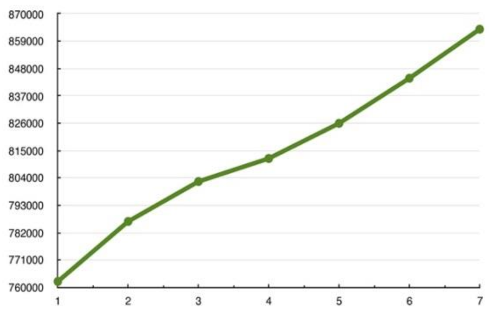

Figure 10 The relation between shutter speed and the number of anchor points in experiment 4.3

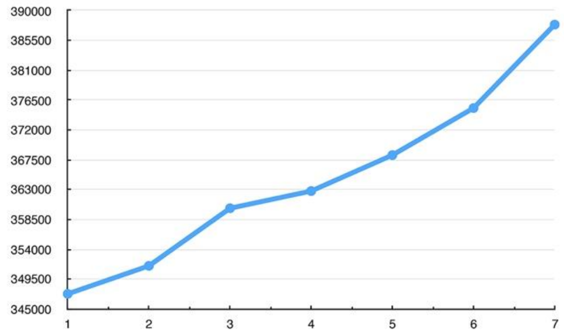

Figure 12 The relation between shutter speed and the length of paths in experiment 4.3

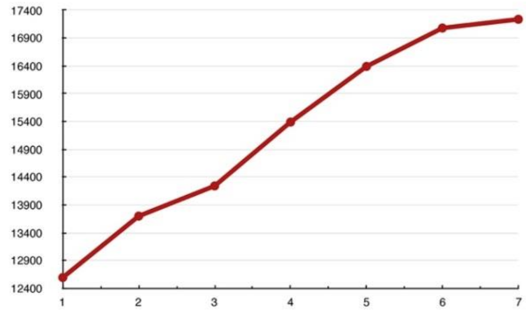

Figure 12 The relation between shutter speed and the number of colors in experiment 4.3

However, to confirm the credibility of the experiment (4.3) results, an additional experiment was designed to ensure that there were no side effects, such as a difference in shadows intensity, or different lighting zones on the background. The additional experiment (4.4) was performed by processing the same digital images used in the experiment (4.3) so that all shadow and background details were deleted and only objects were retained.

Table 8 The analysis of experiment 4.4

No	Shutter Speed	Anchor points	Paths Length mm	Colors
1	6	339012	171482.178	12170
2	10	346374	172427.846	13017
3	20	354906	175743.566	13416
4	45	365984	178821.414	14284
5	90	373538	179463.486	15248
6	180	378730	182597.079	16132
7	350	383222	189022.073	16431

The results of the experiment (4.4) confirmed the results of the experiment (4.3) and opposed the hypothesis: There is no change in the details of the vector image produced through the variable shutter speed in the digital image. Where the results were shown, as indicated in Table (8), there is a steady increase in the number of anchor points, the length of paths, and the number of colors depending on the acceleration of shutter speed.

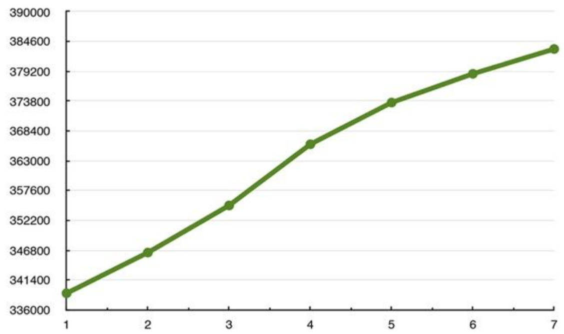

Figure 13 The relation between shutter speed and the number of anchor points in experiment 4.4

The graph in figure (13) shows the effect of the variable shutter speed on the number of anchor points in the vector images. The graph in Figure (14) shows the effect of the variable shutter speed on the length of paths in the vector images. The graph in Figure (15) shows the effect of the variable shutter speed on the number of colors in the vector images.

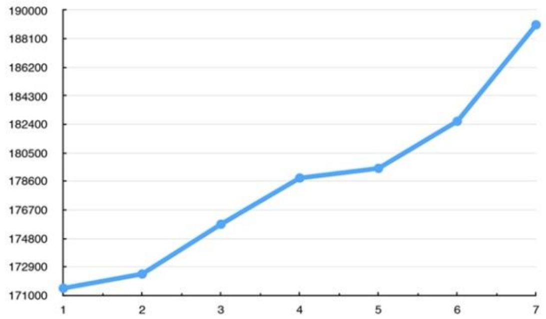

Figure 15 The relation between shutter speed and the length of paths in experiment 4.4

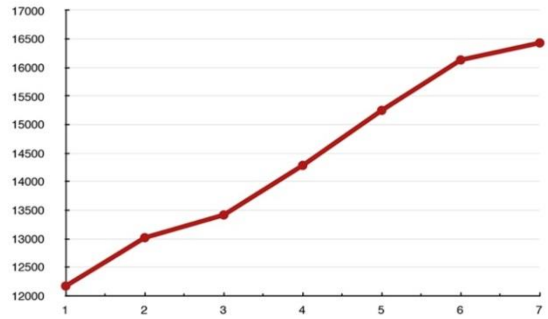

Figure 15 The relation between shutter speed and the number of colors in experiment 4.4

Conclusion

Based on the analysis of the results of the experiments, it was found that to get the best results for light intensity in a digital image to trace it to a vector image, it must increase the light intensity to allow for the narrowest opening of the lens aperture, select the lowest sensitivity speed (ISO), and select the fastest shutter speed.

Narrow lens apertures increase the depth of the field, which increases the sharpening of digital image details, thus increasing the accuracy of the details of the paths produced in the vector image, which is an expected result matching the hypothesis. There is an increase in the details of the vector image produced through the lens aperture reduction (increase aperture number) in the digital image.

Also, using slow sensitivity speeds (ISO) increases the accuracy of the details of the paths produced in the vector image. As a result, the digital image noise decreases, which is due to the increased sensitivity speed (ISO) of the image sensor. This is an expected result, one that matches the hypothesis that there will be an increase in the details of the vector image produced through an increase in sensitivity speed (ISO) in the digital image because of noise, an additional effect of the ISO increase. The small random dots are not from objects in the image but are caused by the interference of electronic signals in the image sensor, increasing the unwanted details of the produced vector image.

However, increasing the shutter speed increases the sharpness of the digital image details, which, in turn, increases the accuracy of the details of the paths produced in the vector image. This is an unexpected result that does not match the hypothesis. There is no change in the details of the vector image created through variable shutter speed in the digital image, and no change is supposed to occur in the details of the digital image in the case of still objects photographed at variable shutter speed.

This result may be caused by the fact that although, the steady of light intensity that reaches the image sensor through its equalization of the shutter speed, increasing the light intensity of the light source leads to an increase in contrast. Which enhances the clarity of detail in the digital image, increasing the accuracy of the paths details in the vector image. It is therefore recommended to use fast shutter speeds to increase the accuracy of the details of the vector image produced through the digital image.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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