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THAYER COUNTER-SHADING APPLIED FOR CAMOUFLAGING OBJECTS IN IMAGES USING IN-PAINTING

Shailesh Kumar,
Research scholar,
Department of CS&E,
JJT University, Jaipur
Rajasthan, India
shailu_kumar_c@yahoo.com

Harsha S,
Assistant Professor,
Department of
InformationScience &
Engineering,Jyothy Institute
of Technology, Bengaluru
harsha@jyothyit.org

Dr. Khalid Nazim Abdul
Sattar,
Assistant Professor,
Department of
CSI,Azzulfi Majmaah
University,KSA
k.sattar@mu.edu.sa

Dr. Hani Alquhayz,
Dean, Department of
CSI,College of Science in
Azzulfi, Majmaah
University, KSA,
h.alquhayz@mu.edu.sa

Abstract—**Camouflaging is the art of hiding objects in plain sight using colors/patterns that blend with the background to cover the objects in question. It is a widely used technique in the armed forces of almost all the nations since the advent of modern warfare. Given the context, there are many types of camouflage clothing as military uniforms suiting the terrain/ vegetation where the military units are deployed. The widespread use of such clothing has given rise to the noun "camouflage" to mean such clothing. However camouflaging the objects may not be the final solution for the problem of secrecy as modern techniques like computer vision and object identification using pattern recognition and feature isolation still pose a threat to camouflaging. In this paper we discuss an adaptation of a technique developed by Abbott Thayer in the beginning of the 20th century in his paintings to hide objects using a combination of light and resulting shadows to effectively hide objects inside an image. The idea is suited for transmission of images in any network that is exposed to external threats. The images would have a set of objects that are already camouflaged. Our technique is to modify the image using Thayer counter-shading for image in-painting to blend the objects of interest completely with the background so that without the aid of the inverse function the objects are rendered practically invisible.**

Keywords—camouflage; in-painting; Thayer counter-shading; Military Histogram.

I. INTRODUCTION

Camouflaging is the key feature of any country's defense as the outcome of war depends greatly on the adaptability of a country's forces to the terrain of the battle field. In the present Communication era, where enemies engage in electronic warfare, it becomes imperative that enough steps are to be taken to ensure the safety of data in storage or transit[3]. Dependency of nations on private data service providers has been questioned worldwide[4]. Hence the concept of high level data security (Application Layer) is a promising solution to the above cited problems. In this work, We present an idea and its implementation to take a regular image and hide the object/s of interest in the image using a modified, digitized version of Thayer Counter-shading[1] and image in-painting[10].

II. HISTORY

Animals resort to counter shades naturally to avoid being detected by predators as well as prey. This is clearly shown in Figure 2.1. An owl uses the fallen dry leaves as a background to camouflage itself. Also it can be seen from Figure 2.2 that humans use clothing to match their surroundings to hide from animals while hunting. A H Thayer[1] was the first person to notice that light intensity and angle of incidence played a major role in camouflaging. He attempted to develop an artistic model out of it. His paintings were so close to perfection that [1] to convince people and critics that he was not cheating and the objects were there in the image, he was forced to vow using religious scriptures. Figure2.3 shows the best ever recorded attempt in counter-shading. There are two identical ducks in the image. But only one (left) is visible and the one on the right is counter shaded by Abbott H Thayer using the combination of the background color and the color of the shadow it casted on the background which renders it invisible.

Figure 2.1. Owl using Natural Camouflage

Figure 2.2. A hunter using Thayer counter shaded Camouflage (Physical)

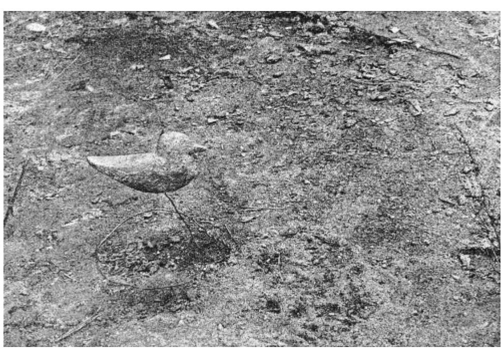


Figure 2.3.The original work of Abbott H Thayer- The vanishing duck

III. METHODOLOGY

The algorithm to implement the proposed idea for communication is explained in two stages.

Stage 1: Camouflaging the Object of Interest. Here we explain the algorithm to effectively blend an object in the foreground with the background.

1. Histogram development for all colours and light intensity
2. Using the shadow casted by the object, to obtain the position of source of light
3. Averaging Histogram to obtain mean point of light intensity.
4. Averaging the color Histograms
5. Obtaining above and below average points for the histogram
6. Using the results of 1 and 4 to counter-shade the object in an attempt to render it invisible.

The following section depicts the methodology as a pseudo code at the level of an abstract algorithm.

1. Histogram development: The image in any format is read and its components (CMYK or RGB) are plotted against the pixel position along the X-axis. This set of graphs from the histograms of the image. An example is shown in Figure 3.1.[9]
   a. Declare an integer array that holds every possible level of colours (R :0-255, G: 0-255, B:0-255, I:0-255)
   b. Loop 0 through each parameter (R,G,B,I)
   c. Initialize said array to all 0
   d. Loop 1 through each row of the image
   e. Loop 2 through each pixel in the current row
   f. Get colour value at [row, column]
   g. Increment the histogram array at the index obtained by the colour value from above by 1
   h. End of loop 2
   i. End of loop 1
   j. End of parameter Loop 0

2. The light intensity histogram {I} is used to obtain the position of the light source. Highest intensity point and the slope to each corner of the image are the components used to determine this.
3. The intensity histogram {I} is then averaged and then the new values are stored back into the image. This results in a flat image where the light intensity no longer produces the depth (3- d perception) to the image.
4. Obtain the averages of colour histograms
   a. Declare 3 integer values Ra, Ga, Ba for averages and initialize to 0's
   b. Loop through colours
   c. Loop through Colour histograms
   d. Equate Colour average to sum of all values of {Red R} and divide by N (number of pixels)
   e. End histogram loops
   f. End colour loops
   g. Obtain the color averages Ra, Ga, Ba

5. The color histograms are used to obtain secondary points (Standard Deviation based) for each component. They determine the colours to be used for counter shading.
   a. Declare 3 arrays for colours (Rd, Gd, Bd) for deviation
   b. Initialize all arrays to all 0's

c. Loop through colour histograms (R,G,B)
d. Equate Colour deviation to Colour average (from 4) ~ Histogram (from 1)
e. End histogram loop

6. The higher average points (Shadow points) are used to shade the lower intensity points and vice versa to obtain the counter shaded image.
    a. Loop 1 through each row of the image
    b. Loop 2 through each pixel in the current row
    c. If (I value at [row, column] < I average
        i. Colour value at [row, column] = Color value at [row, column]+Color deviation
    d. Else Colour value at [row, column] = Color value at [row, column] - Color deviation
    e. End of loop 2
    f. End of loop 1

Image

Histograms:

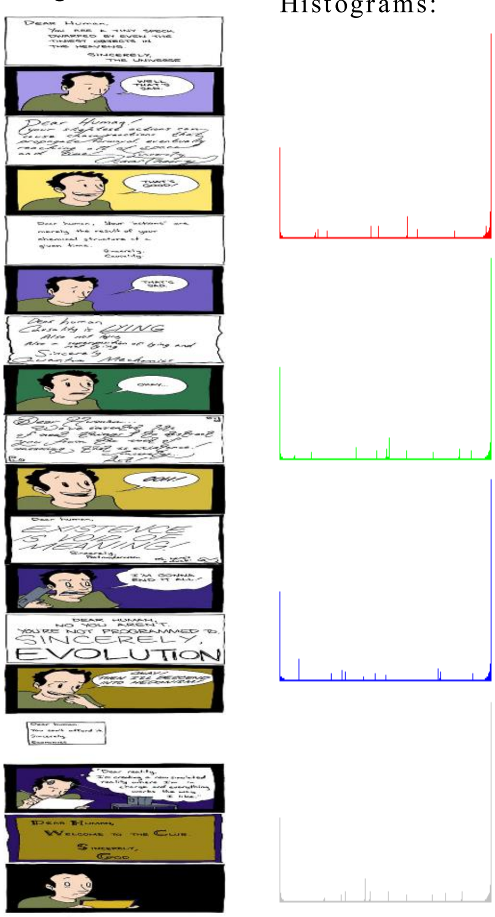


Figure 3.1. A sample image and its R,G,B and Intensity Histograms[9]

Stage 2:Retrieval of Objects of Interest

This stage happens at the receiver. The receiver requires the exact location of the maximum Intensity point in the image and the slopes for this to achieve the complete retrieval. These two parameters are generated in step 1 of stage 1. The steps of retrieval are explained as follows.

1. Image reconstruction using the maximum intensity point, intensity and slope
2. Colour correction using regression for high and low points
3. Human intervention to identify object of interest
4. Repeat 2 and 3 till object of interest obtained.

The detailed process is as follows.

1. Image reconstruction using the maximum intensity point, intensity and slope
    a. Add the intensity into image at the given point
    b. Obtain the other points on the image using the slopes in all directions
2. Colour correction using regression [6] for high and low points
    a. Obtain a full set of low points and high points for each pixel using a deviation constant (In this paper we assume 0.05)
    b. Generate two images using these two sets
3. Check visually if the object of interest is obtained in both cases
    a. Results in the knowledge that which of the two is closer to the original
4. Repeat 2 and 3 till object of interest obtained

IV. Experimentation and Results

The algorithm is applied to a set of images having a small object of interest in a large landscape as background and the results are shown in Table 4.1.

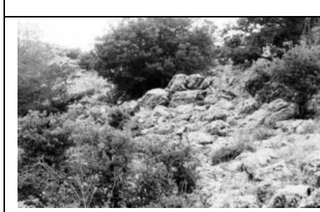
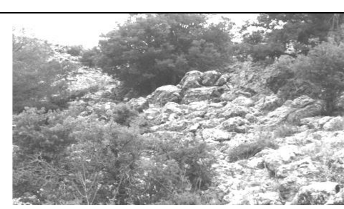
It is evident from the table 4.1 that our algorithm works as expected. However given the nature of the image and the background, it has its limitations. It can perform well on images with large majorly monochromatic backgrounds where as its performance will be diminished when applied on images that have vibrantly colorful backgrounds. The results are analyzed in the next section for visibility at each phase of the algorithm and the analysis reveals that with fine tuning and tweaking our algorithm can deliver the best invisibility in image to the objects of interest, in this case soldiers who are forced to use open data lines for image based communication.

The receiver end process details are given in table 4.2. It can be seen that in most cases, as the source of light is above (the sun), the lower points provide the object of interest. The reconstruction of the image is successful in all the cases from table 4.1.

Table 4.1. Experimentation with the algorithm for some cases at sender side

Source Image (Object of Interest marked in red circle)	Image with Averaged Intensity	Thayer Counter shaded Image	Observations
 4.1.1 A soldier crouching on a rock formation	 Light intensity and colors averaged and image flattened	 Thayer counter-shading applied	Here as the Image is falttened both in colour and intensity the counter shading process appears to be highly effecitve and the object of interest is nearly invisible
 4.1.2. A soldier standing in a shrub background	 Only light intensity averaged	 Thayer counter shading	Here the outline of the soldier is still visible to a small extent as the colour variation is quite high and the flattening of the image is done only on the light intensity
 4.1.3. A soldier using rag based Camouflage	 Only light intensity averaged	 Thayer counter shading (Shoes still visible)	Here the shoes are not camouflaged, however after the application of counter shading the Object of Interest becomes close to invisible.
 4.1.4. A group of soldiers in Camouflage	 Flattened Image with light intensity averaging	 After TCS applied (Variable light sources fail TCS)	In this case the soldier closest to the view (Front-Left) is almost clearly visible as his face is illuminated by a second light source

Table 4.2. Unhiding of the object at the receiver side

TCS Images	Iteration 1	Iteration 2
		

		Not required
		Not required
		Not required

V. Analysis

The analysis of the performance of our algorithm is carried out by comparing the visibility of the Object of Interest[7] before and after applying the proposed algorithm.

The computation of visibility of an object x is done using

$$V(x) = \frac{I(x) - I_B(x)}{I_B(x)} \qquad (1)$$

Where V s the visibility(contrast)[8] and I(x) is the light intensity at x and IB(x) is the average intensity of the background.
The result of the comparison is as shown in table 5.1. From the table 5.1 it is evident that the algorithm achieves camouflaging but under the assumptions as follows

1. Single light source
2. Largely monochromatic background
3. Object of Interest is already using physical camouflage

But it can be seen that this will not be the case in real life as practically one cannot expect all the assumptions to be adhered to. If an image falls into the hands of eavesdroppers/men in the middle without the keys i.e. the maximum intensity point and slopes, it will be very difficult to obtain the position of the object of interest in the image. The following table5.2 shows the time required to obtain the object of interest (not the reconstruction of the entire image) for the same cases in Table 4.1.

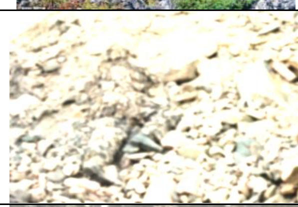
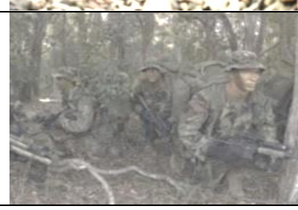
Table 5.1. Visibility test performed on images before and after counter shading (TCS)

Case	I	I_B	Prior to TCS	I	I_B	Post TCS
4.1.1	0.63	0.47	0.3404	0.5	0.47	0.0638
4.1.2	0.72	0.48	0.5	0.63	0.46	0.3695
4.1.3	0.54	0.46	0.1739	0.52	0.46	0.1304
4.1.4	0.86	0.53	0.6226	0.68	0.53	0.2830

Where I is the maximum light intensity (Object of Interest) and I_B is the average Intensity (Background)

It is evident from table 5.2, that images that have diverse backgrounds or more than one light source, can be easily reconstructed at least partially, to reveal the object of interest. This has been done using brute force method [2]

Table 5.2.Unhide attempts on the TCS images using brute force method

TCS Image	Reconstructed Image Without keys	Object of Interest (Y/N)	Time Taken (s)
		Not obtained (N)	1.281
		Visibility improved (Y)	1.322
		Visibility reduced (Y)	1.098
		Visibility improved (Y)	1.024

VI. CONCLUSION

The work aimed at developing a system for effectively hiding objects in an image so that they can blend into the background seamlessly. The goal has been achieved successfully. The limitations of the algorithm have been explored and they can be corrected with further tweaking of the modules of the algorithm. The system can be improved upon by statistically analyzing its performance with larger sets of data and applying non-linear regression[5] to obtain the color averages. Also the output can be taken as an intermediate image and multiple iterations [Gujarati, 2003]can be carried out to enhance the performance. Our algorithm, we hope can be used by the departments of defense of any country to carry out communications even in open channels[2] without risking detection by enemies.

REFERENCES

1. https://en.wikipedia.org/wiki/Abbott_Handerson_Thayer
2. William Stallings, Cryptography and Network Security. 5th Edition, Pearson Publications, 2013
3. H J Highland, “Perspectives in Information Technology Security”, *Proceedings of the 1992 IFIP Congress, Education and Society,* 1992
4. Eli Biham, Adi Shamir, “Differential Cryptanalysis of the Data Encryption Standard”, Springer Verlag, 1993
5. Rabin, M.O., “Probabilistic algorithms: Algorithms and Complexity”, J. F. Traub Education, Academic Press, 1976
6. Damodar Gujarati, Basic Econometrics, 4th edition. McGraw-Hill Publications. 2003.
7. Kim K W, Estimation of visibility using a visual image, 2015 Mar;187(3):66. doi: 10.1007/s10661-015-4297-9, SpringerLink.
8. Zhou Wang, Image Quality Assessment: From Error Visibility to Structural Similarity, IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 13, NO. 4, APRIL 2004

9. www.imgur.com
10. Rajul Suthar, Mr. Krunal R. Pate, A Survey on Various Image In-painting Techniques to Restore Image, Int. Journal of Engineering Research and Applications, ISSN :2248-9622, Vol. 4, Issue 2, (Version 1), February 2014, pp.85-88.