

UNIVERSITY OF ST ANDREWS

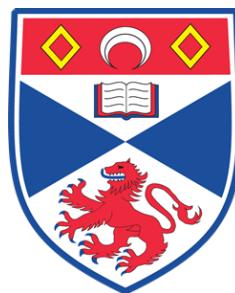
CS4203 COURSEWORK 2

1

Security Tools

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Part I: 1377 Words, Part II: 1230 Words

Goal

The goal of this practical was to use and evaluate common tools and techniques used in security: steganography and penetration testing.

Part I

Steganography

Least Significant Bit (LSB) steganography - specifically LSB1 - involves replacing the last bit of each byte of an image file (called the cover image) with a bit from the data to be hidden. For example, if each character in the message requires a single byte, then it can be hidden in 8 bytes of the cover image. If we instead use the two least significant bits, we can halve the image size needed to mask our message, but this can result in more obvious distortion in the original image. The message being hidden doesn't necessarily have to be text either, images can be masked using other images as well.

Experiment 1 compares various images after LSB steganography is applied to determine the effectiveness of spatial frequency as a metric for choosing cover images. In experiment 2, the effectiveness of peak signal-to-noise ratio (PSNR) as a metric is also evaluated.

1 Spatial Frequencies

1.1 Introduction

Images can contain a range of spatial frequencies. High frequency images show fine details, whilst low frequency images consist of smoother transitions between dark and light (See figure 1). In this experiment, the effect of LSB on images of varying spatial frequencies is compared, using an online image steganography tool [1].



(a) High spatial frequency image

(b) Low spatial frequency image

Figure 1: Comparison of spatial frequencies in images [2]

1.2 Aims

The aims of this experiment are:

1. to determine if spatial frequency is useful as a metric for choosing an effective cover/hidden image combination.
2. to determine whether a high, medium, or low frequency image is a better candidate for a cover file.
3. to determine which combination of high or low frequency cover image and high or low frequency hidden image provides the best concealment.

1.3 Methods

In order to reduce the number of variables in this experiment and simplify masking one image in another, the images used were all cropped and scaled to the size of 640×396 pixels. Three images were used that contained either low, medium or high values spatial frequency components. The images were viewed on a 15.6" Matte FHD LED IPS display with a resolution of 1920×1080 . The *Eye of GNOME* application was used to open and display the image files

A Matlab[®] script was written (*showDCT.m*) that converted the images to grayscale and used Discrete Cosine Transform to show the distribution of spatial frequencies. The images used and their spatial frequencies are shown in figures 2 to 6. The DCT plots show the lowest frequencies in the top left and the highest frequencies in the bottom right.



Figure 2: "Colourful": High frequency image (left) and spatial frequency distribution (right).

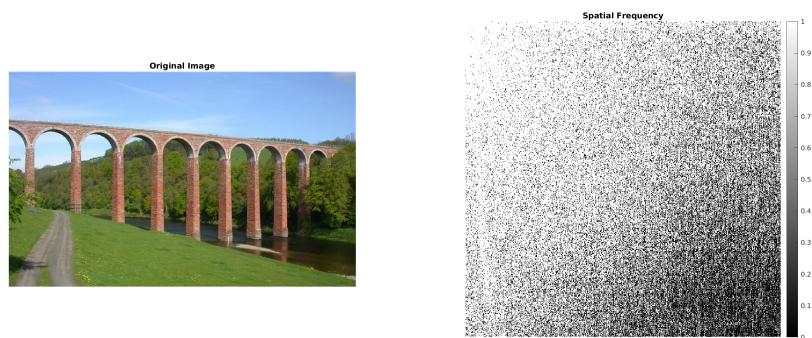


Figure 3: "Viaduct": Mid frequency image (left) and spatial frequency distribution (right).



Figure 4: "Sky": Low frequency image [3] (left) and spatial frequency distribution (right)

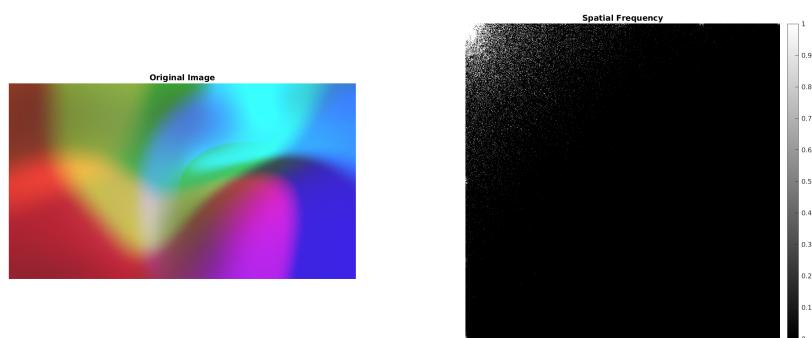


Figure 5: "Blurry": Low frequency image (left) and spatial frequency distribution (right)



Figure 6: "Galette": High frequency image (left) and spatial frequency distribution (right)

Using the online image steganography tool, each of three images (Figure 2 to 4) were combined, using the first, second, and fourth lowest bit planes. The two high frequency images (Figure 2 and Figure 6) and the two low frequency images (Figures 4 and 5) were also merged.

For aim 1, spatial frequency could be deemed useful if there is found to be some correlation between the results and the spatial frequencies of the images. For aim 2, the best cover file would be the one that after hiding have the least visible changes compared to the original. The same metric could be used for aim 3. The cover image with another hidden would first be compared to the original image, and then to the hidden image. If artefacts can be spotted when compared with the original, then the cover image offers very weak protection, but if it can only be noticed when the hidden image is also shown, then the cover image offers some protection. If neither, then the cover image is very effective.

1.4 Experimental Trials

The results are shown in the style of a Cayley table, where the horizontal headers correspond to the cover image used, and the vertical headers correspond to the image that was hidden. A score of 1 to 10 is used for each combina-

tion, where 1 shows clearly the hidden image, and 10 is indecernible from the original cover image. An asterisk is used where no data was recorded.

1.4.1 LSB1

Cover Hidden \	Colourful	Viaduct	Sky
Colourful	*	10	7
Viaduct	10	*	6
Sky	10	10	*
Blurry	*	*	10
Galette	10	*	*

1.4.2 LSB2

Cover Hidden \	Colourful	Viaduct	Sky
Colourful	*	8	4
Viaduct	10	*	3
Sky	10	9	*
Blurry	*	*	9
Galette	10	*	*

1.4.3 LSB4

Cover Hidden \	Colourful	Viaduct	Sky
Colourful	*	3	2
Viaduct	7	*	2
Sky	10	5	*
Blurry	*	*	4
Galette	8	*	*

1.5 Outcomes

For LSB1, the following notes were taken:

- Top portion of Sky image gained unnatural textures when colourful was the hidden image.
- Vertical columns in viaduct were faintly visible when hidden under sky image (Figure 7).



(a) Original Sky Image



(b) Viaduct hidden in Sky Image.

Figure 7: Sky before and after viaduct was hidden using first least significant bit plane.

For LSB2:

- Viaduct image with colourful image hidden showed circle bright spots in sky. Colour transitions became more sudden (posterization).
- Viaduct with sky hidden also suffered from posterization
- Sky with viaduct and colourful hidden begins to clearly show shapes in hidden images.

And finally for LSB3:

- Colourful with viaduct hidden only hints at hidden image in low frequency section (dark wall background).
- Colourful image with Galette appears brighter, slight texture in low frequency regions.
- Viaduct with colourful definitely affected by posterization (Figure 8). Shows some textures from Colourful image in top portion, though rest is fairly unaffected.

The results in regard to the aims of the experiment are:



(a) Original Viaduct Image



(b) Viaduct image with Colourful image hidden.

Figure 8: Viaduct before and after having Colourful hidden within using four least significant bit planes.

1. Since higher spatial frequencies make artifacts harder to notice in an image, spatial frequency could be useful to determine if an image is effective as a cover image.
2. A highly detailed image is best suited to the purpose of cover image.
3. Hiding a low frequency image in a high frequency cover image provides the most concealment

1.6 Discussion

From the results, the colourful high frequency image showed the least distortion when used as a cover image. Only areas of less detail (blocks of solid colour) would show hints of the images underneath. The effectiveness of the less detailed image (sky) as a cover image drops sharply as the number of least significant bits used increases, even when being used to camouflage an image with similar spatial frequencies. From the results, it appears likely that a "white noise" image like television static would be most effective as a cover image.

The experiment could be improved by using a more standardised scoring method, such as the single stimulus continuous quality evaluation (SSCQE) [4], as well as using more participants.

2 PSNR as a Metric

2.1 Introduction

Often the peak signal-to-noise ratio (PSNR) is used as a metric of image quality during compression. It can also be used to quantify the difference between two images [5]. The higher the value of PSNR for the stego image, the more similar it is to the original cover image, which suggests that humans will not perceive that any image is hidden. PSNR is used for this purpose very often as it is fast to compute and trivial to implement [6]. However, using the literal difference between pixels values has been argued to be ineffective, since steganography is most effective when the two images are perceptually similar rather than similar at the byte level (which PSNR evaluates).

2.2 Aims

The aim of this experiment is:

1. To determine the usefulness of PSNR as metric when choosing a cover image for LSB2 steganography.

2.3 Methods

A Matlab script (*calcPSNR.m*) was used to calculate the value of PSNR between the luminance channels of two images. The luminance channel was used as this is the aspect of images that the human eye is most sensitive to [7]. This involves converting both images to YCbCr, and calculating the peak signal-to-noise ratio of the luminance (Y) channel of both images using

$$\text{PSNR} = 10 \log_{10} \left(\frac{\text{peakval}^2}{\text{MSE}} \right) \quad (1)$$

where peakval is the max value of the channel (255 for an 8-bit luminance channel) and MSE is the mean square error [8].

Using the same images from experiment 1, the value of PSNR was calculated between the stego image and the cover image. If a low PSNR value corresponds to an ineffective stego image when plotted, this correlation can be confirmed.

2.4 Experimental Trials

The results are plotted in figure 9. The script *psnrForAllLSB.m* was run for each original image to produce *test.csv*, to which the perceptual scores were then added manually.

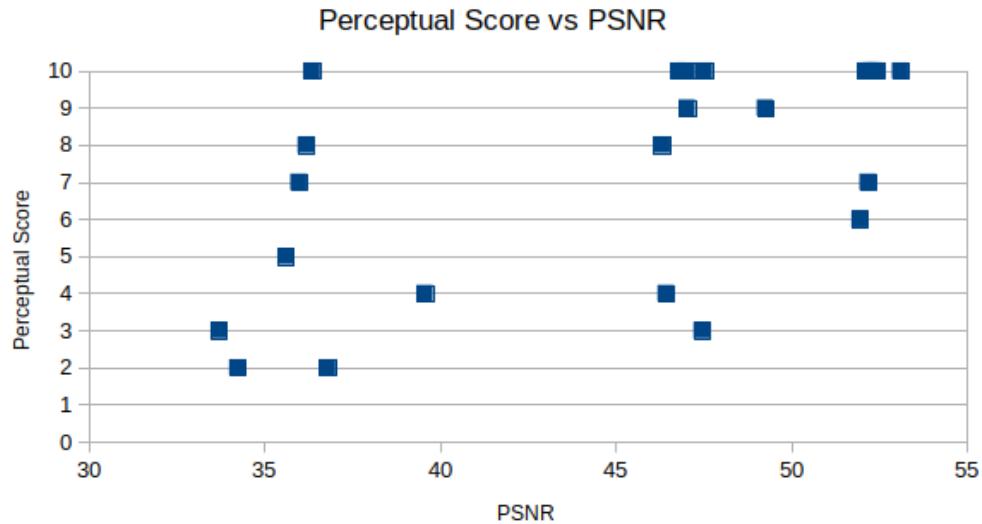


Figure 9: Perceptual scores from experiment 1 against PSNR values of cover image and the stego image.

2.5 Outcomes

No clear correlation between peak signal-to-noise ratio and the perceptual quality score can be seen.

2.6 Discussion

The experiment was carried out on very few images, and relies on the result of the previous experiment which already suffered from few numbers and a non-standardized scoring method. Nonetheless, the results do not seem to suggest any correlation between PSNR and perceptual quality of the stego image, which agrees with other experiments [9]. Having realised this, most

literature on modern steganography favours the use of the structural similarity index (SSIM) as a metric for how similar two images are in terms of human perception [10].

Part II

Penetration Testing

The penetration testing life cycle from Broad and Binder [11] is adopted for this part, which omits the *Covering Tracks* phase.

1 Reconnaissance

The online tool DNSInspect provided a warning that all name servers for the site are located on a single C class network [12]. This is a possible single point of failure. Whois shows that the domain name is assigned to two people in West Yorkshire (Alex Parker and Mark Ducadi), at the address Eukhost Ltd, 7 Commercial Street, Morley, West Yorkshire, LS27 8HX.

Saving an offline copy of the site and examining the source files using the command wget -m -p -E -k -K -np -v http://cybertest.uk allowed for further examination. A few commented out lines in the *cybertest.uk.html* document provided a link to a motivating cover of the Game of Thrones theme [13], as well as a test user account *testuser@cybertest.uk* with a possible password *test underscore user1*.

Another commented out section of the HTML file points us to *http://cybertest.uk/Server/AboutUs.asp*. This is an Active Server Page file, which suggests that the ASP.NET framework has been used for developing the site.

The site does not support HTTPS, which means all connections are insecure as communications are made in plain text. Checking network requests and responses made when loading the page in Chrome, we can see that an Apache server is used to serve the website (Figure 10).

▼ Response Headers [view source](#)

Connection: Keep-Alive
Date: Sun, 25 Nov 2018 17:15:28 GMT
ETag: "cfe36b7-2101-57a2d70c64b9a"
Keep-Alive: timeout=3
Server: Apache

Figure 10: Response headers on GET request to <http://cybertest.uk/>

2 Scanning

In order to assess the structure of the target network further, the command nmap –sS –T4 http://cybertest.uk was used (nmap with aggressive timing and stealth scan i.e. connections left open). A less aggressive timing setting would be used if we wanted the scan to be harder to detect. The output (Figure 11) shows that several TCP ports are open. Specifically, the mail ports (pop3, smtps, pop3s, imap). There is also a mysql server running with the standard port open, which could potentially be very useful when coupled with the login details from earlier.

The UDP (–sU) scan was then tried, though this returned no results. From this we can conclude that it is possible that the ports are open, and/or filtered by a firewall. The ACK scan (–sA) was also carried out, which returned that all ports are unfiltered.

```
Starting Nmap 7.60 ( https://nmap.org ) at 2018-11-25 19:14 GMT
Nmap scan report for cybertest.uk (5.77.35.132)
Host is up (0.015s latency).
rDNS record for 5.77.35.132: ukc02.uk
Not shown: 989 closed ports
PORT      STATE SERVICE
21/tcp    open  ftp
80/tcp    open  http
110/tcp   open  pop3
143/tcp   open  imap
443/tcp   open  https
465/tcp   open  smtps
587/tcp   open  submission
993/tcp   open  imaps
995/tcp   open  pop3s
3306/tcp  open  mysql
8443/tcp  open  https-alt

Nmap done: 1 IP address (1 host up) scanned in 1.62 seconds
```

Figure 11: Response headers on GET request to *http://cybertest.uk/*

3 Exploitation

Exploitation involves executing attacks on the now expected vulnerabilities, without detection.

4 Maintaining Access

This phase involves simplifying access for future exploitation.

5 Reporting

This phase involves analysing and describing the information gained during the attack.

Conclusion

References

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