International Journal of Computer Applications (0975 – 8887)
International Conference on Computer Technology (ICCT 2015)

An Approach to Steganography using Local Binary Pattern on CIELAB based K-Means Clustering

Diljeet Singh
Student, Master of Technology,
Dept. of Computer Engineering,
Punjabi University, Patiala.

Navdeep Kanwal
Assistant Professor,
Dept. of Computer Engineering,
Punjabi University, Patiala.

ABSTRACT
Steganography is the art and science of secret communication. Various types of media, such as images, videos, audio etc. can be used to hide the message. This paper presents an approach to steganography using LBP on a cluster formed by the CIELAB (Informally called Lab) based k-means clustering. Image Steganography embeds the secret message into the images exclusively. Basically Image Steganography uses LSB of pixels to embed the message, but this lone technique is easily detectable, so LBP is the technique which is used in the approach to embed data into image. It uses the pattern classification characteristics to modify the values of pixels in such a way that the modification yields the message requirements and aids the extraction process. But using pure LBP is also detectable and messages can be retrieved. Even to secure the location of LBP hidden message in the image, segmentation is used for hiding the using only desired areas of the image. For segmentation various clustering techniques can be implemented. For the purpose k-means clustering is used, which provides better accuracy for huge data sets. The images have huge number of pixels and every pixel further has 3 components namely red, green and blue for color images. So k-means clustering serves the purpose even concerning the speed. For k-means clustering using Lab color space adds its own advantages, as Lab color space approximates human vision.

Keywords
Steganography, LBP, RGB, CIELAB, K-means

1. INTRODUCTION
Steganography is the art and science of invisible communication. The word steganography is derived from the Greek words ‘stegos’ meaning ‘cover’ and ‘grafia’ meaning ‘writing’ which define it as covered writing. Generally steganography techniques use the advantages of human perceptual weaknesses, like being unable to detect minor changes in colors in images, word or line shifts in texts and little phase-changes in audio signals. So the areas of human ignorance are the areas of interest for steganography.The main difference in Steganography and Cryptography is their main goals as the cryptography aims at keeping the contents of the message secret, whereas steganography aims at hiding the existence of the message. The strength of steganography can be amplified by combining it with cryptography. In digital media, Image Segmentation is the process of dividing a digital image into multiple smaller segments, where each segment is a set of pixels. This is generally achieved by assigning a label to every pixel on the basis of certain characteristics, in such a manner that the pixels with same label belong to same segment, and all the segments combined, constitute the image in whole.

1.1 General Description of Steganography
Many methods can be used to implement steganography but the general description used in each implementation is as follows:

Cover media: The carriage media in which the secret message is to be hidden.

Message or Hidden data: This is the secret information that is hidden in the cover media, and sent over to receiver, such that no one else knows about its existence.

Stego media: The resultant media obtained after embedding the secret message in the cover media.

Stego-key: The key used for encoding or decoding the secret message while embedding and while retrieving message from stego media.

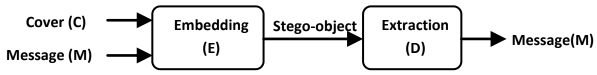


Figure 1.1: Basic steganography methodology.

1.2 K-means Clustering
K-means clustering is a technique which classifies or groups n items into k groups, where k is the pre-determined number of groups. Each group is called the cluster with a unique centroid. The grouping is obtained by minimizing the sum of squared distances (Euclidean distances) between items and the corresponding centroid. In case of k-means, centroids represent the mean vectors.

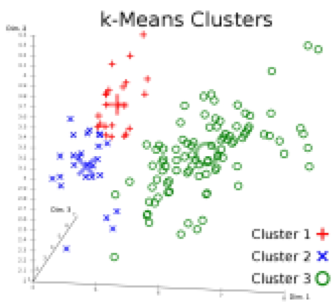


Figure 1.2: A k-means clustered scatter plot.

In the figure 1.2, the dots are data points. The colors represent different clusters created by the k-means. The centroids of the clusters have been highlighted.

1.2.1 Advantages of K-means Clustering
- Speed – The k-means clustering is very fast as compared to others.

- Better Performance for huge data sets [1].

1.3 CIELAB - Lab Color Space

Lab is the informal abbreviation for the L-a-b representation of the CIELAB, where CIE is French abbreviation for International Commission on Illumination (Commission internationale de l'éclairage), it is also including CIE 1994 and CIE 2000 color spaces; and the LAB represents Lab components. The ‘L’ is the Luminance or lightness component and the ‘a’ and ‘b’ are chromatic components of a color. Lab color space is a great color representation model which highly approximates the human vision. All perceivable colors are included in Lab color space, making its gamut exceed gamut of RGB and CMYK color models. Also as the Luminance component is separate, making it very useful where Luminance factor is to be avoided or treated separately. Device Independence is one of the most important attributes of this model. This also makes it useful to be used as an interchange format between different devices with different color models. So color the color model transformation from one to another can be done using Lab color space, like changing color model from RGB to CMYK as for printing images as displayed on the screens.

1.4 LBP

Local Binary Pattern (LBP) is an image classifier feature vector. First description of LBP was given in 1994 [2] [3], which was a special case of Texture Spectrum model proposed in 1990 [4][5]. It has been used as a powerful feature for texture classification and also the LBP operator for steganography. It uses the pattern classification characteristics to modify the values of pixels in such a way that the modification yields the message requirements and aids the extraction process.

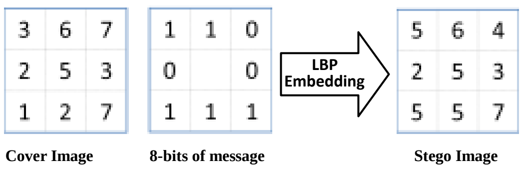


Figure 1.3: LBP encoding sample

2. LITERATURE SURVEY

2.1 Steganography

G. Xinlu et al. (2014) presented Steganalysis of LBP based LSB Matching. Author used Least Significant Bit (LSB) matching and steganography methods which big messages into cover media yielding good visually and statistically unperceivable results. Though, the correlation in adjacency of pixels was effected in smooth areas of images as half of the payload pixels were modified by 1. Local binary patterns (LBPs) were first proposed as texture features, and used for summarizing local image structures efficiently by comparison of pixels with their neighbors. A technique to use LBPs for detecting the LSB matching steganography was proposed. Multi-scaled rotation invariant LBPs were extracted as distinctive features from smooth pixels and linear support vector machine was used to train and classify the features. Experimental results showed the superiority of the method with higher detection accuracy. M. Aggarwal (2013) discussed three novel text steganography approaches. In the first approach, the cover text missed some letters of the words in order to hide the message characters, calling it the missing letter puzzle. The average Jaro score was 0.95 which indicated the closer similarity of the cover and stego file. In second approach, the message was hidden in a wordlist where ASCII value of embedded character determined the length and starting letter of the word. The third approach used the first and the last letters of the cover text to conceal a message, without degradation of cover. It also provided security to the secret message as one-time pad scheme was used for scrambling the message before concealing it into cover. V. Tyagi et al. (2012) discussed a technique based on the LSB and a new symmetric encryption algorithm to increase the security of messages sent over the internet. Algorithm used random size of key and was more secure. Before the data was hidden in an image the application first encrypted it. After the information was converted in secret code or was encrypted then least significant bit was used for the patching of data. G. Nehru et al. (2012) described various techniques of audio steganography using different algorithms like genetic algorithm approach and LSB approach. A robust method of imperceptible audio data hiding was introduced. It provided a good, efficient method for hiding the data from hackers and message was sent to the destination in a safe manner. The proposed method did not change the size of the file even after encoding and was also suitable for any type of audio file format. The technique of audio data hiding could be used for various purposes other than covert communication, deniable data storage, information tracing, finger printing and tamper detection. S. R. Govada et al. (2012) described Text Steganography with Multi level Shielding. Method was a combination of Word shifting, Text Steganography and Synonym Text Steganography. So it was called as “Three Phase Shielding Text Steganography”. It also helped in finding out the embedding rate of a secret message in a text box.

2.2 K-means Clustering and Segmentation

Ms. Bhakti N. Palkar (2014) introduced vector quantization based segmentation approach that was specifically designed to segment low-altitude, high resolution, aerial images, as a preprocessing step to 3D reconstruction. The main approach used vector quantization algorithms-K-Means clustering and KPE to form segments. The criteria to merge adjacent regions used were the color similarity and volume difference. The vector quantization seemed to give far better results as compared to conventional on-the-fly watershed algorithm.Sheetal Thorave et al. (2014) introduced a new technique for fabric defect detection using automatic visual analysis. The K-means clustering technique achieved highly accurate and reliable defect detection keeping in concern the reasonable computing time. Asghar Shahrzad Khashandarag et al. (2011) suggested a hybrid method for color image steganography in the spatial and frequency domains. The method used Lempel–Ziv–Welch (LZW) compression to obtain a low bit rate, then Linear Feedback Shift Register (LFSR) technique to enhance the security. Then author used K-means clustering and EA algorithms for secret data embedding in spatial domain. Coefficients Selection and Frequency Hopping Algorithm (CSFH) and Adaptive Phase Modulation Mechanism (APM) were used in frequency domain for secret data embedding.Naina Pal et al. (2014) threw light on the usage of K-means and fuzzy logic for clustering processes concluding that the k-means clustering was considered hard clustering and fuzzy k-means was soft clustering. Also it stated that Fuzzy K-means took lesser time to cluster the images than K-means. Soumya D. S et al. (2013) introduced an algorithm using k- means clustering, which ran faster than the Improved Adaptive Fuzzy C-Means Clustering (IAFCM) algorithm. The author proposed that a filter can be incorporated with this k-means clustering for de-noising. The author stated that Fuzzy

C-Means Clustering was a soft version of K-means, where each data point has a fuzzy degree of belonging to each cluster. Ms.Chinki Chandhok et al. (2012) presented new approach for image segmentation by applying k-means algorithm. It proposed a color-based segmentation method that used K-means clustering technique. The k-means algorithm was an iterative technique used to divide images into k clusters. According to the author the standard K-Means algorithm only gave accurate segmentation results when applied to images characterized by regions with homogeneity in texture and color, since no local constraints were used to impose spatial continuity. At first, the pixels were clustered on the basis of their spatial and color features, where the clustering process was accomplished. Then the clustered blocks were merged to a specific number of regions with improved quality of segmentation in terms of precision and computational time. T. Kanungo et al. (2002) discussed an efficient K-Means Clustering Algorithm. Author determined the set of k points, called centers, in d-dimensional space 'Rd' minimizing the mean squared distance of each data point from its nearest center, given the set of n data points in Rd, and an integer k. Lloyd's k-means clustering algorithm, also known as filtering algorithm, was implemented in simple and efficient manner. The practical efficiency of the filtering algorithm was established in two ways. Firstly, by presenting a data-sensitive analysis of the running time of the algorithm; secondly a number of empirical studies both on data generated synthetically and on real data sets from applications in data compression, color quantization and image segmentation.

2.3 LBP

Eleni E. Varasaki et al. (2011) discussed the use of LBP and LBP ROT, i.e. LBP Rotation Variant, for hiding the data into the images. The author compared both LBP and LBP ROT performances in spatial domain for the capacity and quality of image and the results concluded that LBP was better, though LBP ROT can withstand the rotational modifications in the image. A partially pattern based spatial domain data embedding technique was also proposed. The author discussed the LBP texture classification approach to be used for transparently and securely embedding secret data into the cover image. It involved modification of pixels in such a way that the texture satisfied the message requirement and compared this with other techniques in spatial domain in terms of capacity and image quality and the results concluded that it performed well for images with smooth areas, making it useful for tamper-proofing, authenticating and secretly communicating.Literature survey highlights need of steganography in communication of present era. Authors have worked upon varied techniques of hiding information in the images. Most of the techniques target for hiding considerable data without losing quality of the image in a faster way. LBP and K-means is being used in various recent research developments. This paper proposes a methodology comprising both K-mean and LBP for steganography that support fast and considerable data hiding in images.

3. PROPOSED METHODOLOGY

Various image steganography techniques use LSB to embed data. In the proposed methodology, LSB of pixel is modified according to LBP, so that the result satisfies the message requirements and can be used for extraction. This is applied only to particular segment selected, out of many which are formed by k-means clustering on the Lab color space of the image.There are mainly two processes: data embedding and data extraction. Both processes share some common initial steps, but the embedding and extraction phases use different steps. The various steps involved for the purpose are as follows:

3.1 For Data Embedding:

1) Read Image (Cover Image)
    a) Cover Image ← User Input
2) Color Based Segmentation using K-means :
    a) Preparing for K-means Clustering :
        i) Convert Image from RGB Color Space to Lab Color Space
        ii) Desired Number of Clusters ← User Input
        iii) Using K-Means Clustering
            (1) Classify the Colors in 'a*b*' Space
            (2) Store cluster centroids (for sorting in later steps)
        iv) Label Every Pixel in the Image Using the Results from K-means (Here, Every Label is the Cluster Number to which that pixel belongs.).
        v) Create separate Images for different segments according to the 'Cluster Number' that pixels belonging to.
3) Choose the desired Cluster(Segment) for Embedding (Data Hiding)
    a) Sort the Cluster Numbers to form Sorted-Index according to the cluster-centroids. (This is done to programmatically set the index of the each cluster same for every run because k-means doesn't return the same cluster index value every time)
    b) Read Choice← User Input
    c) Select Segment Image according to 'Choice' as Cluster of Choice.
4) Embedding the Message into Cluster of Choice :
    a) Read Message ← User Input
    b) Embed Message into Cluster of Choice according to LBP (Linear Binary Pattern) Algorithm [18][19] as :
        i) Divide the original image to K 3 × 3 neighborhoods, where K = [M=3] × [N=3].
        ii) For each ak(i; j) 3 × 3 neighborhood, where k = 1; 2;:::; K detect the edges and classify it as E or U subset.
            (1) E – The block whose every pixel belongs to current cluster - 'Cluster of Choice'
            (2) U - The block whose some pixels (min. 1-pixel) don't belong to current cluster 'Cluster of Choice'
        iii) Split the message in parts of 8 bits. Each 8-bit part is represented by a unique 8-bit binary LBP pattern. Here, the LBP pattern equals to the 8-bit message value. (This correspondence may differ according to the images LBP appearance frequency). Calculate the corresponding LBP pattern and its

corresponding wk(i,j).This is the wk(i,j), which the stego-neighborhood must have, in order to represent the 8-bit message.

iv) For every original ak(i,j) belonging to subset E, calculate the original wk(i,j).

v) To embed an 8-bit message into an ak(i,j) belonging to subset E, modify the original ak(i,j) in a way that ak(i,j), would produce wk(i,j). Pixel modification is made according to step 6. wk(i,j) should then be equal to the one that represents the 8-bit message part.

vi) Pixel values are changed as follows:

- if wk(i,j)=1and ak(i,j)<ak(1,1)then ak(i,j)=ak(1,1)
- if wk(i,j)=1and ak(i,j)≥ak(1,1)then ak(i,j)=ak(i,j)
- if wk(i,j)=0and ak(i,j)≥ak(1,1)then ak(i,j)=ak(1,1)−1
- if wk(i,j)=0and ak(i,j)<ak(1,1)then ak(i,j)=ak(i,j)

vii) Detect edges from the ak(i,j) and check whether it remains into the E subset. If this stands true, continue with the embedding procedure. If this is not the case, keep the neighborhood's changes, so that the neighborhood remains into the U subset, thus excluded from the extraction procedure, but re-embed the 8-bit message part into the next available E neighborhood.

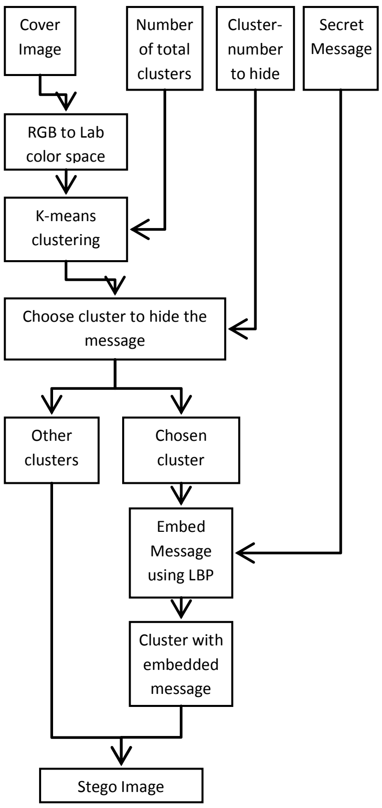


Figure 3.1: Steps for Hiding Message.

5) Combine all the segments (clusters) (including Steganographed-Cluster of Choice) into final STEGO-Image. → Save as Image File.

3.2 For Data Extraction:

1) Steps 1 through 3 are same as for Data Hiding, except that the instead of Cover Image, it would be Stego Image.

2) Extracting the Message from Cluster of Choice

3) Divide the original image to K 3 × 3 neighborhoods, where K = [M=3] × [N=3].

4) For each ak(i, j) 3 × 3 neighborhood, where k = 1; 2;:::; K detect the edges and classify it as E or U subset.

   a) E – The block whose every pixel belongs to current cluster - 'Cluster of Choice'

   b) U - The block in which some pixels (min. 1-pixel) don't belong to current cluster -'Cluster of Choice'.

5) For each 3×3 neighborhood belonging to the E subset, calculate the LBP pattern.

6) Map the pattern value to the 8-bit message.

7) Concatenate the 8-bits segments to form the hidden message.

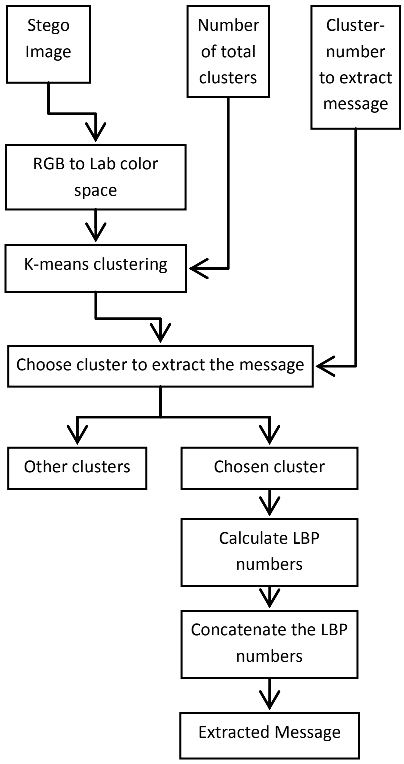


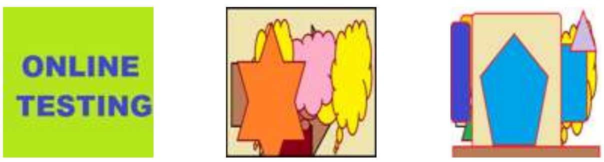
Figure 3.2: Steps for Retrieving Message.

4. RESULTS AND DISCUSSION

Following table shows the Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) obtained for stego-image with cover image, as original reference image, using an approach to Steganography Using Local Binary Pattern on CIELAB Based K-Means Clustering (SLBP). Entropy shows the entropy value of stego-image. The Elapsed Time is the time taken to embed the message into the chosen cluster.These results are for images processed as 8-bit images, such as 24-bit bmp images where each pixel is represented by 3 components red, green and blue and each component has value 0 to 255. In the table 4.1, the images (1-4) are manually created and shown in figure 4.1, images (7-23) are from http://www.imagemagick.org/MagickWandForPHP/download /image-bank/16bit840x840images/images/ and images (5-6) are as used for [19]. Each character in secret message is converted into corresponding 8-bit binary code and embedded. The length of secret message is also embedded along with message to aid the extraction process, so that only that length of extracted message is treated as hidden message. The final hidden message contains 139 bytes.

Table 4.1: Performance metrics results of SLBP

Image	Image Resolution	PSNR	MSE	Entropy	Embedding Time	Clustering Time
1	100x100	65.5381	0.0181	2.46068	0.12474	0.0400
2	100x100	36.7356	13.7887	5.00696	0.03229	0.0411
3	100x100	34.4406	23.3893	4.34273	0.04085	0.0339
4	100x100	40.2774	6.10013	2.57300	0.03389	0.0235
5	512x384	49.2213	0.77794	7.69938	0.18712	2.4614
6	308x196	47.8626	1.06371	6.92344	0.07802	0.4264
7	840x840	59.3103	0.07621	7.29828	0.70700	7.2161
8	840x840	66.7545	0.01372	7.40143	0.61529	4.9187
9	840x840	77.0933	0.00126	6.93469	0.61106	8.7234
10	840x840	58.6599	0.08852	7.41986	0.67886	6.7237
11	840x840	66.0611	0.01610	7.70935	0.68567	6.2155
12	840x840	62.1809	0.03935	7.6715	0.65909	7.5978
13	840x840	63.8212	0.02697	7.29628	0.67550	8.7633
14	840x840	59.0282	0.08133	7.40688	0.69253	4.6351
15	840x840	58.8440	0.08485	7.50046	0.69741	5.7416
16	840x840	60.4852	0.05815	7.42037	0.64569	6.7610
17	840x840	59.7256	0.06926	7.09538	0.63183	6.4007
18	840x840	63.2101	0.03105	7.22547	0.63814	5.1944
19	840x840	61.1040	0.05042	7.40638	0.63964	7.0492
20	840x840	52.7945	0.34169	7.51895	0.61499	6.9513
21	840x840	54.8771	0.21152	6.69051	0.64842	3.7990
22	840x840	71.6049	0.00449	6.61658	0.74054	6.1280
23	840x840	53.6493	0.28063	7.57181	0.61455	6.2537



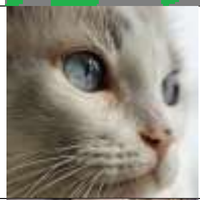
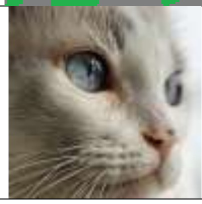
1 2 3

4 5 6

Figure 4.1: Images of table 4.1.

Following table 4.2 shows the original cover image and the corresponding stego-image of the images mentioned with image numbers (4, 11, 12, and 13) in table 4.1.

Table 4.2: Cover and Stego Images

Image Number	Cover Image	Stego Image
4		
11		
12		
13		

4.1 Comparison

Following table shows the PSNR, MSE obtained for stego image with cover image as original reference image. The Elapsed Time is the time taken to embed the message into the cover image, by another Image Steganography technique based on the RGB model (RGBIS) [20]. The hidden messages, in RGBIS, are of maximum 25 characters.

Table 4.3: Performance metrics results of RGBIS

Image	Image Name	MSE	PSNR	Elapsed Time
1	Tulip.bmp	0.027669	15.5569	16.0931
2	Babby.tiff	0.027496	10.6192	27.0167

In the following table 4.4, time taken to hide information by Image Clustering using Hopping Neighbour and Neighboring Techniques is shown [21].

Table 4.4: Time Taken by Image Clustering using Hopping Neighbor and Neighboring Techniques

Technique	Time Taken to Hide Information
Hopping Neighbor Technique	1.0130
Neighboring Technique	1.0139

Observing tables 4.1 and 4.3 shows that the PSNR values are better in the proposed work in performance comparison. The images 1 and 2 of table 4.3 are mentioned in table 4.1 numbered 6 and 5 respectively. The average embedding time of the table 4.1 is 0.5 seconds. So comparing table 4.1 with tables 4.3 and 4.4 shows that time taken for embedding the message is very less in the proposed methodology, highlighting its high speed performance.

5. CONCLUSION AND FUTURE SCOPE

This work uses pure steganography without cryptography of message; still it can provide great security because the cluster number of hidden message can act like the key, as used in encryption-decryption processes. If the total number of clusters to form (i.e. k-clusters for k-means) and the cluster number, in which the message is hidden, are not known then the message cannot be extracted. Multiple clusters can be used to hide different messages in separate non-overlapping clusters. With the currently proposed methodology it is possible to do this by repeating the whole process on Stego images for hiding next messages in the untouched clusters of previous runs. Also it can be customized for automation by fixing number of total clusters for every input image and the number of cluster to be used to hide the data.The work may be extended in many ways, like by adding cryptography, using different types of messages for hiding, usage for video steganography etc.

6. REFERENCES

[1] Osama Abu Abbas, 2008, “Comparison between Data Clustering Algorithms” The International Arab Journal of Information Technology, vol. 5.

[2] T. Ojala, M. Pietikäinen, D. Harwood, 1994, "Performance Evaluation Of Texture Measures With Classification Based On Kullback Discrimination Of Distributions", Proceedings of the 12th IAPR International Conference on Pattern Recognition (ICPR 1994), vol. 1, pp. 582 - 585.

[3] T. Ojala, M. Pietikäinen, D. Harwood, 1996, "A Comparative Study of Texture Measures with Classification Based on Feature Distributions", Pattern Recognition, vol. 29, pp. 51-59.

[4] DC. He, L. Wang, 1990, "Texture Unit, Texture Spectrum, And Texture Analysis", Geoscience and Remote Sensing, IEEE Transactions on, vol. 28, pp. 509 - 512.

[5] L. Wang, DC. He, 1990, "Texture Classification Using Texture Spectrum", Pattern Recognition, vol. 23, no. 8, pp. 905-910.

[6] Xinlu Gui, 2014, “Steganalysis of LSB Matching Based on Local Binary Pattern”, IEEE, pp. 475-480.

[7] M. Aggarwal, 2013, “An Overview of Different Type of Data Hiding Scheme in Image using Steganographic Techniques”, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, pp. 746-751.

[8] V. Tyagi et al., 2012, “Image Steganography Using Least Significant Bit With Cryptography”, Journal of Global Research in Computer Science (JGRCS), pp. 53-55.

[9] G. Nehru et al., 2012, “A Detailed look of Audio Steganography Techniques using LSB and Genetic Algorithm Approach”, International Journal of Computer Science Issues (IJCSI), vol. 9, Issue 1, pp. 402-406.

[10] S. R. Govada et al., 2012, “Text Steganography with Multi level Shielding”, International Journal of Computer Science Issues, vol. 9, Issue 4, pp. 401-405.

[11] Ms. Bhakti N.Palkar, 2014, “Color Image Segmentation using K-means Clustering and KPE Vector Quantization Algorithm”, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, Issue 1.

[12] Sheetal Thorave, Prof.M.S.Biradar, 2014, “New Technology for Fabric Defect Detection Based on K-means Algorithm”, IOSR Journal of Engineering (IOSRJEN), vol. 4, Issue 1.

[13] Asghar Shahrzad Khashandarag, Akbar Shahrzad Khashandarag, Amin Rahimi Oskuei, Hamid Haji Agha Mohammadi and Mirkamal Mirnia, May 2011, “A Hybrid Method for Color Image Steganography in Spatial and Frequency Domain”, International Journal of Computer Science Issues (IJCSI), vol. 8, Issue 3, pp. 15-20.

[14] Naina Pal, Kamiya Arora, Md. Khalid Imam Rahmani 2014, “Clustering of Image Data Using K-Means and Fuzzy K-Means”, International Journal of Advanced Computer Science and Applications (IJACSA), vol. 5.

[15] Soumya.D.S, Arya.V, 2013 “Chromosome Segmentation Using K-Means Clustering”, International Journal of Scientific & Engineering Research, vol. 4, Issue 9.

[16] Ms.Chinki Chandhok, Mrs.Soni Chaturvedi, Dr.A.A Khurshid, 2012, “An Approach to Image Segmentation using K-means Clustering Algorithm”, International Journal of Information Technology (IJIT), vol. 1.

[17] T. Kanungo et al., 2002, An Analysis of LSB based Steganography Techniques, IEEE Computer Communication and Informatic (ICCCI), pp. 1-4.

[18] Eleni E. Varsaki, Vassilis Fotopoulos, Athanassios N. Skodras, 2011, “A Data Hiding Scheme Based On LBPROT Pattern”, SIVip, 7: 247-253.

[19] Eleni E. Varsaki, Vassilis Fotopoulos, Athanassios N. Skodras, 2011, “Data Hiding Based On Image Texture Classification”, vol. 3.

[20] Harpreet Kaur, Gaurav Deep, 2015, “Level’s 4 Security in Image Steganography”, International Journal of Computer Applications (IJCA), vol. 121-No.23.

[21] Mitali Garg et al., 2014 “Data Security with Image Clustering using Hopping Neighbor Technique”, International Journal of Advanced Research in Computer Science and Software Engineering (IJARCSSE), pp. 628-634.