A SECURE APPROACH TO SPATIAL IMAGE STEGANOGRAPHY
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Abstract:
Security for confidential digital information has been an essential business in today’s world. With increase in the efficiency of technology dealing with data hiding as well as extraction, it is very necessary to overcome the every day’s growing technologies that can affect the confidentiality of the data. Steganography is an effective technique to hide confidential data which can be a text, audio or video by using a digital media as the communication channel. The prime aim is to reduce the distortion which occurs after hiding a text inside a cover image. Several algorithms have been developed to reduce the changes in the sum of costs of the pixels which is known as a function of distortion. Previously implemented algorithms are mainly concerned about reducing the changes in the embedded image by updating the costs of the pixels of the entire image at once. Though these algorithms are proven to be secure, the proposed strategy is an enhancement to the existing schemes. In this approach the changes in the neighborhood pixels are taken into picture. The orders in which the pixel are modified are grouped together to form a cluster and rest of the pixel costs are updated in such a manner that they are modified in the same order. This proposed Strategy is a simple but an effective strategy to update the cost of the pixels by following it. As a result of which the embedding area looks more uniform and does not catch attention of the steganalyzer. Therefore this strategy is simulated using Matlab 2016a (Academic version) simulation tool and Matlab programming language.

1. Introduction: (1.1 Background):
Steganography is a Greek word that combines two words i.e. “Stegano” and “Graphein”. Stegano means something in covered or concealed format and Graphein means writing. Hence Steganography is defined as a method of writing a very important data or message in a protected or covered or concealed format in which the message can be reached to the
authorized person and can only be revealed by the same. In ancient days people used to have many methods of writing secret messages such as in invisible ink, human skin or on a bald head where the hair grows later and covers the head entirely. The method of extracting the messages that are hidden in some form of cover is called as Steganalysis. The practical application of steganography is found in following areas.[7]

1. **Storing confidential data:**

This area provides security to the data that is hidden or embedded. Steganography gives the following services.

- A potential capacity to hide the existence of the secret data
- Capacity of extracting the embedded data
- Enhancing the security of embedded data

2. **Protecting the data from getting altered**

In this application area the breakability of the embedded data is taken into consideration. The data being fragile helps in splitting the embedding data and embed in the cover image. However this fragility shows a new idea towards information alteration such as Digital Certificate Document system. Here no authentication is needed. People can send data to any place in the world and nobody can modify or destroy the data.

3. **Media database systems:**

This area deals with combining two types of data into one. Media digital data such as video, photo, music, movie etc have some association with other type of data such as text as title, date and time, camera properties, photographer’s information etc.

### 1.2 Motivation

The primary goal of steganography is to hide secret messages into safe media without drawing attention of the steganalysis. Recently the steganography schemes mainly aim to minimize a distortion function, which is the sum of the cost of the pixels. The distortion function is a function that describes the after effects i.e. the modification changes done to the input cover image corresponding to the output stego object. The distortion function is generally considered as additive. Because when the data is embedded into the cover image, there are modification changes and the changes go in a positive order. The extra cost is added to the input image pixels which increases the embedding changes in the stego image. Hence the main motivation is to calculate the cost of the pixels so that the modification changes can be recorded and can be
taken into action how to minimize them. To minimize this additive distortion function there have been many researches
carried out. Syndrome Trellis codes [6] is one of them. It has performed well in minimizing additive distortion function.
Here every element of stego is assigned a scalar value which expresses the distortion caused by the embedding change,
thereafter by replacing the value of cover image with it. The total embedding change is the sum of individual element changes. Here, both the payload limited sender and distortion limited sender are considered. A payload limited sender
minimizes the total distortion while embedding the data with a fixed payload. A distortion limited sender aims at
maximizing the payload and introduces a fixed distortion. The individual bits are embedded into the cover image. The
binary case is approached using the Syndrome trellis codes. This solution achieves time and space complexity w.r.t. cover
elements. It is a very fast and versatile solution.

1.3 Problem Statement
In accordance to the recently proposed steganographic techniques, it can be easily understood that they are based upon the
cost assignment to an individual pixel. This approach gives security to an extent but leaves many disadvantages. When a
single pixel value will be modified then the area where data is embedded can be identified easily. Because the embedding
area is not uniform.
This approach gives a very small change rate but is very easy for the steganalyzer to detect the embedding area. However
if the neighboring pixels are also modified in the same order in which the embedding pixel is changed then the embedding
area looks uniform. It will be difficult for a human eye to easily understand the changes because the area looks dense.

2. Related Work
V.Holub and J.Fridrich have proposed WOW (Wavelet Obtained Weights) [1], which is an advanced steganography
method used in spatial domain. It can hide the confidential data into cover image according to complexity in the texture of
the image, i.e. it hides the secret data in the heavily textured regions. If the region is more complex then more pixel values
can be modified to store data without drawing attention. In this approach it can achieve good visual quality of the stego
image and can overcome the steganalytic challenges. WOW (Wavelet Obtained Weights) uses the high-pass filters to
get the residuals, which analyses the contents around each neighboring pixel along with multiple orders. Then the
impacts of the embedding changes are analyzed and by measuring the impact of embedding changes, the distortion has to
be high in predictable regions and to be low in the complex regions, where the content can not be predictable. This
The proposed algorithm is highly adaptive. However, according to the analytic point of view, this approach has a limitation. In this algorithm, it is easy to detect the modified regions based on the embedding costs used in WOW. If we extract the features from the heavily textured regions and analyze them, then it is expected that the detection performance would be improved comparatively with that of extracting steganalytic features from the whole image.

V. Holub and J. Fridrich have also proposed a design called UNIWARD (Universal Wavelet Relative Distortion) [2]. Recently, the steganography approach to the digital media is to embed the payload and minimize the distortion function. The design of the distortion function is the only task to the stenographers. Because they can enhance it using the practical codes. The main goal is to design the distortion to obtain an effective scheme with high detectability. UNIWARD (Universal Wavelet Relative Distortion) can be used to embed data in an arbitrary domain. The distortion after embedding is calculated as the sum of the relative changes of the coefficients in a sub part of the cover image considering the orders.

The idea of order deals with the embedding of data in the noisy regions of the cover image. This process avoids the smooth regions and the clean edges to embed data. The experimental demonstrations show that the methods built using UNIWARD outperform all the current state of art in the spatial domain. In the spatial domain, the embedding costs should be low in complex textures or “noisy” areas and high in smooth regions. This paper is an universal design of the distortion function called UNIWARD. This scheme does not deal with the embedding domain. Here, the distortion is only computed in the wavelet domain as the sum of relative changes in the wavelet coefficients. The wavelet functions permit the sender to analyze the neighboring pixels to see the presence of any discontinuity in multiple orders. Then it avoids making any changes to the region that can be modeled in one order. This model is implemented in spatial domain.

Thomas Pevny, Thomas Filler, and Patric Bass have proposed HUGO. [3] Here, the distortion is defined as the difference between the state of art feature vectors. This proposed system allows to follow the model used by the steganalyst and remains undetectable even when the payloads are greater than $10^7$. This model avoids the known security weaknesses. It is an embedding algorithm which is experimentally proven to have embedding capacity 7 times longer than the LSB Steganography. However, in this approach only the considered pixel value is changed but it does not concern about the impact of the embedding orders changes of the entire image.

Bin Li have proposed a cost assignment technique in spatial domain [5]. This paper takes an approach one step forward by defining the process of cost assignment into two phases:
i. Analyzing priority

ii. Specifying a cost-value

The cost-value distribution calculates the change rate of the cover images. When the cost-values are insisted to follow a uniform distribution, the embedding change rate faces a linear relation with the payload. In addition to that this paper proposes few rules to rank the priority for spatial images. By following those rules a five-step cost assignment scheme is proposed. Previous steganographic schemes, such as HUGO, WOW, S-UNIWARD, and MG, are also integrated into this proposed scheme. Experimental results show that the proposed scheme is capable of better facing the challenges of steganalysis with high-dimensional model features.

3. Detailed Design

3.1 Review of the Proposed System

This project describes the detailed analysis of the cost assignment techniques, embedding techniques and how to attain maximum steganographic security by clustering the changing orders of the neighborhood pixels and updating them. In this paper the impacts caused by embedding the data is exploited and the cost is updated accordingly. It enhances the steganographic security.

This paper also follows the existing proposed clustering rules that are used to cluster the modification orders together. The prime goal of this project is to assign cost in such a way that the strategy can be used with every other recently proposed approach. In this paper a cover image is decomposed into four (S X S) sub images, to attain maximum embedding capacity. In order to employ the existing practical steganographic codes the distortion is taken as additive because there are no practical implementation of the non-additive distortion as of now. Then the cost of the pixels are initialized by using some existing cost assignment techniques [5].

The cost after initialization is being adjusted accordingly by taking the modification orders of the neighboring pixels of the sub images in which the first segment of the data is embedded. Though there are no practical implementation of the non-additive distortion but it is implicitly approached in this paper if we take the entire cover image into account. Here the cost of a pixel value is first increased and then decreased by one to differentiate the changes of embedding. This way the modification orders may move in the same orders. Here it is an attempt to update the costs dynamically. It is analyzed that this approach increases the change rate a bit more than the other approaches. However it reduces the detectability and
makes the distortion uniform and does not compromise with the maximum embedding capacity. In the further parts of this paper the cost assignment strategy is described and the simulation is included. To identify the efficiency of the algorithm the experimental analysis is given in further sections. This paper is simulated in a MATLAB simulation software using a normal Computer by taking small images.

### 3.2 Requirement specification

**Hardware Used:**

**Table 3.1: Hardware requirements.**

<table>
<thead>
<tr>
<th>RAM</th>
<th>MEMORY</th>
<th>PROCESSOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>4GB</td>
<td>500GB</td>
<td>INTEL CORE I5@1.70 GHZ 2.40GHZ</td>
</tr>
</tbody>
</table>

**Software used:**

<table>
<thead>
<tr>
<th>OS</th>
<th>Simulation Tool</th>
<th>PHOTO VIEWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows 10 Home Single Language</td>
<td>MATLAB 2015</td>
<td>Windows Photo viewer</td>
</tr>
</tbody>
</table>

Table 3.2 Software Requirement However the limitations to this method is that it only embeds in the heavily textured regions while the assumptions say that the embedding rate should be more to get maximum performance. Also it does not concern about the mutual embedding impacts in the spatial domain.

### 3.3 Preliminary Design

![Preliminary Design](image)

**Fig 3.1** Preliminary Design
Here an input text is hidden inside the input cover image and produce a stego image. The above figure is just an outline of the preliminary design of the project. In the next chapters the detailed design is explained thoroughly to explain how the input text is decomposed into segments and how the input cover image is also subdivided into subparts, how the embedding happens and how the cost function is updated dynamically.

The modification orders can be described as binary, ternary, pentary etc etc.[2][7] here in this project the ternary modification order is used which means the pixel values can be increased by one i.e positive order, decreased by one , i.e. negative order and remain unchanged i.e. zero.

Following are the rules of assigning costs to the pixels which are derived from the previous researches.

**Rule 1: Sorting of the image elements according to their priorities.**

The image elements should be given priority and accordingly the data is embedded into them. To rank them according to the priorities, the following steps are required:

**Complexity-first:** In this rule the image area in which it is more complex i.e the dense regions are given higher rankings. If the data is embedded into the dense regions then it may not draw much suspicion. Because it becomes more dense by adding the information into it. So the change in the pixel values will not cause much difference.

**Spreading Rule:** Normally the neighborhood areas are not considered. But if the pixel value is changed in one particular area then there comes a difference to the eyes of the viewer. Hence if the areas are uniform then the human eye can not detect them properly. Hence the spreading rule suggests that these areas has to be considered and given priority to embed the data into them in order to avoid drawing suspicion. The cost of the neighborhood should also be changed to make the area’s visibility uniform.

**Clustering Rule:** The modifications change in different orders. It may be positive, negative or no change. So its necessary to cluster the modifications of the similar orders together. Hence this clustering rule suggests to group the similar orders together in order to attain simplicity.

**Rule 2: Assigning costs according to the given distribution**

In this section the cost to the pixels is assigned according to the given distribution. The cost assignment plays a vital role in spatial image steganography. The more efficient the cost assignment will be, the more secure the steganography scheme becomes. The above rules are generally applied to the additive distortions but here we can apply it in case of
non-additive distortions too. Even if the stego image is having very less change rate, clustering the modification orders will be proven to be more secure as per the analysis. If we don’t cluster the modification orders then the image will incur high frequency noise and can be captured because of the fluctuations in pixels.

3.4 Proposed system Design

In this section first the method of designing steganography is included. After that the algorithm is described in which the steps of cost assignment is given

3.4.1 Methodology

Previously we know that the more the modification orders are clustered the more steganographic security is attained. To assign the costs the mutual embedding impact is considered. The changes occurred to the neighborhood pixels are also taken into account. It is not required to assign the costs simultaneously. If we increase or decrease the value of a pixel then it’s not necessarily to have the same cost. In this project the secure approach to spatial image steganography is proposed where the previous strategies are used and they are enhanced by clustering modification orders and updating the cost dynamically. Here in this project an input cover image is taken and the data to be hidden be a input text data of some specified length. Initially the cover image is decomposed into several subparts. Again the input data i.e. text is split into several segments. Then the first part or segment of the input data is first embedded into the first subpart of the image that is split.

When the data is embedded into the first part of the image then the pixel value of the first subpart are modified. Hence in the 1st pass the cost of the pixel [5] of the entire image is modified according to the modification changes of the embedding pixels. Here if we set different cost values to the rest of the pixels then the probability of increasing or decreasing a pixel value by one can be balanced. This leads to gain more un-detectability. Then the remaining segments of the data are embedded sequentially one after another. In each pass the cost is updated after embedding the data. Finally the stego image is displayed as output. In this approach the existing additive steganographic schemes are used [4].

4. System Implementation

The implementation part of the system includes four modules as given below.

i. User input

ii. Decomposition
iii. Cost updation

iv. Data embedding and stego output

4.1 Module 1 (Input a text to be hidden and a cover image)

This module is simulated using Matlab simulator. First a cover image is taken from the system as input according to the user’s choice. The cover image can be taken as the size 512X 512 pixels or any value. Mostly the color images have maximum pixel density. Hence to reduce the pixel density motivates the simplicity in embedding the data and faster execution. Hence the following pseudo code will be used to import the image from the system and convert into grey scale image.

4.2 Module 2 (Dividing the Cover Image into Sub Blocks)

It has been analyzed from the previous techniques that the more the embedding capacity will be, the more efficient the steganography is. If the image is divided into various sub blocks then it can attain maximum embedding capacity.

Let’s consider that the size of the cover image is $M_1 \times M_2$ sub images which are not overlapping, where $M_1$ and $M_2$ are both greater than or equal to 1. Here we can describe the index set of a pixel mathematically as given below.

$$C_{x,y} = \{(i,j)| i = x+k_1M_1, j= y+k_2M_2\}$$

$x \in \{1, \ldots, M_1\}, y \in \{1, \ldots, M_2\}$

Here we are decomposing the sub image into non overlapping sub images of size $M_1 \times M_2$.

The elements in each sub block are from different sub images. An example of decomposition of a sub image is given below.

Let’s consider an image of size 8X8 with sub images 2X2 i.e $M_1=M_2=2$

4.3 Module 3 (Cost Assignment and Updation)

This module deals with the cost assignment techniques. Once the cover image and the input image is decomposed into sub images and data segments respectively then the cost of the pixels are initialized.
As discussed earlier in the paper, in this project the ternary embedding is being used, where the pixel cost may increase by one, decrease by one or remain unchanged. So a matlab code is developed to assign the cost of the pixels initially in order to balance the probability of detection.

Now let's take \( t = 1 \). Then the normal image \( X = Y \) (stego image). Because now there is no modification done.

Next the difference image \( D \) is computed as \( D = Y - X \)

The initial costs of the pixels can be calculated by using existing cost assignment techniques used in a proposed algorithm.

Hence the initial cost \( CS = \frac{F2}{Y \times H \times F1 \times F2} \)

Where, \( CS = \) initial cost

\( Y = \) stego image

\( F1 = \) low pass filter

\( F2 = \) low pass filter

\( H = \) High pass filter

In this way we can initialize the costs. The cost initialization roughly defines where we can bring changes to the pixels.

Hence initializing the costs before embedding data is a very good practice. Here in this project the impact of the embedding is concerned. Hence the neighborhood pixels are updated.

In the above two conditions we can alternatively deal with it this way; if the condition is overflowing, we can increase a pixel value by one and if the condition is under flowing then we can decrease the pixel value by one. Now the cost updating can be mathematically done by the following:

\( D = Y - X \)
S_t denotes the sub images

When \( t=1 \), the number of the sub images is one. Hence the cost can be updated according to the difference value \( D \).

But when \( t=1, 3, 4, \ldots, M_1 \), then the number of sub-images are increased. In this scenario the cost can be updated by the following method.

\[
C = \frac{CS}{a}
\]

Where \( C \) = updated cost

\( CS \) = the initial cost of the pixels

\( a \) = scaling factor which is a constant scalar value.

To get a simpler understanding of how the cost is being updated, an example image of the difference image and the initial cost image is given below.

In the above example the cost updation module is clearly understood. In the fig, the sublocks of the cover image are given i.e. 6x6 blocks.
In next figures i.e 2 and 3 the Difference image matrix and the initial cost matrix are given. From the figure it is clear that at A(1,1) the neighboring pixels are moving in more positive order than the negative order. Hence here the positive order is clustered and chosen to change the cost of the current pixel by using the cost assignment technique i.e. CS value was 5 initially in the initial cost matrix. But according to the cost updation rule the updated cost will be \( C = \frac{CS}{a} = \frac{5}{9} = 0.5 \) So the position A(1,1) will be updated as a new cost value 0.5. By following this updation process and clustering the majority of the similar orders the cost value of a pixel can be updated and the sub image will look uniform in texture.

### 4.4 Module 4 (Data embedding and stego output)

This module deals with the patterns or different embedding strategies that are already proposed. Here the sub images are mathematically expressed as \( C_t \) where \( t \) belongs to \( \{1,2,\ldots,M_1M_2\} \). The different embedding schemes are as follows. In this project 3 types of embedding schemes are being used. These are:

i. Horizontal Zig-Zag

ii. Row-by-row

iii. Cross

The scheme is programmed in such a manner that the user will select on what type of embedding scheme he wants to follow. In this paper the horizontal zig-zag is used. In this module the data is embedded into the sub images of the decomposed cover image. The embedding of the data follows any of the embedding patterns given above. The first message segment is embedded into the first sub image. After embedding the cost of the entire image pixels are updated according to the modification order of clustering rule. Once all the costs are updated, the next segment of the data is embedded into the next sub-image and after that again the cost is updated accordingly. In the project the main focus is on updating the costs in every pass according to the orders pf the modification. If the modification orders are both same i.e. similar number of positive and negative order changes then the cost remains same.

```matlab
%% embedding data into the cover image
out_stego_img=stego_process(data,s1, img2, hiding_direction, patch_minus, patch_0, patch_plus);
figure, imshow(out_stego_img); title('stego image');
t=toc;
disp('Steganography done');
disp(['time taken: ' num2str(t) ' sec']);
```
This embedding process continues until and unless the t value reaches $M_1.M_2$. Once t value reaches $M_1.M_2$, then the stego image is displayed as output. The main focus of the project is on cost assignment effectively by clustering the modification orders. Hence many existing algorithms have been followed in this project.

5. Results and Discussions

5.1 Simulation using Matlab

In order to visualize the embedding changes occurred due to the hiding of the message into the cover image a sample image is taken with a size of 285 X 274 pixels.

Now to visualize the embedding changes in the stego image a very small part of the source image is taken to embed the data.
5.2 Input message to be embedded

The user can input any message within a quotation. In this simulation the user message is ‘i am Susmita,M.Tech it from vit university’

After giving the input message the code will ask for the embedding pattern to choose.

5.2 Discussions

In the proposed scheme the cost of the pixels are dynamically adjusted by considering the stego image. The initial costs are calculated using the stego image in which the sub images are modified. The cost of the sub images are then updated according to the modification orders of the pixels. Here the embedding impacts are considered and the similar modification changes are clustered. In this project the cost updation is so dynamic that it is very difficult for any adversary to detect or guess the exact cost value of a pixel. In the stego image there is no clue given to reverse the action.
If the steganalyzer has to extract the data from the cover image then he has to extract the cover image first which is very difficult.

5.3 Parameters under study

In this project the following parameters are used which can be modified according to the user’s choice.

\( M_1 \) And \( M_2 \) => the size parameter

The above parameters are required to set the size of the image i.e. \( M_1 \times M_2 \)

The number of the sub images can be determined by \( M_1 \times M_2 \)

Normally we take \( M_1 = M_2 = M \) for creating \( M \) sub images for simpler understanding.

If the value of \( M \) is 1, then the proposed scheme can not work. Because there will not be any sub images. So the clustering of the modification orders will not work.

If the value of \( M \) becomes more then the scheme will be more complex and more data can be embedded.

If the number of sub images are equal to \( M \) then the process of updating the cost is \( M^2-1 \) times.

Hence the size parameter have a role to play in clustering the similar changing orders.

Next, the data embedding pattern plays a role in this proposed scheme. In the project the embedding impacts of the 4 neighborhood are only considered. Hence the embedding pattern should be either vertical or horizontal.

Next parameter can be the constant \( a \), which is used to update the cost .This factor should not be 1. Because according to the formula the updated cost \( C = CS/a \)

If the value \( a = 1 \) then the proposed system will be equal to Gibb’s construction.

It has to be noted that in this project the steganography is spatial.

There are \( M^2-1 \) number of passes followed in this method.

There are some important differences between the existing and proposed algorithm

5.4 Comparative Analysis

The proposed scheme also possesses many similarities with the existing schemes. In Gibb’s construction the sub image division is similar to the proposed scheme. In both the schemes the cost is updated according to the previous sub images. The difference between the strategies are as follows: In all the existing techniques the embedding passes are repeated many times. In contrast to those algorithms the proposed algorithm has a better strategy i.e. every sub image is
processed only one time. The entire image need not to be processed again and again. Hence the execution becomes faster comparatively. The number of the sub images can be minimum four when M=2.

Similarly the size of M can be taken as 2,4,6,8,…etc.

Also different type of embedding order like zig-zag, row by row and cross can be taken to compare the impacts of the different methods.

**Tabulation:**

<table>
<thead>
<tr>
<th>Embedding pattern</th>
<th>Sub-image size</th>
<th>Change-rate</th>
<th>Time-taken (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Zig-Zag</td>
<td>M=2</td>
<td>0.1045</td>
<td>12.50</td>
</tr>
<tr>
<td>Row by Row</td>
<td>M=2</td>
<td>0.1100</td>
<td>10.01</td>
</tr>
<tr>
<td>Cross</td>
<td>M=4</td>
<td>0.1033</td>
<td>8.82</td>
</tr>
</tbody>
</table>

From the above table it is understood that among the three embedding patterns, by using the proposed scheme i.e clustering the modification changes the Cross embedding pattern gives minimum change rate and less time taken. However the goal is to modify or update maximum number of pixels in order to make the area look uniform. Hence the Row by row pattern may be more effective even if the change rate is more. Analysis shows that Horizontal Zig Zag technique will be a better option because the four neighborhood pixels can be easily processed.

**Fig 6.1. Comparision between embedding modes.**
6. Conclusion & Future Work

In the proposed system the changing order of the pixels are considered and grouped together to update the neighboring pixels. This strategy is proven to be the best as its is experimented and analyzed using Matlab. The analysis shows that if we group the changing order into one and update the cost of the pixels accordingly then the area of hidden data looks more uniform and smooth and for a human eye it is quite difficult task to understand. However in future the proposed system can be enhanced by giving efforts to decrease the rate of change whereas increasing the capacity of embedding maximum data. This scheme gives the maximum benefits because it can be used in every existing algorithms to reduce the embedding change i.e. function of distortion.

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