Some New Steganographic Techniques using Spatial Resolution Reduction

H. Faheem Ahmed and U. Rizwan

Abstract—In this paper, we present four new techniques to hide a large volume of text in a gray level image by reducing its spatial resolution to its half, to its quarter and by reducing the spatial resolution in width and in height. The actual image and the data embedded stego-images using the techniques are given. The Mean Square Error (MSE) and Peak to Signal Noise Ratio (PSNR) values have been determined. Histograms for the computed values of MSE and PSNR indices and embedding capacity are drawn.

Index Terms—Steganography, Spatial Resolution Reduction, Mean Square Error, Peak to Signal Noise Ratio.

I. INTRODUCTION

Sampling is the principal factor determining the spatial resolution of an image. Basically spatial resolution is the smallest discernible detail in an image. The measure of how closely lines can be resolved in an image is called spatial resolution, and it depends on properties of the system creating the image, not just the pixel resolution in pixels per inch (ppi). For practical purposes the clarity of the image is decided by its spatial resolution, not the number of pixels in an image. In effect, spatial resolution refers to the number of independent pixel values per unit length. Spatial resolution is a term that refers to the number of pixels utilized in construction of a digital image. Images having higher spatial resolution are composed with a greater number of pixels than those of lower spatial resolution. In short, spatial resolution is the density of pixels over the image: the greater the spatial resolution, the more pixels are used to display the image. We can experiment with spatial resolution to hide very huge amount of data.

II. REDUCING THE (SPATIAL RESOLUTION) IMAGE TO ITS HALF

Consider a 256 x 256 gray scale image. As the neighboring pixels are similar values in uniform region except boundaries, we can reduce the image to half of its size and use pixel values other than the rectangle ones to hide the text. By taking out every other row and every other column, thus leaving only those matrix elements whose row and column indices are even:

\[
\begin{array}{cccccccc}
  x_{11} & x_{12} & x_{13} & x_{14} & x_{15} & x_{16} & \ldots \\
  x_{21} & x_{22} & x_{23} & x_{24} & x_{25} & x_{26} & \ldots \\
  x_{31} & x_{32} & x_{33} & x_{34} & x_{35} & x_{36} & \ldots \\
  x_{41} & x_{42} & x_{43} & x_{44} & x_{45} & x_{46} & \ldots \\
  x_{51} & x_{52} & x_{53} & x_{54} & x_{55} & x_{56} & \ldots \\
  x_{61} & x_{62} & x_{63} & x_{64} & x_{65} & x_{66} & \ldots \\
  \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots
\end{array}
\]

By this technique, about 75% of pixels values can be changed, giving a hiding capacity of 75 percent and retaining only 25 percent of image as shown below.

\[
\begin{array}{cccc}
  x_{22} & x_{24} & x_{26} & \ldots \\
  x_{42} & x_{44} & x_{46} & \ldots \\
  x_{62} & x_{64} & x_{66} & \ldots \\
  \vdots & \vdots & \vdots & \ddots
\end{array}
\]

Consider the following 16x16 image, which we refer as Matrix -1.

\[
\begin{array}{cccccccccccccccc}
  1 & 17 & 33 & 49 & 65 & 81 & 97 & 113 & 129 & 145 & 161 & 177 & 193 & 209 & 225 & 241 \\
  2 & 18 & 34 & 50 & 66 & 82 & 98 & 114 & 130 & 146 & 162 & 178 & 194 & 210 & 226 & 242 \\
  4 & 20 & 36 & 52 & 68 & 84 & 100 & 116 & 132 & 148 & 164 & 180 & 196 & 212 & 228 & 244 \\
  6 & 22 & 38 & 54 & 70 & 86 & 102 & 118 & 134 & 150 & 166 & 182 & 198 & 214 & 230 & 246 \\
  8 & 24 & 40 & 56 & 72 & 88 & 104 & 120 & 136 & 152 & 168 & 184 & 200 & 216 & 232 & 248 \\
  9 & 25 & 41 & 57 & 73 & 89 & 105 & 121 & 137 & 153 & 169 & 185 & 201 & 217 & 233 & 249 \\
 10 & 26 & 42 & 58 & 74 & 90 & 106 & 122 & 138 & 154 & 170 & 186 & 202 & 218 & 234 & 250 \\
 12 & 28 & 44 & 60 & 76 & 92 & 108 & 124 & 140 & 156 & 172 & 188 & 204 & 220 & 236 & 252 \\
 14 & 30 & 46 & 62 & 78 & 94 & 110 & 126 & 142 & 158 & 174 & 190 & 206 & 222 & 238 & 254 \\
 15 & 31 & 47 & 63 & 79 & 95 & 111 & 127 & 143 & 159 & 175 & 191 & 207 & 223 & 239 & 255 \\
 16 & 32 & 48 & 64 & 80 & 96 & 112 & 128 & 144 & 160 & 176 & 192 & 208 & 224 & 240 & 256 \\
\end{array}
\]
Extracting the elements of rows and columns having even suffices, we arrive at the matrix of half of its size in both width and height (8x8).

<table>
<thead>
<tr>
<th>18</th>
<th>50</th>
<th>82</th>
<th>114</th>
<th>146</th>
<th>178</th>
<th>210</th>
<th>242</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>52</td>
<td>84</td>
<td>116</td>
<td>148</td>
<td>180</td>
<td>212</td>
<td>244</td>
</tr>
<tr>
<td>22</td>
<td>54</td>
<td>86</td>
<td>118</td>
<td>150</td>
<td>182</td>
<td>214</td>
<td>246</td>
</tr>
<tr>
<td>24</td>
<td>56</td>
<td>88</td>
<td>120</td>
<td>152</td>
<td>184</td>
<td>216</td>
<td>248</td>
</tr>
<tr>
<td>26</td>
<td>58</td>
<td>90</td>
<td>122</td>
<td>154</td>
<td>186</td>
<td>218</td>
<td>250</td>
</tr>
<tr>
<td>28</td>
<td>60</td>
<td>92</td>
<td>124</td>
<td>156</td>
<td>188</td>
<td>220</td>
<td>252</td>
</tr>
<tr>
<td>30</td>
<td>62</td>
<td>94</td>
<td>126</td>
<td>158</td>
<td>190</td>
<td>222</td>
<td>254</td>
</tr>
<tr>
<td>32</td>
<td>64</td>
<td>96</td>
<td>128</td>
<td>160</td>
<td>192</td>
<td>224</td>
<td>256</td>
</tr>
</tbody>
</table>

Excluding the above pixel locations, the remaining pixels marked with X are used for embedding text data.

Excluding the above pixel locations, the remaining pixels marked with X are used for embedding text data.

```
for i=1:rows
    for j=1:cols
        if ( i is odd or j is odd )
            Embed a character in image pixel location i,j
        end
    end
end
```

3. Display the stego image (of alternate rows and columns)
4. end

The original image (cameraman.tif) Figure 1, the stego image embedded with 49152 characters of text (Figure 2) and the stego image reduced to a size half its original dimensions (Figure 3) and the stego image in figure 3 doubled in dimensions (Figure 4) are given below.

Note here that out of 256 ( = 16x16) pixel values, only select 64 ( = 8x8) are retained and the remaining 192 ( = 256 – 64) pixels can be utilized for hiding the text.

For a 256 x 256 8-bit grey scale image, the effective resolution of the new image is only 128 x 128. That is, out of 65536 pixels required for storing the original image, only 16384 pixels are retained, and the remaining 49152 pixel positions are utilized for hiding the data, there by achieving 75 percent of embedding capacity. The algorithm to carry out this procedure is given below.

**Algorithm**

1. Read the image
2. Let \( r, c \) be the size of the image (width, height)

Excluding the above pixel locations, the remaining pixels marked with X are used for embedding text data.

```
X X X X X X X X X X X X X X X X X
X 18 X 50 X 82 X 114 X 146 X 178 X 210 X 242
X X X X X X X X X X X X X X X X X
X 20 X 52 X 84 X 116 X 148 X 180 X 212 X 244
X X X X X X X X X X X X X X X X X
X 22 X 54 X 86 X 118 X 150 X 182 X 214 X 246
X X X X X X X X X X X X X X X X X
X 24 X 56 X 88 X 120 X 152 X 184 X 216 X 248
X X X X X X X X X X X X X X X X X
X 26 X 58 X 90 X 122 X 154 X 186 X 218 X 250
X X X X X X X X X X X X X X X X X
X 28 X 60 X 92 X 124 X 156 X 188 X 220 X 252
X X X X X X X X X X X X X X X X X
X 30 X 62 X 94 X 126 X 158 X 190 X 222 X 254
X X X X X X X X X X X X X X X X X
X 32 X 64 X 96 X 128 X 160 X 192 X 224 X 256
```

```
Fig 1. Original image 256x256
```

```
Fig 2. Stego image embedded with 49152 characters
```

```
Fig 3. Reduced stego image to its ½
```

```
Fig 4. Stego image doubled in dimensions
```

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III. REDUCING THE (SPATIAL RESOLUTION) IMAGE TO ITS QUARTER

Consider a 256 x 256 gray scale image. As the neighboring pixels are similar values in uniform region except boundaries, we can reduce the image to one-quarter of its size and use pixel values other than the boxed ones to hide the text data. By taking out every other row and every other column, thus leaving only those matrix elements whose row and column indices are even:

By this technique, about 93.75 percent pixels values can be changed, giving a hiding capacity of 93.75 percent and retaining only 6.25 percent of image as shown below.

Excluding the above pixel locations, the remaining pixels marked with X are used for embedding text data.

For a 256 x 256 8-bit grey scale image, by reducing to one-quarter, the effective resolution of this new image is only 64 x 64. That is, out of 65536 pixels required for storing the original image, only 4096 pixels are retained, and the remaining 61440 pixel positions are utilized for data hiding thereby achieving 93.75 percent of embedding capacity.

The stego image embedded with 61440 characters of text (Figure 5) and the stego image reduced to a size ¼ its original dimensions (Figure 6) and the stego image in figure 6 enlarged to 4 times in dimensions (Figure 7) are given below.
**IV. Reducing the Spatial Resolution of Width (or Height) to its Half**

By embedding data in alternate rows (or columns) and displaying image pixels in unaltered rows (or columns), the image is reduced to half in width (or in height) as shown below. By this technique 50 percent of pixel values can be changed. In the above example of 256 x 256, by this method, a total of 32768 characters are hidden and at the same time the quality of image is maintained except the width (or height).

The figures Fig 8 to Fig 9 give a view of the data embedded actual sized stego image and reduced stego image reduced to its width in one-half in size.

The figures Fig 10 to Fig 11 give a view of the data embedded actual sized stego image and reduced stego image reduced to its height in one-half in size.

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**Fig 6. Reduced stego image to its quarter**

**Fig 7. Enlarged Stego image**

**Fig 8. Stego image embedded with 32768 characters**

**Fig 9. Reduced stego image to its Half in width**

**Fig 10. Stego image embedded with 32768 characters**

**Fig 11. Reduced stego image to its Half in Height**

The Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) are performance parameters to measure the quality of image.

- **MSE:** It is defined as square of error between cover stego-image. The error indicates the distortion in an image. MSE can be calculated by using two dimensional mathematical equation described as follows:

\[
MSE = \left( \frac{1}{N} \right)^2 \sum_{i=1}^{M} \sum_{j=1}^{N} (X_{ij} - \overline{X}_{ij})^2
\]
where \( X_{ij} \) = the value of pixel in cover image and \( X_{ij}^\prime \) =the value of pixel in stego-image and \( N \) is the size of image.

- **PSNR**: It is a measure of quality of image. PSNR can be calculated by using the mathematical formula given below:

\[
PSNR = 10 \times \log_{10} \frac{255^2}{MSE} \text{ dB}
\]

Table 1. The computed values of PSNR and MSE

<table>
<thead>
<tr>
<th>No.</th>
<th>Spatial Resolution Reduction</th>
<th>PSNR</th>
<th>MSE</th>
<th>No. of bytes hidden</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>To one-half</td>
<td>33.3266</td>
<td>30.2289</td>
<td>49152</td>
</tr>
<tr>
<td>2.</td>
<td>To one-quarter</td>
<td>30.0236</td>
<td>64.6732</td>
<td>61440</td>
</tr>
<tr>
<td>3.</td>
<td>To one-half in width</td>
<td>32.0679</td>
<td>40.3913</td>
<td>32768</td>
</tr>
<tr>
<td>4.</td>
<td>To one-half in Height</td>
<td>32.0594</td>
<td>40.4708</td>
<td>32768</td>
</tr>
</tbody>
</table>

The histograms of the computed values of PSNR and MSE indices for various techniques developed in this paper are presented in Fig.12. It is observed that the PSNR value is least for one-quarter spatial resolution reduction technique, whereas the corresponding MSE value is highest for this technique. Further, the amount of data hidden, using this technique, is high when compared with the other techniques.

The histogram representing the embedding capacity, while using each of the four techniques developed in this paper is presented in Figure 13. It is observed here that the spatial resolution reduction embedding technique to its one-quarter yield the optimum result.

V. CONCLUSION

In this paper, we have proposed four new techniques for embedding text in a gray level image by reducing the spatial resolution of the image. Several examples have been included to explain the concept in detail. An actual image 256 x 256 cameraman.tif was taken for implementing the above methods and document of 30 pages was embedded and retrieved. The actual image along with data embedded stego image are shown explicitly for each method.

REFERENCES


AUTHORS BIOGRAPHY
H. Faheem Ahmed earned his M.Tech. degree in Information Technology from Punjabi University and M.Phil. degree in Computer Science from Manonmaniam Sundaranar University. He is pursuing Ph.D. in Computer Science. He has guided 50 M. Phil. Research scholars in Computer Science. He is currently serving as the Associate Professor and Head of the Department of Computer Science and Applications, Islamiah College, Vaniyambadi and is serving the institution for the past 28 years. His research interest includes Steganography and Image processing. He has published 8 research articles and authored one book.

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