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Case Study of using Speech Samples LSBs for Message Steganography

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Abstract: Digital speech file is one of the most widely used type of digital data, it usually has a huge size, and the binary value of each sample is composed of a long number of digits, making speech file a convenient media to hold secret messages. In this paper research a detailed study will be provided to examine various ways of using the LSBs of the binary values of the speech samples to hide secret messages. It will be shown in this paper research that using one or more LSBs will keep the stego file in excellent quality. Speech file samples binary values will offer the capability of controlling the speech file hiding capacity, the user can control the hiding capacity by selecting the number of LSBs to be used for data steganography. It will be shown in this paper research that using the 32 LSBs of the speech sample binary value for data hiding will not much affect the sample value, thus the quality of the stego file will always be high. Several digital speech file will be selected and used as a covering files, different set of LSBs will be tested, the quality, speed of the message steganography will be examined to show how better to use the digital speech file as media of holding secret messages. A simple way of using speech samples LSBs for data hiding and extracting will be proposed, and it will be applied by performing simple matrix reshaping and assignment operations, thus the sequence of complex logical operations used in standard methods of message steganography will be eliminated.

Keywords: Steganography, SM, DSF, MBM, SBM, reshaping, LSBs set, hiding capacity, quality.

Introduction

Secret message (SM) is a set of characters; this message can be represented as shown in figure 1 by [11-16]:

- The set of characters.
- The decimal array of ASCII values of the characters, this array contains unsigned decimal values; each value is within the range 0 to 255.
- Message binary matrix (MBM) using 8_bits binary representation, this matrix can be obtained by converting the decimal values of the characters to binary. MBM contains 8 columns and number of rows equals the message length. MBM can be easily reshaped to any number of columns to meet the needs for message hiding and message extracting. MBM can be easily converted back to decimal to form the message [17-22].

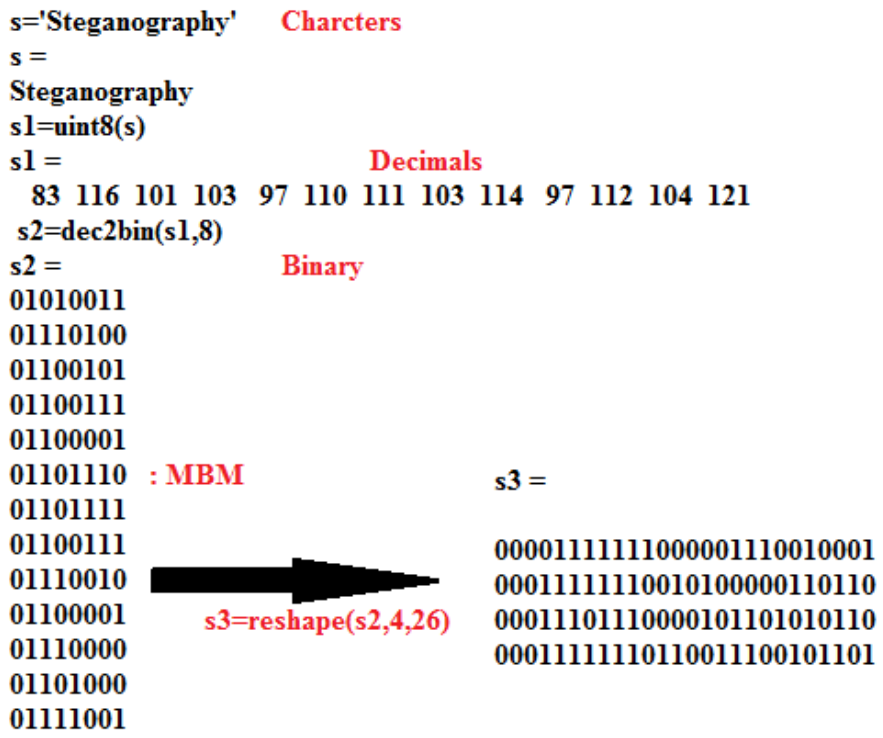

Figure 1: SM presentation

Digital speech file (DSF) [1-10] is a set of samples values organized in one or two columns (depending on the speech type: mono or stereo). The value of the speech sample is signed decimal fraction and it is always within the range -1 to +1. The DSF usually has a huge size, this size depends on the recording time and the sampling frequency, and this size will provide a good media to hold secret messages (short and long messages [23-30].

Each speech sample value can be converted to binary using 64_bits binary representation, the binary value of the speech sample is divided into three parts as shown in figure 2 (the sign part (one digit), the value part (52 digits) and the exponent part (11 digits)) [31-36].

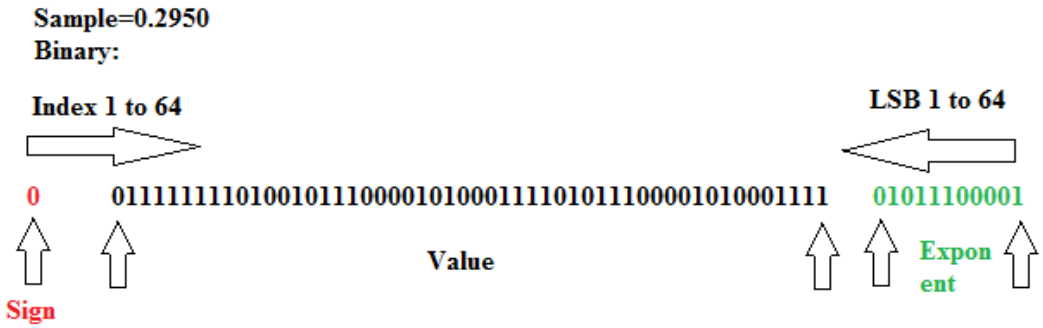

Figure 2: Speech sample binary value (Example)

In this paper research we will refer to the bit 64 as least significant bit 1 (LSB1), the second LSB2 and so on. The bits orders will start from the most significant bit, we will refer to this bit as bit with order 1 (index), this order will be increased when moving to the LSB; the LSB will have the order 64.

DSF can be represented as shown in figure 3 by [37-43]:

- DSF wave form.
- DSF histogram [12-18]
- DSF decimal matrix [19-25].
- DSF binary matrix (SBM), this matrix can be obtained by converting the decimal matrix to binary using the 64_bits binary representation. SBM contains 64 columns and number of rows equals the number of samples in the DSF. SBM can be easily converted to decimal to form the speech matrix [44-50].

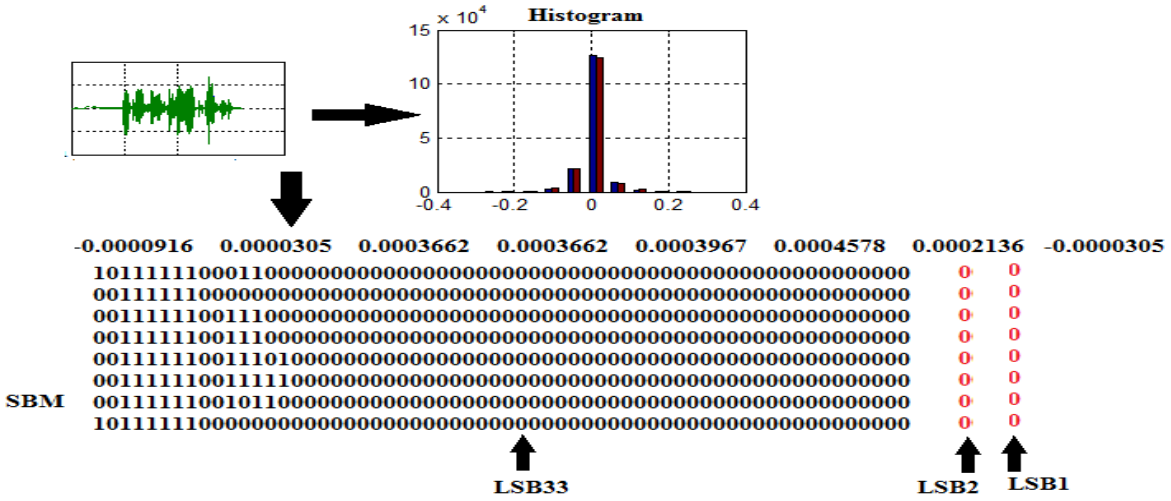

Figure 3: DSF presentation (example)

DSF sample binary value has a big number of digits, this value has interesting features which can be applied in data cryptography [26-35] and data steganography [36-43], and these features are [51-56]:

- Changing the bits starting from bit 25 will not change much the sample value, so we can use any bit from this position (or a set of bits) for data hiding, the low changes in the samples values will lead to obtain a stego file with high quality [57-63].
- Changing the low order bit (from 1 to 24) will change the sample value, and this will lead to produce a DSF with low quality, so these bits or set of bits can be used for DSF cryptography to get a destructive encrypted DSF [44-51].

To prove the previous features (fact) the following example was performed by replacing some bits of the DSF sample by the binary value of the character ‘g’ (see table 1)

Example:

Speech sample value= 0.4527

Binary:

00111111110111001111100100001001011010111011100110001100011111110

Character ‘g’

Decimal: 103

Binary:

01100111

Table 1: Effects of replacing 8 bits in the speech sample value by the character ‘g’

Order of 8LSB	New sample value	MSE[52-55]	PSNR[56-60]
1 to 8	**2.0654e+192**	**Infinity**	**0**
2 to 9	7.2119e-059	0.2049	0
9 to 16	0.0029	0.2023	0.1297
17 to 24	0.4438	7.9408e-005	78.5586
25 to 32	**0.4527**	**5.0227e-010**	**198.2693**
26 to 33	0.4527	1.0267e-010	214.1446
27 to 34	0.4527	1.5476e-011	233.0672
28 to 35	0.4527	6.9633e-013	264.0790
29 to 36	0.4527	4.9050e-013	267.5831
30 to 37	0.4527	1.8674e-013	277.2401
40 to 47	0.4527	7.2469e-019	401.8349
50 to 57	0.4527	3.1509e-025	548.3189
57 to 64	**0.4527**	**1.6301e-030**	**670.0386**

SM steganography [64-69] is the process of hiding this message in a covering media (such as DSF) without much affecting the quality of the covering media, the holding media must be closed to the covering media. The process of SM steganography can be applied by using hiding function (see figure 4) to hide the message and extracting function to recover the message (see figure 5) [55-60]. Hiding function processes the covering DSF and the SM to produce a stego file, while the extracting function processes the stego DSF to produce the SM.

The stego system must satisfy the following requirements [49-53]:

- Excellent quality of the recovered message, the recovered SM must be identical to the source hidden SM, and the mean square error (MSE) [55-60] measured between the source and the recovered messages must equal zero, while the peak signal to noise ratio (PSNR) [61-66] measured between the two messages must be infinity.
- Excellent quality of the stego file, the stego file must be closed to the covering file, and MSE measured between the two files must be low, while the PSNR must be high [67-69].
- A high speed of steganography, the hiding and extracting times must be minimized as much as possible.
- Simplicity of data hiding and extracting, the hiding and extracting functions must use a simple procedures to apply

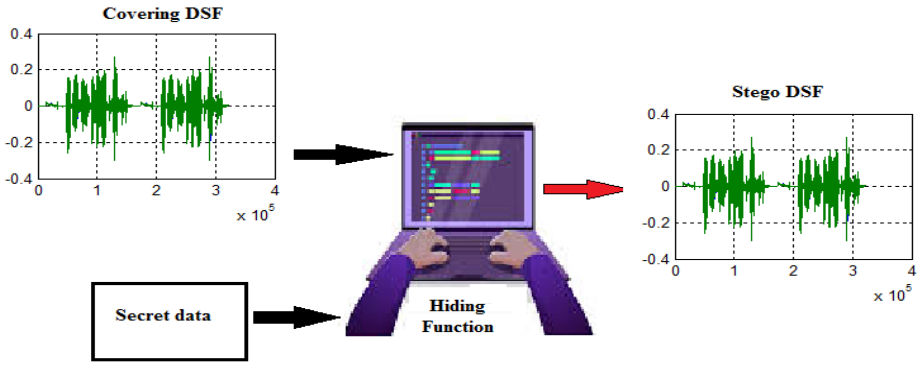

Figure 4: Stego system hiding function

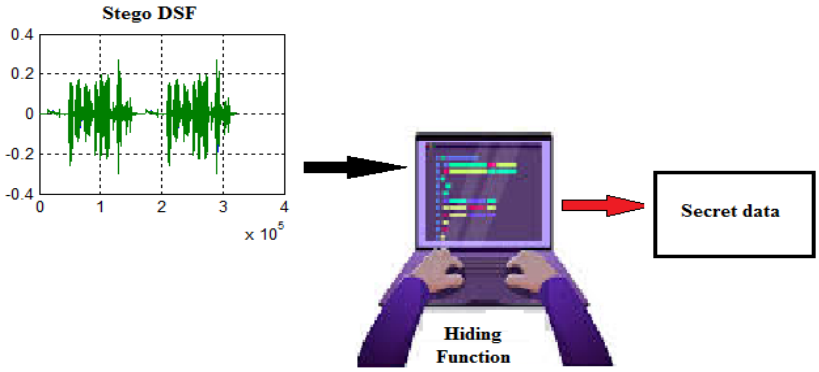

Figure 5: Stego system extracting function

Case Study of using LSBs of the DSF samples values

In this case study we will use various LSBs to hide-extract the SM, the quality of the stego file will be analyzed and the speed of SM steganography will be discussed to raise a valuable recommendations of how to use DSF as good media to hide SMs [1-5].

Simple procedures of SM hiding and extracting will be used. The process of SM hiding can be performed using any bit or set of bits from the samples values starting from the bit with order 25.

The process of SM hiding can be implemented applying the following steps:

Step 1:

SM preparation:

1) Get the message.
2) Retrieve the message length.
3) Convert the message to decimal.
4) Convert the decimal message to binary to get the MBM.
5) Reshape MBM to number of columns depending of the number of used LSBs

Step 2:

DSF preparation:

1) Get the DSF.
2) Retrieve the file size.
3) Reshape the file matrix to one row matrix.

Step 3:

SM hiding:

1) Get the covering samples depending on the number of used LSBs.

2) Convert the samples values to binary.
3) Let the selected LSBs equal the reshaped message binary matrix.
4) Convert the samples back to decimal to get the stego samples.
5) Return back the stego samples to the DSF row matrix.
6) Reshape the DSF row matrix back to original sizes to get the stego DSF.

Figures 6 thru 10 show some examples of applying the process of SM hiding:

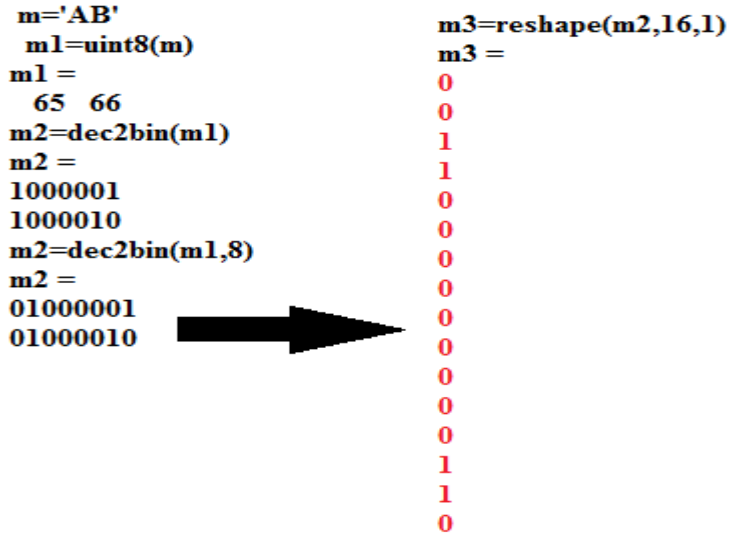

Figure 6: Preparation of SM when using LSB1

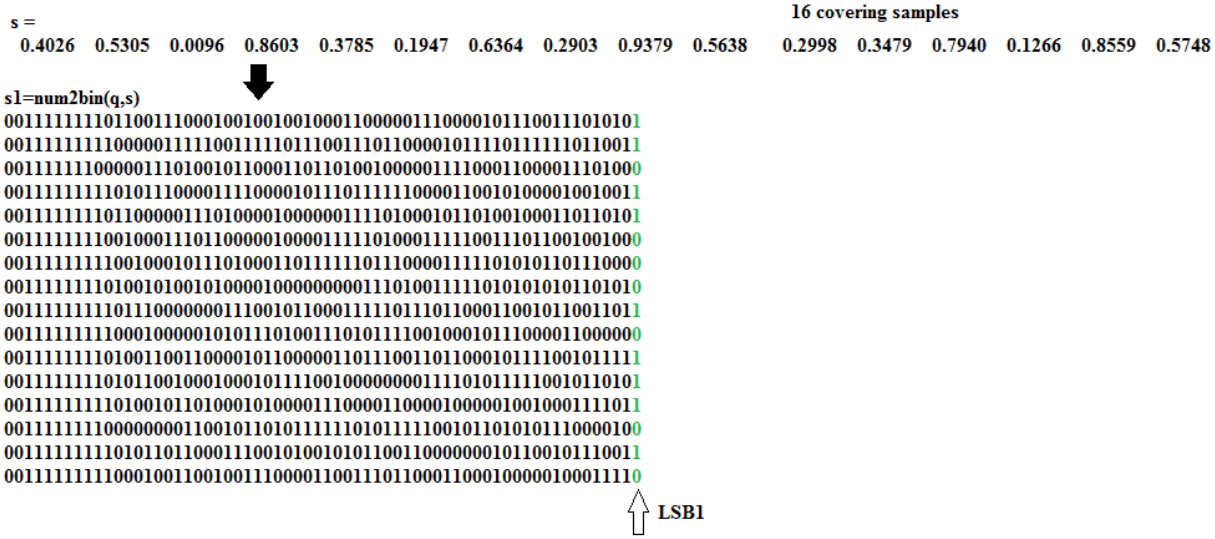

Figure 7: Preparation of DSF when using LSB1

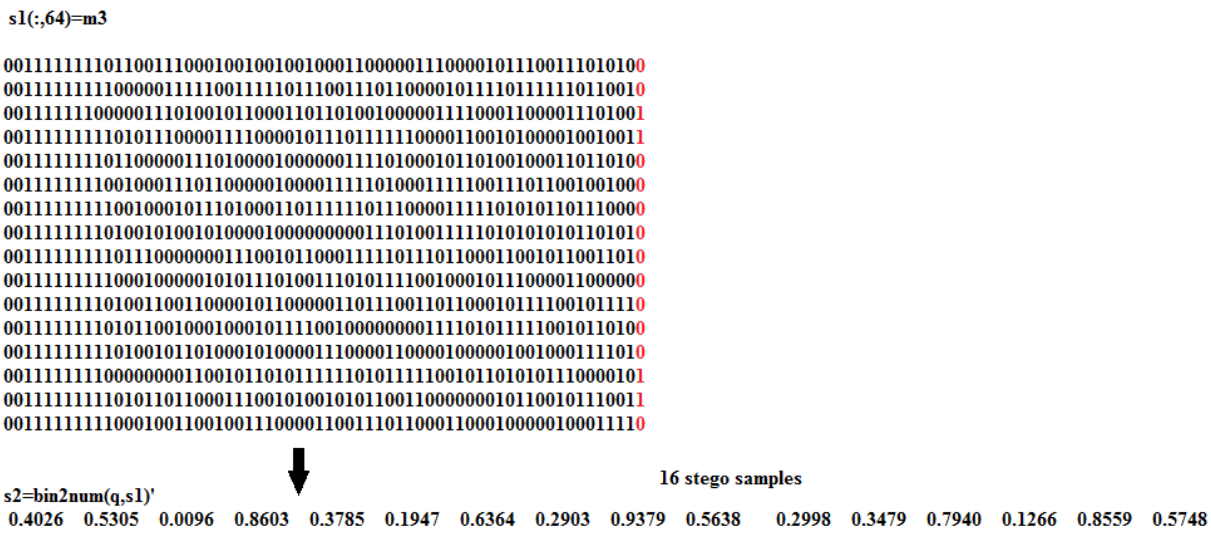

Figure 8: SM hiding when using LSB1

Figure 9: SM hiding when using LSB4 to LSB1

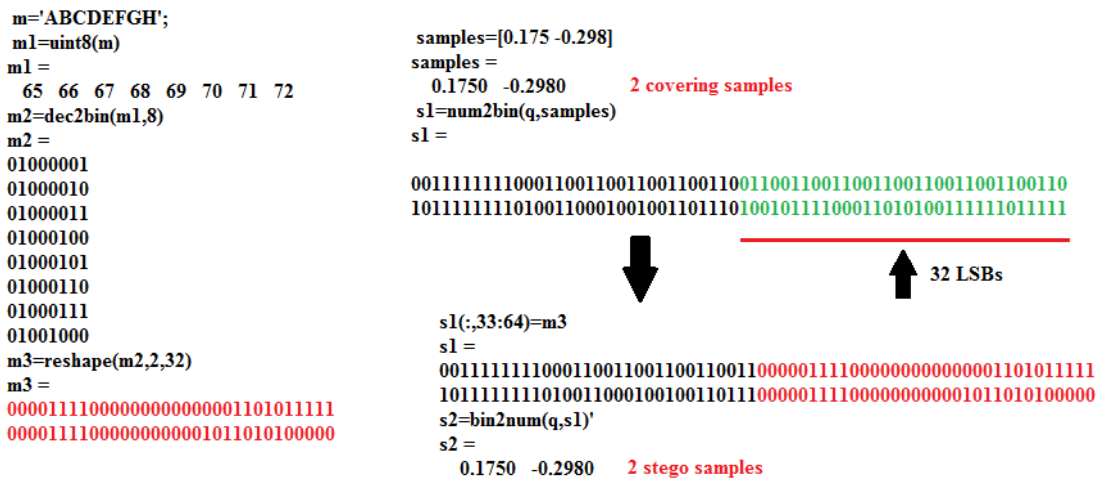

Figure 10: SM hiding when using LSB32 to LSB1

The extracting function will be implemented applying the following steps:

Step 1:

Stego DSF preparation:

1) Get the stego DSF.
2) Retrieve the file size.
3) Reshape the file matrix to one row matrix.

Step 2:

SM extraction:

1) Get the message length.
2) Get the stego Samples.
3) Convert the stego samples to binary.
4) Extract the required columns.
5) Reshape the extracted columns to 8 columns matrix to get MBM.
6) Convert MBM to decimal.
7) Convert the decimal matrix to characters to get the SM.

The following code can be useful to study the process of using DSF as a covering media:

```
;SM hiding
[c1 fs1]=wavread('C:\Users\win 7\Desktop\voices\az1.wav');
[nn1 nn2]=size(c1);L1=nn1*nn2;
c2=reshape(c1,1,L1);
q=quantizer('double');
m='Using speech sample bit for message steganography';
  m1=uint8(m);
LM=length(m1);
m2=dec2bin(m1,8);
m3=reshape(m2,LM*8,1);
c3=c2(1,1:LM*8);
c4=num2bin(q,c3);
c4(:,64)=m3;
c5=bin2num(q,c4)';
c2(1,1:LM*8)=c5;
c6=reshape(c2,nn1,nn2);
```



```
;SM extracting
c7=reshape(c6,1,L1);
c8=c7(1,1:LM*8);
c9=num2bin(q,c8);
c10=c9(:,64);
m4=reshape(c10,LM,8);
m5=bin2dec(m4)';
m6=char(m5)
```

For the purposes of studying using DSF as a covering media, some DSFs were selected and table 2 shows the main information of these files:

Tab1e 2: Selected DSFs basic information

DSF number	Size	Length in sample	Length in bytes
1	160768x2	321536	2572288
2	100352x2	200704	1605632
3	113664x2	227328	1818624
4	215040x2	430080	3440640
5	86016x2	172032	1376256
6	66560x2	133120	1064960
7	106496x2	212992	1703936
8	136192x2	272384	2179072
9	82880x1	82880	663040
10	64448x1	64448	515584

A message of 16 K bytes was selected and processes using LSB1 (one bit) from the DSF samples, the quality parameters were calculated, and the speed parameters were also calculated (hiding time in seconds (HT) , extracting time in seconds (ET), hiding throughput in K bytes per second (HTP), and extracting throughput in K bytes per second (ETP)) and table 3 shows the obtained results:

Table 3: Results when using LSB1 (one bit)

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	4.8418e-036	786.8364	5.4110	1.5260	2.9569	10.4849
2	3.5177e-036	787.8069	5.3110	1.6680	3.0126	9.5923
3	4.0508e-036	786.5303	5.3410	1.6690	2.9957	9.5866
4	1.6701e-036	798.7990	5.4870	1.6620	2.9160	9.6270
5	2.1958e-036	771.8472	5.2490	1.7140	3.0482	9.3349
6	2.5885e-036	764.1529	5.4250	1.5580	2.9493	10.2696
7	2.8540e-036	778.6469	5.4150	1.5380	2.9548	10.4031
8	3.3125e-036	781.7659	5.3220	1.5290	3.0064	10.4644
9	Not enough capacity					
10	Not enough capacity					
Remarks	Very low	Very high	Good speed parameters			

The previous experiment was repeated for the following cases:

- Using 2 bits for data hiding.
- Using 4 bits for data hiding
- Using 8 bits for data hiding
- Using 16 bits for data hiding.

- Using 32 bits for data hiding.

Tables 4 thru 8 show the obtained results:

Table 4: Results when using LSB2 and LSB1 (two bits)

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	7.3832e-036	782.6173	2.7090	0.8190	5.9062	19.5360
2	2.3531e-035	768.8016	2.9520	0.8160	5.4201	19.6078
3	2.7935e-035	767.2205	2.7030	0.8210	5.9193	19.4884
4	3.4505e-037	814.5689	2.7170	0.8440	5.8888	18.9573
5	1.3289e-035	753.8435	2.6690	0.8390	5.9948	19.0703
6	1.3550e-035	747.5997	2.6890	0.8530	5.9502	18.7573
7	1.0762e-035	765.3738	2.8720	0.8380	5.5710	19.0931
8	7.2643e-036	773.9130	2.8250	0.8460	5.6637	18.9125
9	2.5347e-035	753.0679	2.9870	0.7920	5.3565	20.2020
10	Not enough capacity					
Remarks	Very low	Very high	Good speed parameters			

Table 5: Results when using LSB3 to LSB1 (4 bits)

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	1.1220e-035	778.4328	1.3490	0.4720	11.8606	33.8983
2	1.4309e-035	773.7757	1.3540	0.4690	11.8168	34.1151
3	1.6230e-035	772.6509	1.3430	0.4740	11.9136	33.7553
4	7.4582e-036	783.8350	1.3620	0.4700	11.7474	34.0426
5	2.0577e-037	795.5226	1.4230	0.5660	11.2439	28.2686
6	9.1763e-035	728.4714	1.3160	0.5050	12.1581	31.6832
7	9.8502e-035	743.2333	1.3230	0.4980	12.0937	32.1285
8	7.2908e-036	773.8767	1.4270	0.6580	11.2123	24.3161
9	4.2128e-034	724.9617	1.4050	0.5440	11.3879	29.4118
10	1.1656e-033	713.7804	1.5870	0.4320	10.0819	37.0370
Remarks	Very low	Very high	Good speed parameters			

Table 6: Results when using LSB7 to LSB1 (8 bits)

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	2.0299e-033	726.4517	0.6810	0.2920	23.4949	54.7945
2	2.0956e-033	723.9089	0.6710	0.2950	23.8450	54.2373
3	2.8919e-033	720.8226	0.6740	0.2920	23.7389	54.7945
4	1.3415e-033	731.9126	0.6840	0.2950	23.3918	54.2373
5	0	Infinity	0.6670	0.3190	23.9880	50.1567
6	0	Infinity	0.6630	0.3180	24.1327	50.3145
7	0	Infinity	0.6650	0.3200	24.0602	50.0000
8	0	Infinity	0.6560	0.3110	24.3902	51.4469
9	3.3378e-032	681.2381	0.7270	0.2560	22.0083	62.5000
10	1.5763e-031	664.7102	0.8290	0.2620	19.3004	61.0687
Remarks	Very low	Very high	Good speed parameters			

Table 7: Results when using LSB16 to LSB1 (16 bits)

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	1.2031e-033	731.6831	0.3710	0.1900	43.1267	84.2105
2	2.6464e-033	721.5753	0.3720	0.1940	43.0108	82.4742
3	3.4785e-033	718.9757	0.4610	0.2220	34.7072	72.0721
4	1.5794e-033	730.2801	0.3670	0.1930	43.5967	82.9016
5	0	Infinity	0.3630	0.2000	44.0771	80.0000
6	0	Infinity	0.3600	0.2220	44.4444	72.0721
7	0	Infinity	0.3610	0.1960	44.3213	81.6327
8	0	Infinity	0.3630	0.1980	44.0771	80.8081
9	5.1692e-030	630.8122	0.3930	0.1650	40.7125	96.9697
10	2.2709e-027	568.9556	0.3930	0.1670	40.7125	95.8084
Remarks	Very low	Very high	Good speed parameters			

Table 8: Results when using LSB33 to LSB64 (32 bits)

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	2.2850e-024	518.0353	0.2240	0.1330	71.4286	120.3008
2	4.4525e-024	509.1401	0.2150	0.1340	74.4186	119.4030
3	5.0246e-024	508.0656	0.2140	0.1340	74.7664	119.4030
4	2.4933e-024	518.4816	0.2160	0.1340	74.0741	119.4030
5	0	Infinity	0.2450	0.1460	65.3061	109.5890
6	0	Infinity	0.2120	0.1360	75.4717	117.6471
7	0	Infinity	0.2130	0.1390	75.1174	115.1079
8	0	Infinity	0.2120	0.1380	75.4717	115.9420
9	1.4535e-020	413.2409	0.2250	0.1200	71.1111	133.3333
10	2.4409e-019	384.0270	0.2900	0.1250	55.1724	128
Remarks	Very low	Very high	Good speed parameters			

To see the effects of SM length increasing, a message of 32 K bytes was selected and processed using 32 bits for message bits hiding, and table 9 shows the obtained results:

Table 9: Results for hiding a message with 32 K characters using 32 bits for message hiding

DSF number	MSE	PSNR	HT	ET	HTP	ETP
1	5.0344e-024	510.1361	0.4170	0.2660	76.7386	120.3008
2	1.1354e-023	499.7788	0.3810	0.2630	83.9895	121.6730
3	1.4745e-023	497.3004	0.3870	0.2590	82.6873	123.5521
4	7.1998e-024	507.8774	0.4300	0.2580	74.4186	124.0310
5	0	Infinity	0.3790	0.2660	84.4327	120.3008
6	0	Infinity	0.3790	0.2640	84.4327	121.2121
7	0	Infinity	0.4030	0.3660	79.4045	87.4317
8	0	Infinity	0.3790	0.2650	84.4327	120.7547
9	2.1330e-020	409.4055	0.4560	0.2350	70.1754	136.1702
10	9.6291e-018	347.2770	0.5350	0.2850	59.8131	112.2807
Remarks	Very low	Very high	Good speed parameters			

From the obtained experimental results we can see the following facts:

- DSF is a very convenient and efficient covering media, it can hold short and long messages keeping the stego file in excellent quality.
- Any bit form bit order 33 to 64 can be efficiently used for message hiding, the quality of the stego DSF remain excellent when changing the bit order.
- Any set of bits can be used efficiently from the speech samples to hold the SM bits; the quality of the stego file will be excellent.
- The capacity hiding will be increased when increasing the number of sample bits used for message hiding, the maximum capacity will be achieved when using 32 bits, and here the DSF capacity hiding will equal the file size in samples multiplied by 4.
- The speed parameters mainly depend on the SM length, increasing the message length will slowly increase the hiding and extracting time.
- For a selected message length, the speed parameters remain almost stable regardless the size of the used DSF.
- Using DSF as a covering media provides the user with a fixable covering digital media, the user can select any bit or set of bits from the speech samples values to get a stego file with excellent quality, the stego file will always closed to the covering file.
- The DSF capacity hiding, the quality parameters, and the speed parameters can be controlled by setting the number of bits from the speech samples to be used for message bits hiding.
- Using DSF for message hiding is better than using any other digital data such as color images, the quality results of using DSF is better [1-10].

Conclusion

Digital speech files as a covering data in the message steganography process were studied. Different DSF were processed to hold various secret messages. The obtained results showed that DSF are very convenient digital dat to be used for message steganography. The big number of bits in the speech binary value gives us the chance to select one or more bits from this value to hold the message bits.

The provided experiments show that any bit or set of bits from the speech sample value can be used for message hiding, these bits can be selected by the user and he can control the DSF hiding capacity, quality parameters and speed parameters.

References

[1]. Prof. Ziad A.A. Alqadi, Prof. Mohammed K. Abu Zalata, Ghazi M. Qaryouti, Comparative Analysis of Color Image Steganography, JCSMC, Vol.5, Issue. 11, November 2016, pg.37–43.

[2]. M. Jose, "Hiding Image in Image Using LSB Insertion Method with Improved Security and Quality", International Journal of Science and Research, Vol. 3, No. 9, pp. 2281-2284, 2014.

[3]. Emam, M. M., Aly, A. A., & Omara, F. A. An Improved Image Steganography Method Based on LSB Technique with Random Pixel Selection. International Journal of Advanced Computer Science & Applications,1(7), pp. 361-366, (2016). https://doi.org/10.14569/IJACSA.2016.070350.

[4]. Mohammed Abuzalata; Ziad Alqadi; Jamil Al-Azzeh; Qazem Jaber, Modified Inverse LSB Method for Highly Secure Message Hiding, IJCSMC, Vol. 8, Issue. 2, February 2019, pg.93 – 103.

[5]. Rashad J. Rasras, Mutaz Rasmi Abu Sara, Ziad A. AlQadi, Engineering, A Methodology Based on Steganography and Cryptography to Protect Highly Secure Messages Engineering Technology & Applied Science Research, Vol.9 Issue 1, Pages 3681-3684, 2019.

[6]. Zhou X, Gong W, Fu W, Jin L. 2016An improved method for LSB based color image steganography combined with cryptography. In 2016 IEEE/ACIS 15th Int. Conf. on Computer and Information Science (ICIS), Okayama, Japan, pp. 1–4 . https://doi.org/10.1109/ICIS.2016.7550955.

[7]. Wu D-C, Tsai W-H. A steganographic method for images by pixel value differencing. Pattern Recognition. Lett. 24, 1613–1626. 2003 https://doi.org/10.1016/S0167-8655(02)00402-6.

[8]. Das R, Das I. Secure data transfer in IoT environment: adopting both cryptography and steganography techniques. In Proc. 2nd Int. Conf. on Research in Computational Intelligence and Communication Networks, Kolkata, India, pp. 296–301, 2016. https://doi.org/10.1109/ICRCICN.2016.7813674.

[9]. Rashad J. Rasras, Mutaz Rasmi Abu Sara, Ziad A. AlQadi, Rushdi Abu zneit, Comparative Analysis of LSB, LSB2, PVD Methods of Data Steganography, International Journal of Advanced Trends in Computer Science and Engineering, vol. 8, issue 3, pp.748-754, 2019, http://www.warse.org/IJATCSE/static/pdf/file/ijatcse64832019.pdf

[10]. Ayman Al-Rawashdeh, Ziad Al-Qadi, using wave equation to extract digital signal features, Engineering, Technology & Applied Science Research, vol. 8, issue 4, pp. 1356-1359, 2018.

[11]. K Matrouk, A Al-Hasanat, H Alasha'ary, Z. Al-Qadi Al-Shalabi, "Speech fingerprint to identify isolated word person", World Applied Sciences Journal, Vol. 31, No. 10, pp. 1767-1771, 2014.

[12]. Saleh Khawatreh, Belal Ayyoub, Ashraf Abu-Ein, Ziad Alqadi , A Novel Methodology to Extract Voice Signal Features , International Journal of Computer Applications, Volume 179 – No.9, January 2018.

[13]. Ziad Alqadi, Bilal Zahran, Qazem Jaber, Belal Ayyoub, Jamil Al-Azzeh, Enhancing the Capacity of LSB Method by Introducing LSB2Z Method, International Journal of Computer Science and Mobile Computing, vol. 8, issue 3, pp. 76-90, 2019.

[14]. Ziad A. Alqadi, Majed O. Al-Dwairi, Amjad A. Abu Jazar and Rushdi Abu Zneit, Optimized True-RGB color Image Processing, World Applied Sciences Journal 8 (10): 1175-1182, ISSN 1818-4952, 2010.

[15]. Waheeb, A. and Ziad AlQadi, Gray image reconstruction. Eur. J. Sci. Res., 27: 167-173, 2009.

[16]. A. A. Moustafa, Z. A. Alqadi, "Color Image Reconstruction Using a New R'G'I Model", Journal of Computer Science, Vol.5, No. 4, pp. 250-254, 2009.

[17]. Prof. Ziad A.A. Alqadi, Prof. Mohammed K. Abu Zalata, Ghazi M. Qaryouti, Comparative Analysis of Color Image Steganography, JCSMC, Vol.5, Issue. 11, November 2016, pg.37–43.

[18]. H. Alasha'ary, K. Matrouk, A. Al-Hasanat, Z. A alqadi, H. Al-Shalabi (2013), Improving Matrix Multiplication Using Parallel Computing, International Journal on Information Technology (I.RE.I.T.) Vol.1, N. 6 ISSN 2281-2911.

[19]. Bilal Zahran, Ziad Alqadi, Jihad Nader, Ashraf Abu Ein A COMPARISON BETWEEN PARALLEL AND SEGMENTATION METHODS USED FOR IMAGE ENCRYPTION-DECRYPTION, International Journal of Computer Science & Information Technology (IJCSIT) Vol 8, No 5, October 2016.

[20]. Z.A. Alqadi, A. Abu-Jazar (2005), Analysis of Program Methods Used for Optimizing Matrix Multiplication, Journal of Engineering, vol. 15 n. 1, pp. 73-78.

[21]. Jamil Al-Azzeh, Bilal Zahran, Ziad Alqadi, Belal Ayyoub, Muhammed Mesleh: A Novel Based On Image Blocking Method to Encrypt-Decrypt Color JOIV: International Journal on Informatics Visualization, 2019.

[22]. Jamil Al-Azzeh, Bilal Zahran, Ziad Alqadi, Belal Ayyoub and Mazen Abu-Zaher: A Novel Zero-Error Method to Create a Secret Tag for an Image; Journal of Theoretical and Applied Information Technology 15th July 2018.

[23]. Jamil Al Azzeh, Ziad Alqadi Qazem, M. Jabber: Statistical Analysis of Methods Used to Enhanced Color Image Histogram; XX International Scientific and Technical Conference; Russia May 24-26, 2017.

[24]. Jamil Al Azzeh, Hussein Alhatamleh, Ziad A. Alqadi, Mohammad Khalil Abuzalata: Creating a Color Map to be used to Convert a Gray Image to Color Image; International Journal of Computer Applications (0975– 8887). Volume 153 – No2, November 2016.

[25]. Khaled Matrouk, Abdullah Al- Hasanat, Haitham Alasha'ary, Ziad Al-Qadi, Hasan Al-Shalabi Analysis of Matrix Ziad Alqadi et al, International Journal of Computer Science and Mobile Computing, Vol.8 Issue.3, March- 2019, pg. 76-90.

[26]. Mohammed Abuzalata; Ziad Alqadi, Jamil Al-Azzeh; Qazem Jaber Modified Inverse LSB Method for Highly Secure Message Hiding: International Journal of Computer Science and Mobile Computing, Vol.8 Issue.2, February- 2019, pg. 93-103.

[27]. Qazem Jaber Rashad J. Rasras, Mohammed Abuzalata, Ziad Alqadi, Jamil Al-Azzeh; Comparative Analysis of Color Image Encryption-Decryption Methods Based on Matrix Manipulation: International Journal of Computer Science and Mobile Computing, Vol.8 Issue.2, 2019/3.

[28]. Jamil Al-Azzeh, Ziad Alqadi, Mohammed Abuzalata; Performance Analysis of Artificial Neural Networks used for Color Image Recognition and Retrieving: International Journal of Computer Science and Mobile Computing, Vol.8 Issue.2, February- 2019.

[29]. Rashad J. Rasras, Mohammed Abuzalata; Ziad Alqadi; Jamil Al-Azzeh; Qazem Jaber, Comparative Analysis of Color Image Encryption-Decryption Methods Based on Matrix Manipulation International Journal of Computer Science and Mobile Computing, Vol.8 Issue.3, March- 2019, pg. 14-26.

[30]. AlQaisi Aws, AlTarawneh Mokhled, A Alqadi Ziad, A Sharadqah Ahmad , Analysis of Color Image Features Extraction using Texture Methods , TELKOMNIKA, vol. 17, issue 3, 2018.

[31]. B. Zahran, J. AL-Azzeh, Z. Al Qadi, M. Al Zoghoul and S. Khawatreh, "A MODIFIED LBP METHOD TO EXTRACT FEATURES FROM COLOR IMAGES", Journal of Theoretical and Applied Information Technology(JATIT), Vol.96. No 10, 2018.

[32]. J. AL-AZZEH, B. ZAHRAN, Z. ALQADI, B. AYYOUB, M. ABU-ZAHER, "A novel Zero-error Method to Create a Secret Tag for an Image", Journal of Theoretical and Applied Information Technology(JATIT), Vol.96. No 13, 2018.pp: 4081-4091.

[33]. J. AL-AZZEH, B. ZAHRAN, Z. ALQADI," Salt and Pepper Noise: Effects and Removal", International Journal on Informatics Visualization, Vol.2. No 4, 2018.pp: 252-256.

[34]. Jihad Nader, Ziad Alqadi, Bilal Zahran, "Analysis of Color Image Filtering Methods", International Journal of Computer Applications (IJCA), Volume 174, issue 8, 2017, pp:12-17.
[35]. Ziad Alqadi, Bilal Zahran, Jihad Nader, " Estimation and Tuning of FIR Low pass Digital Filter Parameters", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 7, Issue 2, 2017, pp:18-23.
[36]. Khaled Aldebei, Mua'ad M. Abu-Faraj, Ziad A. Alqadi, Comparative Analysis of Fingerprint Features Extraction Methods, Journal of Hunan University Natural Sciences, vol. 48, issue 12, pp. 177-182, 2022.
[37]. Dr. Mohamad Barakat Prof. Ziad Alqadi, Highly Secure Method for Secret Data Transmission, International Journal of Scientific Engineering and Science, vol. 6, issue 1, pp. 49-55, 2022.
[38]. Ziad A. Alqadi Mua'ad M. Abu-Faraj, Rounds Reduction and Blocks Controlling to Enhance the Performance of Standard Method of Data Cryptography, International Journal of Computer Science and Network Security, vol. 21, issue 12, pp. 648-656, 2021.
[39]. Ziad Alqadi Mua'ad Abu-Faraj , Khaled Aldebei, DEEP MACHINE LEARNING TO ENHANCE ANN PERFORMANCE: FINGERPRINT CLASSIFIER CASE STUDY, JOURNAL OF SOUTHWEST JIAOTONG UNIVERSITY, vol. 56, issue 6, pp. 686-694, 2021.
[40]. Ziad A. Alqadi Mua'ad M. Abu-Faraj, Improving the Efficiency and Scalability of Standard Methods for Data Cryptography, International Journal of Computer Science and Network Security, vol. 21, issue 12, pp.451-458, 2021
[41]. Mua'ad M. Abu-Faraj Prof. Ziad Alqadi, Using Highly Secure Data Encryption Method for Text File Cryptography, International Journal of Computer Science and Network Security, vol. 20, issue 11, pp. 53-60, 2021.
[42]. AlQaisi Aws, AlTarawneh Mokhled, A Alqadi Ziad, A Sharadqah Ahmad, Analysis of Color Image Features Extraction using Texture Methods, TELKOMNIKA, vol. 17, issue 3, 2018.
[43]. Ziad A AlQadi Amjad Y Hindi, O Dwairi Majed, PROCEDURES FOR SPEECH RECOGNITION USING LPC AND ANN, International Journal of Engineering Technology Research & Management, vol. 4, issue 2, pp. 48-55, 2020.
[44]. Ziad A Alqadi, Mohamad Tariq Barakat, A Case Study to Improve the Quality of Median Filter, International Journal of Computer Science and Mobile Computing, vol. 10, issue 11, pp. 19 – 28, 2021.
[45]. Dr. Hatim Ghazi Zaini Prof. Ziad Alqadi, High Salt and Pepper Noise Ratio Reduction, International Journal of Computer Science and Mobile Computing, vol. 10, issue 9, pp. 88 – 97, 2021.
[46]. Prof. Mohamad K. Abu Zalata, Hussein N. Hatamleh, Prof. Ziad A. Alqadi, Detailed Study of Low Density Salt and Pepper Noise Removal from Digital Color Images, IJCSMC, Vol. 11, Issue. 2, PP. 56 – 67, February 2022.
[47]. M. Abu-Faraj, A. Al-Hyari, K. Aldebei, B. Al-Ahmad, and Z. Alqadi, "Rotation Left Digits to Enhance the Security Level of Message Blocks Cryptography," IEEE Access, vol. 10, pp. 69388- 69397, 2022, doi:10.1109/ACCESS.2022.3187317.
[48]. M. Abu-Faraj, A. Al-Hyari, and Z. Alqadi, "Experimental Analysis of Methods Used to Solve Linear Regression Models," CMC-Computers, Materials & Continua, vol. 72, no. 3, pp. 5699-5712, 2022, doi:10.32604/cmc.2022.027364. (Web of Science Indexed, Scopus Indexed).
[49]. M. Abu-Faraj, A. Al-Hyari, and Z. Alqadi, "Complex Matrix Private Key to Enhance the Security Level of Image Cryptography," Symmetry, vol. 14, Iss. 4, pp. 664-678, 2022, doi:10.3390/sym0664. (Web of Science Indexed, Scopus Indexed)
[50]. M. Abu-Faraj, K. Aldebei, and Z. Alqadi, "Simple, Efficient, Highly Secure, and Multiple Purposed Method on Data Cryptography," Traitement du Signal, vol. 39, no. 1, pp. 173-178, 2022, doi:10.18280/ts.390117. (Web of Science Indexed, Scopus Indexed)
[51]. M. Abu-Faraj, and Z. Alqadi, "Rounds Reduction and Blocks Controlling to Enhance the Performance of Standard Method of Data Cryptography," International Journal of Computer Science and Network Security (IJCSNS), vol. 21, no. 12, pp. 648-656, 2021, doi: 10.22937/IJCSNS.2021.21.12.89. (Web of Science Indexed)
[52]. M. Abu-Faraj, and Z. Alqadi, "Improving the Efficiency and Scalability of Standard Methods for Data Cryptography," International Journal of Computer Science and Network Security (IJCSNS), vol. 21, no.12, pp. 451-458, 2021, doi:10.22937/IJCSNS.2021.21.12.61. (Web of Science Indexed)
[53]. M. Abu-Faraj, and Z. Alqadi, "Using Highly Secure Data Encryption Method for Text File Cryptography," International Journal of Computer Science and Network Security (IJCSNS), vol. 21, no.12, pp. 53-60, 2021, doi:10.22937/IJCSNS.2021.21.12.8. (Web of Science Indexed)
[54]. M. Abu-Faraj, and M. Zubi, "Analysis and Implementation of Kidney Stones Detection by Applying Segmentation Techniques on Computerized Tomography Scans," Italian Journal of Pure and Applied Mathematics, iss. 43, pp. 590-602, 2020. (Scopus Indexed)
[55]. Prof. Ziad Alqadi, Bits Substitution to Secure LSB Method of Data Steganography, International Journal of Computer Science and Mobile Computing, vol. 11, issue 8, pp. 9 – 21, 2022.
[56]. Mohammad S. Khrisat Prof. Ziad Alqadi, Enhancing LSB Method Performance Using Secret Message Segmentation, International Journal of Computer Science and Network Security, vol. 22, issue 7, pp. 1-6, 2022.
[57]. Hatim Ghazi Zaini and Ziad A. Alqadi Mohammad S. Khrisat, Adnan Manasreh, COVER IMAGE REARRANGEMENT TO SECURE LSB METHOD OF DATA STEGANOGRAPHY, Journal of Engineering and Applied Sciences, vol. 17, issue 3, pp. 294-302, 2022.
[58]. Mohamad K Abu Zalata, Mohamad T Barakat, Ziad A Alqadi, Carrier Image Rearrangement to Enhance the Security Level of LSB Method of Data Steganography, International Journal of Computer Science and Mobile Computing, vol. 11, issue 1, pp. 182 – 193, 2022.

[59]. Dr. Mohamad barakat Prof. Ziad Alqadi, IMAGE TRANSFORMATION TO INCREASE THE SECURITY LEVEL OF LBS METHOD OF DATA STEGANOGRAPHY, International Journal of Engineering Technology Research & Management, vol. 6, issue 1, pp. 42-53, 2022.

[60]. Naseem Asad, Ismail Shayeb, Qazem Jaber, Belal Ayyoub, Ziad Alqadi, Ahmad Sharadqh, creating a Stable and Fixed Features Array for Digital Color Image, IJCSMC, Vol. 8, Issue. 8, August 2019, pg.50 –62.

[61]. Majed O. Al-Dwairi, Amjad Y. Hendi, Mohamed S. Soliman, Ziad A.A. Alqadi, A new method for voice signal features creation, International Journal of Electrical and Computer Engineering (IJECE), vol. 9, issue 5, pp. 4092-4098, 2018.

[62]. Akram A. Moustafa and Ziad A. Alqadi, A Practical Approach of Selecting the Edge Detector Parameters to Achieve a Good Edge Map of the Gray Image, Journal of Computer Science 5 (5): 355-362, 2009.

[63]. ZA Alqadi, Musbah Aqel, Ibrahiem MM El Emary, Performance analysis and evaluation of parallel matrix multiplication algorithms, World Applied Sciences Journal, vol. 5, issue 2, pp. 211-214, 2008.

[64]. Ismail Shayeb, Naseem Asad, Ziad Alqadi, Qazem Jaber, Evaluation of speech signal features extraction methods, Journal of Applied Science, Engineering, Technology, and Education is licensed under an Attribution-Non Commercial-Share Alike 4.0 International (CC BY-NC-SA 4.0)

[65]. Dr. Mohammed Abbas Fadhil Al-Husainy, COMPARISON STUDY BETWEEN CLASSIC-LSB, SLSB AND DSLSB IMAGE STEGANOGRAPHY, ICIT 2013 The 6th International Conference on Information Technology.

[66]. Kaur, R. Dhir, & G. Sikka,"A new image steganography based on first component alteration technique", International Journal of Computer Science and Information Security (IJCSIS), 6, pp.53-56, 2009.http://arxiv.org/ftp/arxiv/papers/1001/1001.1972.pdf.

[67]. Alvaro Martin, Guillermo Sapiro, &GadielSeroussi,"Is Steganography Natural", IEEE Transactions on Image Processing, 14(12), pp.2040-2050, 2005.doi: 10.1109/TIP.2005.859370 .

[68]. Bhattacharyya, A. Roy, P. Roy, & T. Kim, "Receiver compatible data hiding in color image", International Journal of Advanced Science and Technology, 6, pp.15-24, 2009.http://www.sersc.org/journals/IJAST/vol6/2.pdf .

[69]. Namer Ali Aletawi; Mansour A. Abu Sameha; Prof. Ziad Alqadi, Modified LSB2 Steganography Method to Secure the Embedded Secret Message, IJCSMC, Vol. 11, Issue. 8, August 2022, pg.22 – 44.

