IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 8, August. 2019, ||Series -II || PP 43-53

Analysis of Data Hiding Capacity in Sudoku Puzzles

Shalu[1], Shradhanjali Singh[2]
[1](*Department of Computer Science Rajasthan Technical University Kota, India)*
[2](*Department of Computer Science Rajasthan Technical University Kota, India)*
Corresponding Author: Shalu
Received 15 August 2019; Accepted 30 August 2019

Abstract: Steganography is defined in terms of hidden or secret communication. It is hiding the presence of information or data from the unauthorized users. Therefore, we need a medium that hides the message or work as cover media for steganography. Many multimedia files such as Image, audio, video etc. are very frequently used for a cover medium in steganography. Other than these It Is also possible to use video games as the cover medium that makes a message more undetectable. In this paper we implementing the game based steganography methods. Therefore, Sudoku Puzzles are used as the cover medium. It is freely available online. The purpose of using this due to its hiding capacity and the popularity among the people availability and the hiding capacity.

Keywords: Steganography, Entropy, hiding capacity, Sudoku Puzzles.

I. INTRODUCTION

Unfortunately, Cryptography is not enough to keep the information safe always due to the suspension of the attacker. It may also be required to keep the presence of the information hidden from the users. To achieve this goal a technique is used that is called steganography.

Steganography method is like a hide and seeks game. It is a combination of arts and sciences of invisible communication. It is derived from the Greek words "stegos" means "cover" and "grafia" means "writing", defining it as "covered writing". Steganography is nowadays commonly used, for communication or information exchange without raising suspicions and protect the copywriters of digital media. There are much software used for hiding messages in a video such as mp4, audio such as mp3, images such as jpg, png etc., and other not so common media such as text, TCP/IP packets, executable files, DNA pattern, XML file etc. Sometimes using these increase suspicion to them due to the large size.Nowadays it becomes interesting to use games as a cover medium for steganography techniques. Games like Sudoku, Tetris, jigsaw puzzle, minesweeper etc. are used. Using games make difficult to suspicion of a message.

Hernandez Castro JC, Blasco Lopez I, Estevez- Tapiador JM, Garnacho AR (2006) Go game in steganography. It requires that both the sender and receiver have the same software, encryption keys, and some parameters. The idea for this is threshold value T computed for each position in the game and encode the secret information. The value of T denote the good moves, not bad ones. Make the list of good moves and arrange them in order and covert these moves into binary form. So log2(good moves) bits are able to hide. For good moves selection, searching algorithms are used. Therefore, a different2 game form required different algorithms.

En Jung Farn, Chaur-Chin Chen (2009) propose a novel method using the jigsaw puzzle. Because it is not used Pixel values to hide the data so it comes the on compression attacks. The player knows the size of the puzzle so the method is limiting by the size.

En Jung Farn, Chaur-Chin Chen (2009) a proposed method used jigsaw puzzle image to hide the data. So it divides the puzzle into many blocks with a special pattern. Each Block has a semi-circle. Moreover, the secret data is used hide on these semi-circles. The proposed method has some loss of data due to the format of image and compression based attack is also possible on it.

AbdelrhmanDesokey, Mohammad Younis. (2009) proposed a chestega a chess steganography methodology. This paper used the chess game as the cover medium for stenographic techniques. This methodology is different from other game steganography methods because it does not use the noise and distortion in an image. In the stand of this it uses chess board position, a color of a board, moves of game and result etc. to hide the data. We can able to use more than one chessboard to hide the information. It uses the chess game as an image, graphics, and audios. This method can be applied to other board game such as cross board, checkerboard etc.

Lee HL, Lee CF, Chen LH (2010) Proposed steganography Method by using Maze game. It is puzzle game where player need to find the correct path from stating point to final point. In maze game only one solution path is possible for one /maze puzzle so authors used this solution path to hide the secret information. It have good hiding capacity and the people are not easily detect the presence of information in game.

Zhan He Ou, Ling Hwei Chen (2014) used popular Tetris game for hiding information. Tetris game have seven termino sequence. Sender used these sequence to hide the information in game and upload or send this to the receiver. Receiver extract information from game using extraction algorithms.

SusmitaMahato, Dilip Kumar Yadav and Danish Ali Khan (2017) Proposed method by using Minesweeper game as cover medium for hiding the information. First of all select the starting point that is always safe and position of mines are used to store the data. So Mines represent the no of 1's and other cells represent no. of 0's in message. Different level of game have the different capacity of hiding information.

In proposed method we use Sudoku puzzle as a cover medium for hiding information for that we using cell for hiding information. It is easy to implement. And the hiding capacity is much higher than the other used game. This paper has proposed an algorithm to embed the secret data in Sudoku puzzles. The rest of the paper details the following Section in a given way, section II about Sudoku Puzzles details about a game basis, Section III Proposed method Section IV Experimental results and Analysis a, Section V Conclusion and Future scope.

II. SUDOKU PUZZLES

This Section discusses about the Sudoku basis. So, that help to understand the algorithm.

Sudoku is come under the category of mind games. These are the logic based number placement puzzles and they are easy to learn and understand. The main aim of Sudoku puzzle s is to fill a 9×9 grid with digits from 1 to 9 so that each column, each row, and each of the nine 3×3 grids block that makes up the larger 9×9 grid. Some cell in Sudoku puzzles are filled initially. These filled cell help to find the solution of Sudoku puzzles.Switzerland is the origin of Sudoku puzzles. In 18th century Leonhard euler Created "carré Latin" which is similar to a Sudoku puzzle but without the additional constraint on the contents of individual regions. An American architect Howard Garns was the person who invented first real Sudoku puzzle and it is published in 1979.The real worldwide popularity started in Japan in 1986, after it was published and given the name Sudoku by Nikoli. The modern Sudoku Puzzle was designed by 76 year old retired architecture Howard Garns That was published in 1979 by Dell Magazines as number place.

It is more important to note down when solving the Sudoku. That there is no duplication of digits from 1 to 9 in any row, column and 3*3 grids. There is only single solution possible for a Sudoku puzzle. There are more than 6,670,903,752,021,072,936,960 Sudoku are possible.

There are many type of variant available for Sudoku puzzle.

1. Killer Sudoku
2. Mini Sudoku
3. Alphabetical Sudoku

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

Figure 1: 9x9 grid Sudoku puzzle used.

4. Hyper Sudoku
5. Twin Sudoku
6. Large Sudoku With 16x16 grid, 25x25 grid and 100x100 grid etc.

2.1 Rules for Sudoku:-

It is quite interesting to solve Sudoku puzzles. The Rules for Solving Sudoku is Easy.

1. There is no repeating of number from 1 to 9 in each row, column, and nonet.
2. The sum of all numbers in any nonet, row, or column must match the small number printed in its corner. For traditional Sudoku puzzles featuring the numbers 1 to 9, this sum is equal to 45.

These rules are for 9x9 Sudoku puzzles for other type of the Sudoku puzzles rule no. 1 is same but second rule change in with the type of Sudoku.

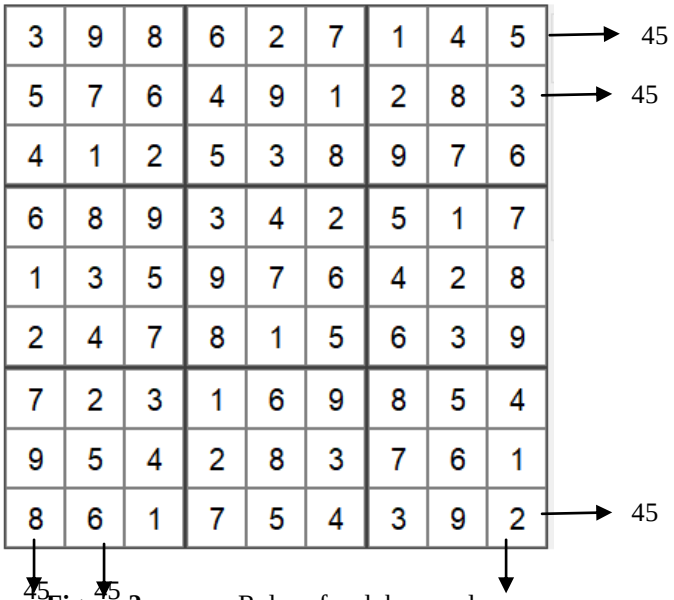


Figure 2: Rules of sudoku puzzles

2.2 Sudoku solving Techniques:-

There are two main techniques one can use to solve a Sudoku puzzle. These two techniques are simple, sufficient, straightforward and reliable in solving most standard Sudoku puzzles.

1. Crosshatching

These are the following steps to explain the crosshatching technique for Sudoku puzzles solving.

- We start with selecting on 3x3 block and try to fill this 3x3 block.
- In 3x3 block blank cell are filled by following the Sudoku rules means there is no repeating of number in any single row or column.
- According to that rule filled all blank cells of Sudoku.

It is best method for solving any type of Sudoku puzzles.

2. Pencilling In

We all knows that crosshatching is best method to solving any type of Sudoku puzzles. But there another method different the crosshatching that is penciling technique.These are the following steps to explain the crosshatching technique for Sudoku puzzles solving.

- We start with selecting on 3x3 block.
- And try to fill all blank cell with all numbers that are missing from every single row or column.
- After writing numbers in all blank cell check these cell with crosshatching technique.
- In all blank cell remove the number one by one and find the correct number for that cell.
- Fill all cells accordingly and find solution of the Sudoku puzzle.

III. PROPOSED METHOD.

Sudoku Puzzle are best brain exercise game. That is popular across the world. There are many online and offline variant of Sudoku are very popular and the time taken by the player to solve the Sudoku is important that decide the level of intelligence of people. All other details of game is show in in Section II. In this Section we details the proposed method to hide the secret information in Sudoku puzzles.

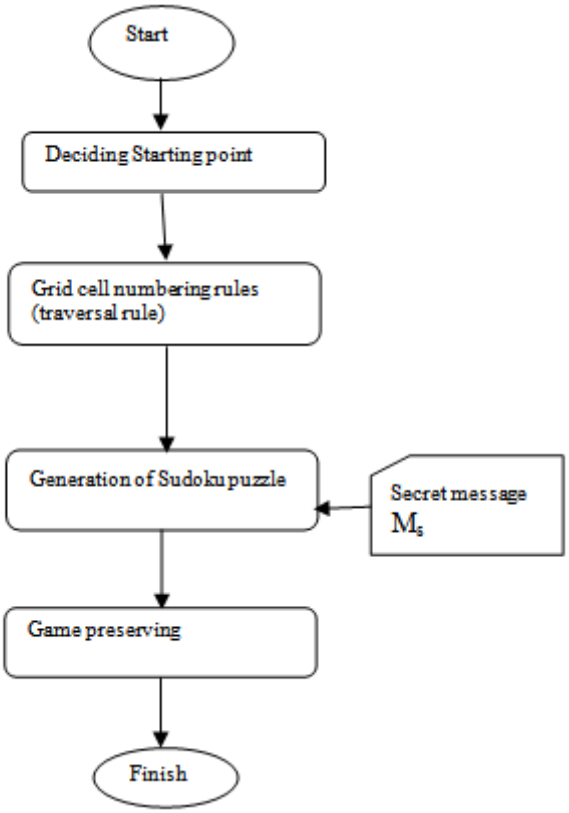
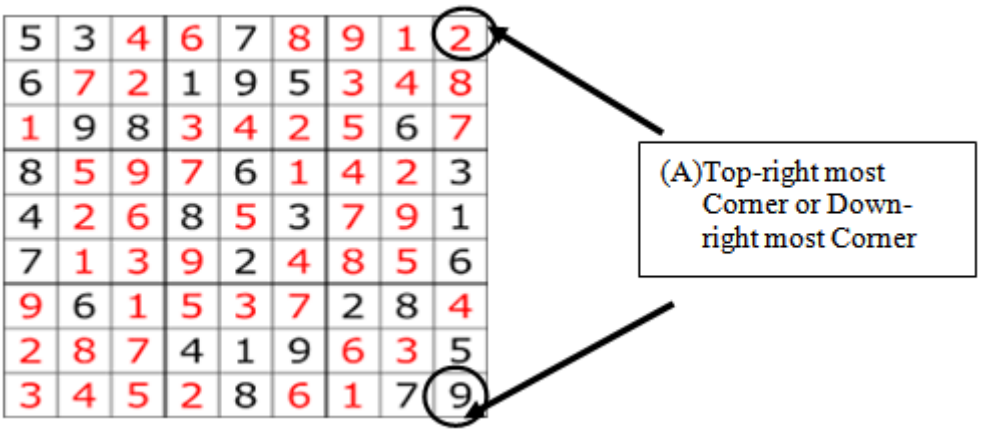


Figure 3: Block diagram of proposed method

3.1 Deciding staring Point*:*

We free to select Starting from Sudoku anywhere.The starting point of Puzzles are following Top-left most Corner, Top-right most Corner, Down-left most Corner, Down-right most Corner and Middle of grid. Fig. show the all possible starting there many other cells are also to select as starting cell.



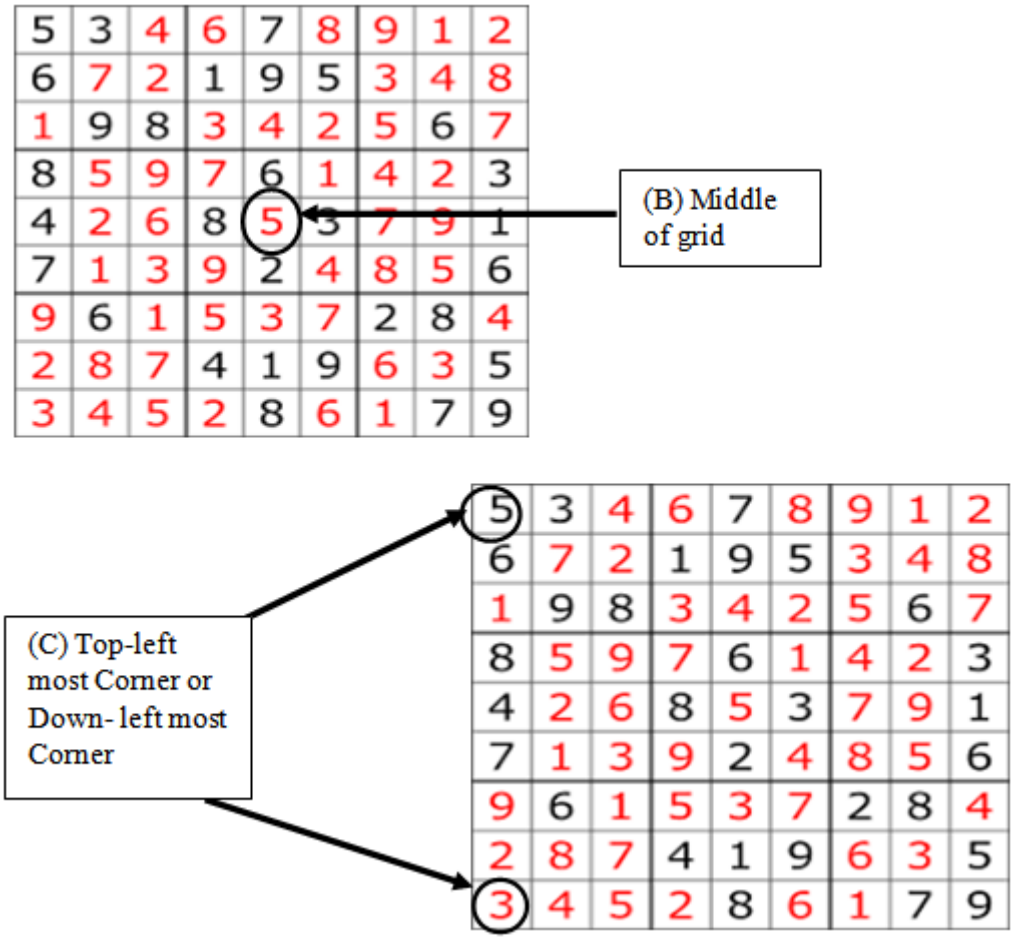


Figure 4: Stating Cell Selection of grid show in A,B and C.

3.2 Grid cell numbering:

Therefore, record the first click position. For numbering the cell in the minesweeper grid different2 matrix traversal approaches are designed according to the first click of the player. The moves can be followed towards the Left (→), Right (←), Up (↑), down (↓), left-right (→←), right–left (←→) Up-down (↑↓), and down-up (↓↑) in alternately and from outer to inner, or outer to inner. These rules are show on figure 5.

In the paper, we used Left-down-right-up approach for numbering the cells in a grid. After grid cell numbering, an embedded message is hidden in a grid and send to the receiver. He/ She receive the game link play the game and extract the message from it.

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
9	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
18	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
27	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**
36	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**
54	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**
63	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**
72	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**

(a). Left-Left traversal.

0	9	18	27	36	45	54	63	72
1	10	19	28	37	46	55	64	73
2	11	20	29	38	47	56	65	74
3	12	21	30	39	48	57	66	75
4	13	22	31	40	49	58	67	76
5	14	23	32	41	50	59	68	77
6	15	24	33	42	51	60	69	78
7	16	25	34	43	52	61	70	79
8	17	26	35	44	53	62	71	80

(b). Down-Down traversal.

48	47	46	45	44	43	42	63	80
25	24	23	22	21	20	41	62	79
26	9	8	7	6	19	40	61	78
27	10	1	0	5	18	39	60	77
28	11	2	3	4	17	38	59	76
29	12	13	14	15	16	37	58	75
30	31	32	33	34	35	36	57	74
49	50	51	52	53	54	55	56	73
64	65	66	67	68	69	70	71	72

(c). Left-down-right-up traversal.

Figure 5: (a),(b) and (c) are show different traversal rules

3.3 Embedding Algorithm:

These are the steps for embedding algorithm.

a. Let S_o be the Pain text string.
b. Now convert this Plain text S_o into Binary sequence Bo according to ASCII Table.
c. After converting So into Bo Binary string divide this string into number of groups by using equation.

$$Gn= Y /N-9$$

Where Gn Show the no of groups, N is total no of cell in nxmgrid and Y denote the size of bit string.

d. Starting nine cell in Sudoku grid are used to store the data information bit. Starting one bit is initial bit it may be 0/1. Here 0 means there is no further group exit and 1means it is not last group further group is possible.
e. And other 8 bit denote the divided into two part of three and five bits. First five bits O denote the game no game or order of game. And three bit r denote the no of character hidden in puzzle.

Where $0\leq O \leq 25$ and $0\leq r \leq 7$ (here 0 means 1 character, 1 means 2 character ,2 means 3chracter and so on.)

f. Add these nine bits to every group.
g. After that we can select the bit placing method(three type of bit placing method are possible that are explain in furthur).
h. After that deciding the blank cell positions.
i. After all these steps we are now share these puzzle to receiver. Receiver receive the puzzle use extraction algorithm to find the secret message from it.

Bit placing method: -There three type of bit placing schemes.

1. Odd-even placing: - In that type of placing we are deciding which bit from 0 and 1 representing odd position and which representing the even position. We can understand this with following

0 bit →even/odd position

1 bit →odd/ even position

After that we decide whether that have bit or not have information bit are blank or not blank.

2. Numeric placing: -In this type of bit placing technique we are first divide the bit stream into 2/3/4 bit size groups depend upon the type of Sudoku puzzles used for information hiding. Now convert these group into the decimal number.

After that place this number stream into the solve Sudoku for generating the Sudoku puzzles. Remove the numbers one-by-one from the Sudoku. After placing these bit in Sudoku new Sudoku puzzles are generate.

3. Easy placing: - In this scheme just all data bits and information bits on Sudoku grid from starting point to last point. After that decide the blank cell position weather 1 represent empty cell and 0 represent number containing cell or vice versa is also possible.

We comparing the result of calculate with these three method that is show with the help of graph it shows. It shows that these three technique provide different –different value of hiding capacity and entropy value, that is represent in figure. It shows that the easy placing technique have the highest value hiding capacity. And number placing scheme have the minimum hiding capacity. These value of hiding capacity vary with Sudoku type.

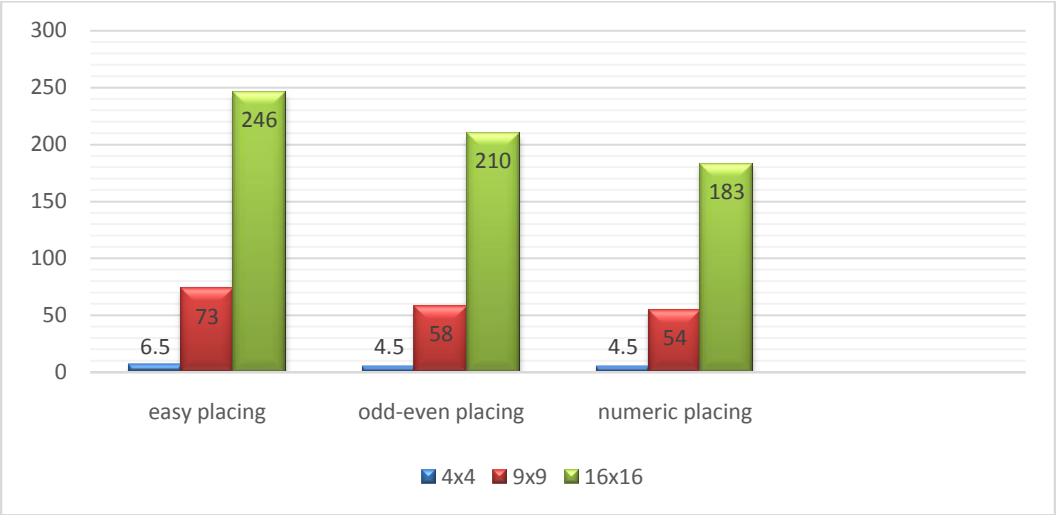


Figure 6: Graph show the relationship of different technique hiding capacity.

We are also calculate the entropy value that are show in Figure. 6

3.4 Extraction Method:

The receiver does extraction for that extraction algorithm is required. Extraction algorithm is the reverse of the encoding process.

a.The receiver receive the puzzle to solve it.

b. Starting point and cell numbering is decided by the communicating parties accordingly.

c.Blank cell represent the 0 bit and other represent the 1 bit and vice versa is also possible. So according to pre share details the binary string is constructed.

d. Now remove the nine information bit (1 bit for initial bit , 5 bit for group number and #bit for number of letter)

e.After removing them the rfrom each group combine all the group we get the bits string and divide this stringinto 8 bits size sub strings.

f. With the help of ASCII table, these 8 bits groups are converted into a plain text message or secret message that is received by the receiver securely.

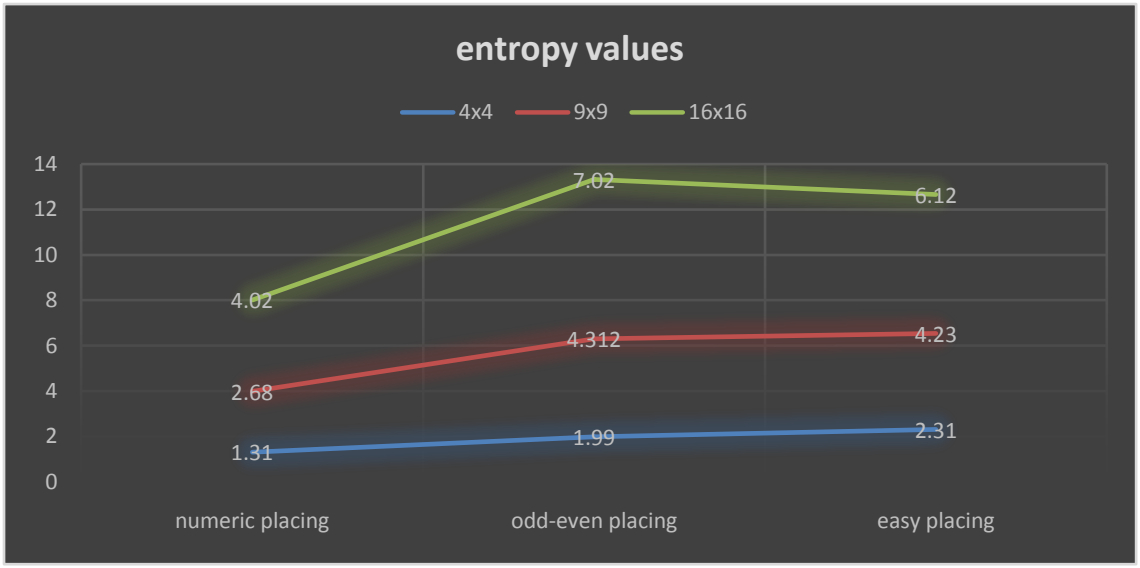


Figure 7: Graph show the relationship of different techniques and entropy values.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

This section deals with the experimental result case and analysis the different result for different type of Sudoku hiding capacity and entropy values show in tables.

4.1 Case study

Following case study show the process of hiding secret message into Sudoku using the odd-even placing technique.

- Plain text message "Steganography".
- ASCII Value of 115 116 101 103 97 110 111 103 114 97 112 104 121
- Binary representation of plain text using ASCII table

01110011|01110100|01100101|01100111|01100001|01101110|01101111|01100111|01110010|01100001|01110000|01101000|01111001

- Divide into groups Gi =No of Bits /(total no of cell -9)

Gi=104/(81-9)
=2(approximate)

- After adding starting bit and 8 data bits are adding.

G_1=1000010010111001101110100011001010110011101100001011011100110111101100111011100 10
G_2=00010000001100001 01110000 01101000 01111001

- Represent 0 => Blank cell and 1=>filled cell.
- Generate the game.
- Now send this to the user we want to communicate or share information.

Now, this show the process of extraction algorithm.

- Based on the starting cell the receiver also does numbering for the cell based on the pre decided rule. Until the cells contain the last cell of grid and 0 is put in the cell where cell is blank and 1 is put otherwise.

1000010010111001101110100011001010110011101100001011011100110111101100111011100 1000010000 01100001 01110000 01101000 01111001

- Now divide this bits string into 81 bits sub string.
- After that remove the initial bit and data information bit from each group we get and merge them we get bits string

011100110111010001100101011001110110000101101110011011110110010110000 1 01110000 01101000 01111001

- Now divide this into 8 bits group and find the character using the ASCII table

01110011|01110100|01100101|01100111|01100001|01101110|01101111|01100111|01110010|01100001|01110000|01101000|01111001

- Plain text message "Steganography".

Now this is show how the Prosed method is run.

4.2 Working outline

Here we show the outline of the proposed method to transfer the information using the Sudoku puzzles. For that purpose we already explain about the Sudoku puzzles in section II Sudoku puzzles. Let assume Alice andBob are two friends. They can communicate to each other by using a Sudoku puzzles with the help of proposed method. For that these are following steps must we follow.

a. Both of them sharing some keys and information regarding to the scenario.
b. Bob will create an online Sudoku puzzles game similar to reference 13 and 14 that provide some type of Sudoku puzzles.
c. Where user can play or solve Sudoku puzzles.
d. On online Sudoku puzzles it provide two section one have the Sudoku puzzles space and other side have some bottom (New game, check, exit)and some hint for solving Sudoku puzzles. All these things make them similar to the original one.
e. When Bob want to share some secrete information with Alice then he need to hide this information into Sudoku puzzles according to pre-shared information.
f. After that share the link of this created puzzle to Alice via using the email, WhatsApp and other.
g. When Alice receive this information then she link to the proposed puzzles where she able to extract the hidden information from Sudoku puzzles by raking the help of pre shared information about scenario.

4.3 Result and graphs

In this section we show the result and comparison of different result of the method.For that we are comparing this method with other in terms of hiding capacity and pros of using that game as cover medium. So, let first define the term hiding capacity of any game used for hiding information.

- Hiding capacity: - Hiding capacity is defined according to the numbers of bits hide on single game means the total numbers of bits that possible to hide in single game. So hiding capacity is calculated different for different game used.

Hiding capacity=numbers of hidden bits in game.

In table we are comparing the average hiding capacity of proposed method with the other already used method. We are comparing the hiding capacity of easy and hard level of every game and we find in terms of this proposed method have much higher hiding capacity and security then the other's. And analysis the pro of the game used for information hiding and communication.

TABLE 1. Comparison of different games used for information hiding.

S. No.	Name of game	Passible attacks/ Pro's	Hiding capacity	
			Easy level	Hard level
1.	Minesweeper Game	Hiding capacity is low	17.6 bits	75 bits
2.	Jigsaw game	Compression based attacks due to distortion of image	12 bits	56 bits
3.	Modified Jigsaw game	deciding correct jigsaw puzzle with secret data is difficult sometimes	16 bits	289 bits
4.	Maze game	Brute force attack	50 bits	198 bits
5.	Sudoku puzzles	Required pre-shared secret key	73 bits	246 bits

And after that we analysis the results of the proposed methods.so we are try to hide the secret information in game in three different ways. These three method are differ from each other at the time when we are placing bits on Sudoku grid or hiding the bits on Sudoku grid. We comparing all the three method with each other according to the average hiding capacity and average entropy values for 4x4, 9x9 and 16x16 modern Sudoku puzzles show in TABLE 2 and 3. For calculating the average values of hiding capacity and entropy we try to hide the information in all type of Sudoku puzzles. For that we are performing more than 80 puzzles to hide the information and calculate the average hiding capacity and entropy value.

- Entropy: - Entropy is define in terms of displacement or out of order of data. It is calculating with the help of probability values. Following formula used to calculate the entropy value H(x).

$$H(x)= -\sum_{i=1}^{n} p(xi)\text{Log}_2 p(xi).$$

Where p(x) is the probability of x.
For better understanding of entropy it is define in reference [].
Here we are explaining the entropy of game. So we are going to calculating the entropy of example explain in section 4.1. Entropy $H(x)= -\sum_{i=1}^{n} p(xi)\text{Log}_2 p(xi)$.
$p(xi) = p(0,1, 2, 3, 4, 5, 6, 7, 8, 9)$
={.45,0.061,.049,.074,.037,.061,0.061,0.087,0.061,0.049}
H(x)=2.34

TABLE 2. Comparison of different method average hiding capacities.

Level/Method	Proposed method	method 1	Method 2
4*4	6.5bits	4.5bits	4.5bits
9*9	73bits	58 bits	54 bits
16*16	246 bits	210 bits	183 bits

TABLE 3. Comparison of different method average entropy values.

Level/Method	Proposed method	method 1	Method 2
4*4	2.31	1.31	1.99
9*9	4.23	2.68	4.312
16*16	6.12	4.02	7.02

V. CONCLUSION

In the proposed method we are using a Sudoku Puzzles as the cover medium for hiding information. Solving Sudoku puzzles are good exercise for mind. We hide the information in Sudoku in three different ways and we analysis the hiding capacity and entropy. And we find that both hiding capacity and entropy are improved. It is a new concept and there are many new things can be done for securing information in communication. It shows that games are a good medium to hide secret data. Because they are undetectable by attacker easily. It is possible to use other than already used game for improving hiding capacity and undetectably of information. For that purpose Game Image and frameworks both things are used easily. Use Cryptography techniques before hiding information in game increase security level of information.

REFERENCES

[1]. Susmita Mahato, Dilip Kumar Yadav, Danish Ali Khan. "A Minesweeper Game-based steganography scheme", *in Journal of information security and application, pp.1-14, 2016.*
[2]. Hernandez-Castro JC, Blasco-Lopez I, Estevez- Tapiador JM, Garnacho AR. "Steganography in Games: a general Methodology and its application to the game of go computer Security", *in computer security, vol. 5, pp.64-71, 2006.*
[3]. LEE HL, LEE CF, CHEN LH. "a perfect maze based stenographic method", *in journal system security, vol.83, pp.2528-2535, 2010.*
[4]. EN JUNG FARN, CHAUR-CHIN CHEN. "jigsaw image for steganography" *in optical engineering, vol. 48, pp.0770061-12, 2009.*
[5]. MORKEL T, ELOFF JHP, OLIVER MS. "an overview of image steganography", *in proc issa, pp. 1-11, 2005.*
[6]. ZHAN HE OU, LING HWEI CHEN. "a stenographic method based on tetris games", *information science new york, vol. 276, pp. 343-353, 2014.*
[7]. TD Kieu, ZH Wang, CC Chang, MC Li. "A Sudoku based wet paper hiding scheme", *in International Journal Smart Home, vol. 3, pp.1-12, 2009.*
[8]. EN JUNG FARN, CHAUR-CHIN CHEN. "A novel stenographic method for based on jigsaw puzzle images", *in journal electronic image, vol.18, pp. 0130031-10, 2009.*
[9]. Abdelrhman Desokey, Mohammad Younis. "CHESTEGQ: Chess steganography methodology", *in security and communication networks, vol. 2, pp.555-556, 2009.*
[10]. Web Sudoku - Billions of Free Sudoku Puzzles to Play Online *https://www.websudoku.com/*
[11]. Play Free Sudoku online - solve daily web Sudoku puzzles *https://sudoku.com/*
[12]. Altaay, A.A.J., sahib, S.B., Zamani, M. "An introduction to Image steganography Techniques", *in*

International conference on advanced computer science application and Technologies, pp.122-126, 2012.
[13]. Chance Gibbs and Narasimha ShashiDhār. "Stegorouge: Steganography in 2-dimension Video Game maps", *in an international Journal on ACSIJAdvances in computer science, vol 4, pp. 141-146, 2015.*
[14]. Niels Provos, Peter Honeyman. "Hide and seek: An introduction to steganography", *in IEEE Computer Society, pp32-44, 2003.*
[15]. Fabien AP Petitcolas, Ross J Anderson, Marku G Kuhn. "Information Hiding-A survey", *in Proceeding of The IEEE 7th conference, vol. 87, pp.1062-78, 1999.*
[16]. Abbas cheddad, Joan Condell, Kevin Curran, Paul Mc Kevitt." Digital image steganography: Survey and analysis of current methods", *in Signal processing, vol. 90, pp.727-52, 2010.*

Shalu. "Analysis of Data Hiding Capacity in Sudoku Puzzles." IOSR Journal of Engineering (IOSRJEN), vol. 09, no. 08, 2019, pp. 43-53.