IMAGE STEGANOGRAPHY BASED THE BEHAVIOR OF PARTICLE SWARM OPTIMIZATION

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ABSTRACT

The growing possibilities of modern communications and the explosive growth of information technology imposed special means of security. Image steganography is one class of this security. However, in the modern world new techniques are appeared continuously such as swarm intelligence. Therefore, this work presents an enhancement of security in the field of image LSB steganography using the behavior of PSO algorithm. Specifically, SPSO algorithm represents the standard behavior of PSO, QPSO algorithm represents the quantum behavior of PSO and HPSO algorithm represents the human behavior of PSO. In this paper, three image steganography techniques are proposed using (SPSO, QPSO, and HPSO) algorithms. These algorithms are used to determine the best locations in the cover image pixels to embed the secret text message using LSB technique. Therefore, this paper presents a comparison and evaluations between these types of PSO algorithms in the field of image steganography. Experimental results for hiding different size text messages in four BMP cover images with different sizes, prove that the proposed image steganography using QPSO has best performance. However, PSNR of QPSO system stegocovers is (81.709 dB), the PSNR of HPSO system stegocovers is (81.143 dB), and the PSNR of SPSO system stegocovers is (81.012 dB). Hence, the proposed method using quantum behavior of PSO algorithm is the best performance system from steganography point of view.

Keywords: *PSO, SPSO, QPSO, HPSO, LSB.*

1. INTRODUCTION

In the growing linked modern world, one may wish to be able to protect not only secrecy of the communication but also privacy of the communicators [1]. Therefore, information hiding gets its way in modern communication. Information hiding is the process of hiding amount of data called secret message into a cover media that may be audio, video or image in an imperceptible way to build a covert channel [2].The two basic requirement of information hiding system are usually referred to as transparency and robustness. Transparency means that the stego- medium should be similar to cover medium according to a suitable distortion measure. Whereas, robustness means that hiding message should survive the implementation of any data processing method with a certain class to stego - medium [3].This paper presents an efficient image hiding scheme based on the behavior of PSO in order to find best locations in cover image to hide text secret message.

The rest of the paper is organized as follows: Section 2 presents related work. Section 3 explains PSO, QPSO, and HPSO. The proposed technique for secret message embedding and extraction is explained in section 4. Section 5 presents the experimental results with discussion. Finally, section 6 draws the conclusion of this paper and Suggestion for future work.

2. RELATED WORK

In this section, we will show some of the previous studies about PSO algorithm in the field of image steganography

* Xiaoxia Li and Jianjun Wang (2007) [4], proposed a technique that can conceal large messages as well as keeping the quality of stego image acceptable. Also, their proposed method derives an optimum substitution matrix by SPSO algorithm to change the secret message and then conceals secret message into the cover image through a modified JPEG quantization table. Moreover, the proposed method helps to embed the secret messages with high level of security because one cannot be able to extract the

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secret messages correctly without knowing the substitution matrix.

* Ruchika Bajaj et. al. (2010) [5], developed a method for embedding secret messages of variable length with high embedding capacity based on SPSO. This method finds the best pixel positions in the cover image, which can be used to conceal the secret message. In the proposed method, M bits of the secret message are substituted into M least significant bits of the image pixel, such as M varies from 1 to 4 depending on the message length.

* Feno Heriniaina Rabevohitra and Jun Sang (2011) [6], proposed a secure data hiding scheme for embedding secret message into a cover image with least significant bit (LSB) substitution in discrete cosine transformation domain (DCT). Firstly, the secret message was divided into partitions, whereas the cover image splits into blocks of 2x2 size. The DCT was used to change the blocks from spatial to frequency domain. The proposed method results an increasing in efficiency, as well the security level, because SPSO algorithm is used for finding an optimal transformation matrix T.

* Parisa Gerami et. al. (2012) [7], developed a technique which is based on SPSO algorithm to find the best pixel locations, thus the secret image is transformed inside the cover image. Optimal Pixel Adjustment (OPA) scheme is used to further increase the quality image. Moreover, the proposed approach was compared to other previous approaches. The results show that the proposed method provides better PSNR. The quality of cover image did not change very much and achieved better imperceptibility with the same payload capacity.

* Anu Garg and Navdeep Kaur (2014) [8], proposed a new method for data hiding that is using the hybrid algorithm of PSO with ACO. The results were calculated using PSNR and MSE values providing increased security and quality of the stego image.

* Vaddadi Swetha et. al. (2016) [9], implemented biometric feature for skin tone region of images. Data hiding is done at detected skin tone regions. A novel steganography scheme was proposed that uses particle swarm optimization algorithm (PSO) for data hiding. It assured high security, good invisibility and robustness. The secret data is embedded with a cover image to improve the security of stego images by means of PSO algorithm.

The previous related works show that image steganography using PSO is not a new field. However, these previous works did not take in consideration the effect of an individual's behavior in PSO algorithm. Therefore, there is no similar claims published in this field based on behavior of PSO. In other words, this paper is concerned with building image steganographic system depending on behavior of PSO.

3. SPSO, QPSO AND HPSO

3.1 Standard Particle Swarm Optimization (SPSO)

Particle swarm optimization (SPSO) [10], is a heuristic optimization method based on the behavior of social insects, such as ants, termites, bees, and wasps; as well as of other animal societies as flock of birds; or a school of fish. SPSO model consists of a swarm of particles, which are initialized with a population of random candidate solutions. They move iteratively through the d-dimension problem space to search for the new solutions, where the fitness, f, can be calculated as the certain qualities measure [11]. Each particle has a position represented by a position-vector xi (i is the index of the particle), and a velocity represented by a velocity-vector vi. Each particle remembers its own best position value is pbest(pid)[11]. The best position among the swarm value is gbest(pgd). Essentially, SPSO is simply described by the following two straightforward velocity and position update equations, shown in equations (1) and (2) respectively [12].

$$V(id+1) = w\ vid + c1\ r1 * (pid - xid) + c2\ r2 * (pgd - xid) \quad (1)$$

$$X(id+1) = xid + v(id+1) \quad (2)$$

where i =1,2,…..,N; w is the inertia weight, r1 and r2 are the random numbers, which are used to maintain the diversity of the population, and are uniformly distributed in the interval [0,1] for the d-th dimension of the i-th particle. C1 is a positive constant, called coefficient of the self-recognition component; c2 is a positive constant, called coefficient of the social component. The general basic algorithm for the Particle Swarm Optimization can be described in Figure 1 after [12].

```
Begin
Generate an initial random population positions
and velocities with size M and the dimensions
D of the particles.
Repeat
For i = 1 to M do
if (f(Xi)<f(Pi )then Pi = Xi , G=argmax (f(Pi))
For j = 1 to D do
Update Velocity with Eq. (1);
Update Position with Eq. (2);
End/end for loop j; End/end for loop I;
Until termination criterion is met. End
```

Figure 1 Pseudo code of PSO (SPSO)

3.2 Quantum Behaved–Particle Swarm Optimization (QPSO)

Recently, inspired by quantum mechanics and dynamical analysis of SPSO algorithm [13], Sun et. al. proposed a new version of SPSO which is Quantum-Behaved Particle Swarm Optimization (QPSO) algorithm [14] [15]. QPSO makes use of a strategy based on a quantum delta potential well δ model to sample around the SPSO best positions. As per classical PSO[10], a particle is stated by its position vector x and velocity vector v, which determine the trajectory of the particle. The particle moves along a determined trajectory following Newtonian mechanics. However if we consider quantum mechanics, then the term trajectory is meaningless, because x and v of a particle cannot be determined simultaneously according to uncertainty principle. QPSO differs from SPSO algorithm in some characteristics. Firstly, the exponential distribution of positions makes QPSO global convergent. Also, the introduced mean best position (mbest) into the evolution equation of QPSO is a second improvement of QPSO. In SPSO, each particle converges to its global best position independently. While in the QPSO with mbest position, each particle cannot converge to global best position without considering its colleagues as shown in Figure 2.

```
Initialize Swarm
Begin
While the condition termination not met
Do
Calculate mbest by equation (6)
Update particle positions by using equation (3)
Update pbest
Update gbest
End do
End
```

Figure 2 the Movement of Particles in (a) PSO (b) QPSO

In the quantum model of a PSO, the state of a particle is depicted by wave function Ψ (x, t) instead of position and velocity. The particles can appear anywhere in the feasible region, even a position far away from the current position, according to the probability density function depending on the potential field the particle lies in[16]. The particles move according to the following iterative equations [14] [15]:

$$x(id+1)=p+ \alpha| mbest- x(id) | * \ln(1/u) \text{ if } k\geq 0.5 \quad (3)$$

$$x(id+1)=p- \alpha| mbest- x(id) | * \ln(1/u) \text{ If } k<0.5 \quad (4)$$

Where

$$p=Q\ pid + (1-Q)\ pgd \quad (5)$$

$$mbest = \frac{1}{m}\sum_{m}^{i=1} p_i \quad (6)$$

Mean best (mbest) of the population is defined as the mean of the best positions of all particles, u, k, Q are uniformly distributed random numbers in the interval [0,1]. The parameter α is called contraction expansion coefficient. The pseudo code of QPSO algorithm is shown in figure 3 after [16].

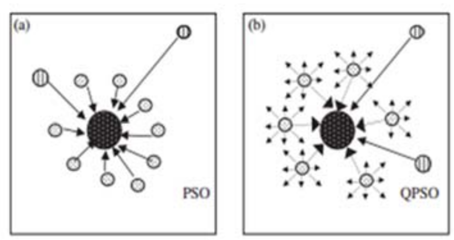

Figure 3 pseudo code of QPSO algorithm

3.3 Human behavior – Based particle Swarm Optimization (HPSO)

Hao Liu et al. [17], proposed a new version of SPSO based on human behavior, which is called HPSO. HPSO is used to enhance the implementation of SPSO. With SPSO [10], all particles only learn from the best particles Pbest and Gbest. Obviously, it is an ideal social condition. However, considering the human behavior there exist some people who have bad habits or behaviors around us, at the same time, as we all known that these bad habits or behaviors will bring some effects on people around them. It is beneficial to take warning from these bad habits or behaviors. Conversely, it is harmful to learn from these bad habits or behaviors .Therefore,

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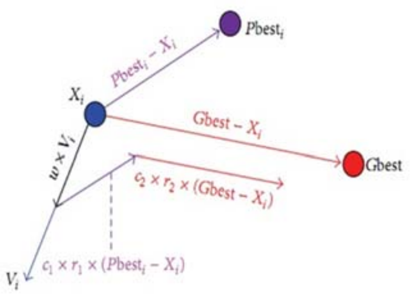
it is better to give an objective and rational view on these bad habits or behaviors. To simulate the human behavior, the global worst particle was introduced into the velocity equation of SPSO, and the learning coefficient r3 which obeys the standard normal distribution that is r3 ∈N(0,1), can balance the exploration and exploitation abilities by changing the flying direction of particles. At the same time, the acceleration coefficients c1 and c2 have been replaced with two random numbers, whose sum is equal to 1 in [0, 1]; this strategy decreases the dependence on parameters of the solved problem [17]. In SPSO, the cognition and social learning terms move particle i towards good solutions based on personal best position Pbest and global best position Gbest in the search space. This strategy



makes a particle fly fast to good solutions, so it is easy to trap in local optima as shown in figure 4. From figure 5, both impelled learning term and penalized term can be clearly observed to provide a particle with the chance to change flying direction. Therefore, the impelled/penalized term plays a key role in increasing the population diversity, which is beneficial in helping particles to escape from the local optima and also to enhance convergence speed. In HPSO, the impelled/penalized learning term performs a proper trade between the exploration and exploitation [17].

Figure 4 Cognition and social terms in SPSO

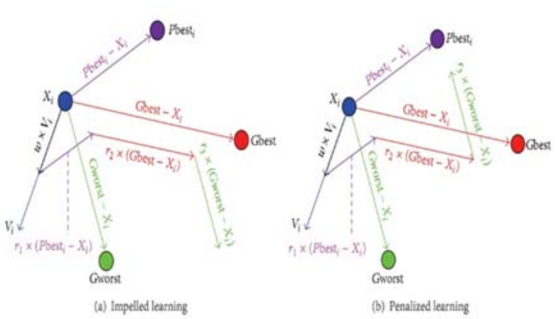


Figure 5 Impelled/penalized term in HPSO

Therefore, the velocity equation has been changed as shown in the following two equations:

V(id+1)=V(id)+r1(Pbest-X(id))+r2(Gbest-X(id)) +r3(Gworst-X(id)) (7)

X(id+1)= X(id)+ V(id+1) (8)

The pseudo code of HPSO algorithm is shown in Figure 6 after [17].

```
Initialize the swarm with size M, Initialize
Pbest ,Gbest and Gworst.
Set t= 0.Evaluate fitness of all particles.
Begin
While the condition termination not met
Do
For i=1 to M do
Update Velocity according to eq. (6);
Update Position according to eq. (7); End for
Update Pbest, Gbest and Gworst;
t=t+1;
End Do
End.
```

Figure 6 Pseudo code of HPSO algorithm

4. THE PROPOSED METHOD

The aim of research is to evaluate the behavior of PSO algorithm classically, quantitatively and humanly using image steganography. The three types of PSO algorithm are used as powerful swarm intelligence search technique for finding the best hiding positions in the cover image to hide a secret messages so that the produced stego image has good quality and robust to certain image stegoanalysis attacks.

4.1 Transmitter side

In the transmitter side, SPSO, QPSO, HPSO techniques is used for finding the best hiding locations in image cover. These output locations of the SPSO or QPSO or HPSO algorithms are then used to embed the secret massage data by using LSB technique in order to obtain the stego image. The steps of embedding secret message in a cover image are shown in Algorithm1

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Algorithm1: The Proposed Embedding Side Algorithm

Input: Stego image size (M*N)
Output: Secret message size (L)
Step1: Convert Stego image to binary form
Step2: Using the secret keys that are founded by PSO (Pseudo code (1)) or QPSO (pseudo code (2) or HPSO (Pseudo code (3)) in order to obtain the locations of hidden bits
Step3: Secret message bits are extracted from locations (obtained by step 2) of the stego image using LSB technique
Step4: Convert binary sequence into characters
Step5: Get the output of (step 4) as a secret message

The proposed framework for transmitter side is shown in Figure 7:

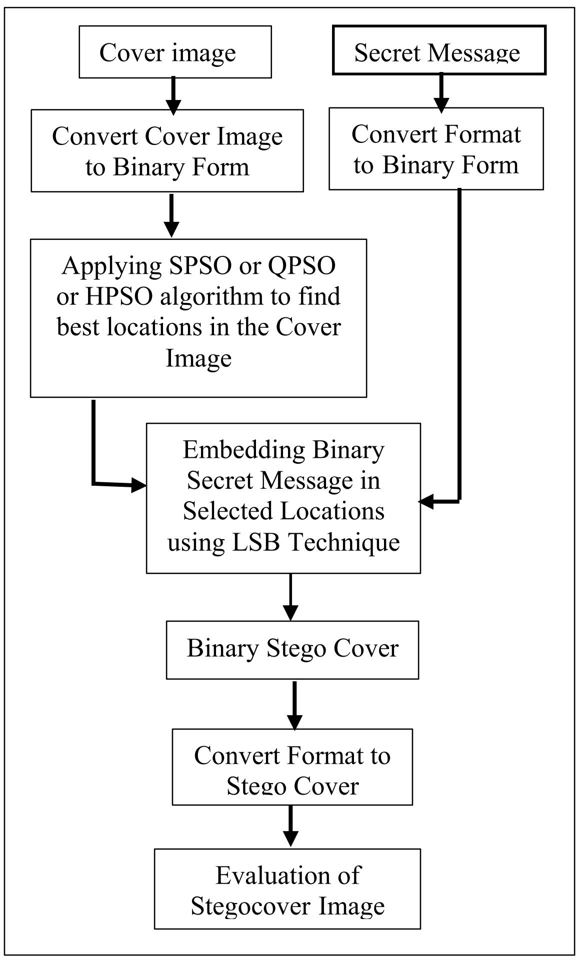

Figure 7: Block Diagram of the proposed Method at the Transmitter Side

4.2 Receiver Side

In the reciever side, SPSO, QPSO, HPSO techniques is used for finding the best hiding locations in stego cover image. These output locations of the SPSO or QPSO or HPSO algorithms are then used to extract the secret message data by using LSB technique in order to obtain secret text message. The steps of extracting secret message in a stego cover image are shown in Algorithm2

Algorithm 2: The Proposed Extracting Side Algorithm

Input: Cover image size (M*N); Secret message size (L).
Output: Stego image.
Step1: Convert Cover image and secret message to binary form.
Step2: Using SPSO (Pseudo code (1)) or QPSO (pseudo code (2)) or HPSO (Pseudo code (3)) as a search technique in order to obtain the best pixels' locations in the cover image.
No. of best locations= 8 * No. of secret characters.
Step3: Secret message bits are embedded in best locations (obtained by step 2) of the cover image using LSB technique.
Step4: Convert binary sequence into pixels format.
Step5: Get the output of (step 4) as a stego

The proposed framework for receiver side is shown in Figure 8:

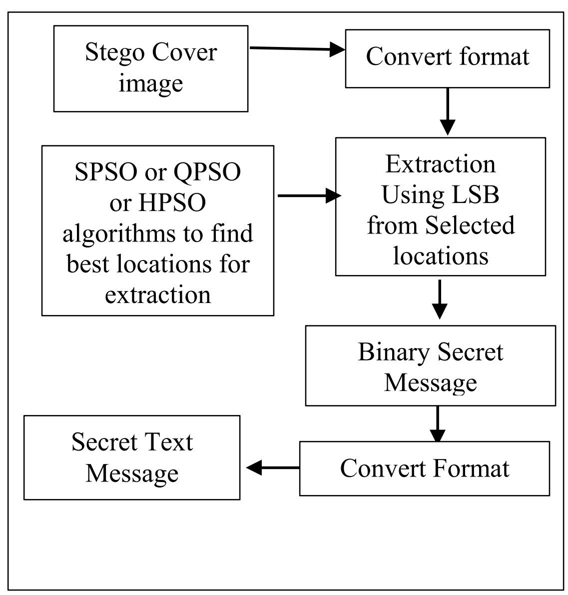

Figure8: Block Diagram of the Proposed Method at Receiver Side

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5. EXPERIMENTAL RESULTS AND DISCUSSION

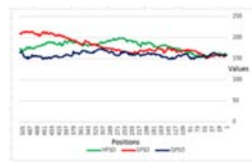
To evaluate the quality of stego cover image, it is important to test secret messages on many different images. Four standard test cover images are used and for a fair comparison the same size of secret messages are tested on these cover image samples.
In this work the size of secret message is set to 256 and 512 secret bits. Test cover image samples are shown in table 1.

Table 1: Cover Image Samples

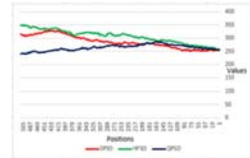
Image Name	Dimension	Figure
Water image.bmp	315×315	
Lena image.bmp	512×512	
Baboon image.bmp	400×400	
Kid image.bmp	200×200	

5.1 Results by Positions and Values

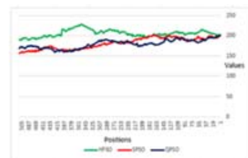
This subsection shows the results of finding hiding positions in the image cover using (SPSO, QPSO, and HPSO) algorithms. The relationship between the positions and the values for (water, Lena, baboon and kid) image covers based on the behavior of PSO are given in Figure 9.



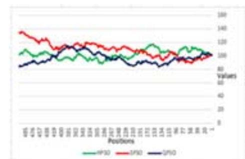
(a)Water Image



(b) Lena Image



(c)Baboon Image



(d) Kid Image

Figure9: Relationship between Values and Positions of Cover Images

It has been shown from Figure 9 that (SPSO, HPSO, and QPSO) algorithms can be used as a suitable search method in steganography Paradigm. Also, figure 9 shows how the particle in PSO behaves to select best positions whether standard, quantitative or human behaviors.

5.2 Quality Metrics Results

Different objective quantitative measures are used for comparison between the cover images and stego images. These measures are: Peak Signal Noise Ratio (PSNR), Mean Squared Error (MSE), Number of Pixel Change Rate Test (NPCR) and Unified Average Changing Intensity Test (UACI).The results of these measures on stego images for the proposed method (PSO, QPSO and HPSO) with secret message of lengths: (256, 512) and the total time required for embedding and extraction (sec) are shown in Table 2.It has been shown from table 2 that in most cases of the cover images used, the quality metrics by the proposed method using quantum behavior of PSO algorithm gives better stegocover quality than the proposed methods using human behavior based PSO algorithm, in which it is, in turn, better than the proposed image steganography method using the classical behavior of PSO. However, the quality metrics of three proposed image steganography system (SPSO, HPSO, QPSO) depended on the nature of cover image and text size.

Also, table 2 showed that in most cases the time consumed by the proposed image steganography using QPSO is more than the time consumed by the proposed image steganography system using HPSO or the time consumed by the proposed image steganography method using SPSO. However, the tradeoff between time consumed and efficiency of three proposed image steganography method using (SPSO, HPSO or QPSO) depended on the nature of cover image.

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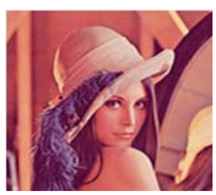
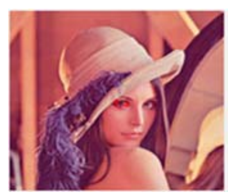
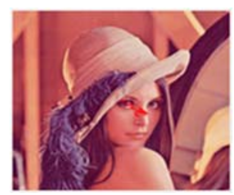
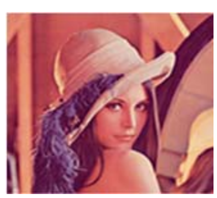
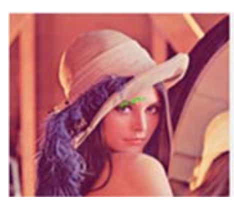
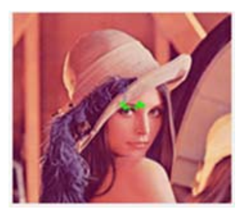
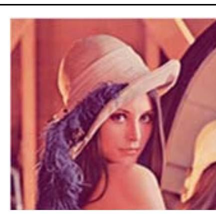
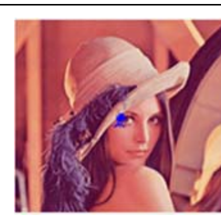
The stego images and stego images with hiding locations on (Water, Lena, Baboon, and Kid) cover images for the proposed method using the three types of PSO are shown in Table 3.

Figure 10 shows that the histograms of the PSNR quality measure of the proposed method for (Water, Lena, Baboon and Kid) stegocover images for 256, 512 Secret Bits using the quantum behavior of PSO obtained best performance than the proposed methods using human behavior based PSO algorithm, and the proposed image steganography method using the classical behavior of PSO so that the produced stego image has good quality and robust to certain image stegoanalysis attacks..

Table 2: Quality Metrics Comparison Results

Cover Image	Evolution Criteria	256 Secret Bits			512 Secret Bits		
		SPSO	HPSO	QPSO	SPSO	HPSO	QPSO
Water	PSNR	76.4833	76.89111	77.02491	73.8809	74.1524	74.20535
	MSE	0.00146	0.001350	0.001289	0.00266	0.002499	0.0024691
	NPCR	0.14613	0.135007	0.128999	0.266061	0.249937	0.2469135
	UACI	0.000570	0.000517	0.000503	0.001039	0.000976	0.000964
	Total Time	00:00:28	00:00:26	00:00:30	00:00:44	00:00:36	00:01:08
Lena	PSNR	81.0128	81.143489	81.7092	78.05109	78.35420	78.47804
	MSE	0.00051	0.0004997	0.00043	0.001018	0.000949	0.000923
	NPCR	0.05149	0.049972	0.04386	0.101854	0.094989	0.092315
	UACI	0.00020	0.000195	0.00017	0.000398	0.000370	0.000360
	Total Time	00:00:44	00:00:42	00:01:08	00:01:30	00:01:38	00:02:16
Baboon	PSNR	78.77321	78.900955	79.49014	75.82631	75.89065	76.21000
	MSE	0.00086	0.0008375	0.00073	0.0017	0.001675	0.001556
	NPCR	0.08625	0.08375	0.07312	0.17	0.1675	0.155625
	UACI	0.00033	0.0003271	0.00028	0.000664	0.000654	0.000607
	Total Time	00:00:38	00:00:32	00:00:34	00:01:16	00:01:00	00:01:12
Kid	PSNR	72.7212	72.816014	73.0793	69.96839	69.96839	70.17200
	MSE	0.00347	0.0034	0.0032	0.00655	0.00655	0.00625
	NPCR	0.3475	0.34	0.32	0.655	0.655	0.625
	UACI	0.00135	0.001328	0.00125	0.002558	0.002558	0.002441
	Total Time	00:00:0	00:00:10	00:00:0	00:00:16	00:00:18	00:00:17

Table 3: Comparison between the Stegocovers of the Proposed Method

Cover Image	Algorithm	StegoCover Image	Stego Image with Hiding Locations for 256 Secret bits	Stego cover image with hiding Locations for 512 Secret Bits
Water	SPSO			
	HPSO			
	QPSO			
Lena	SPSO			
	HPSO			
	QPSO			

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	SPSO			
Baboon	HPSO			
	QPSO			
	SPSO			
Kid	HPSO			
	QPSO			

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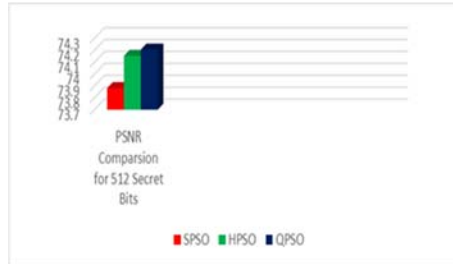
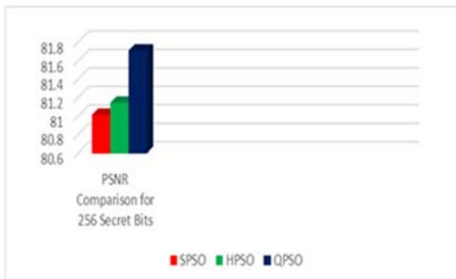
Water

PSNR quality measure of the proposed method for (Water) stegocover with 256 Secret Bits



PSNR quality measure of the proposed method for (Water) stegocover with 512 Secret Bits

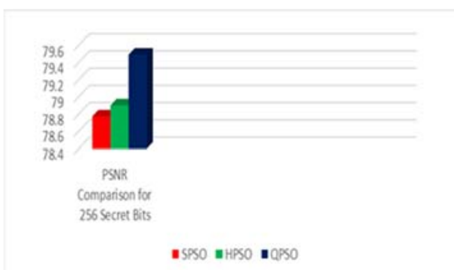
Lena



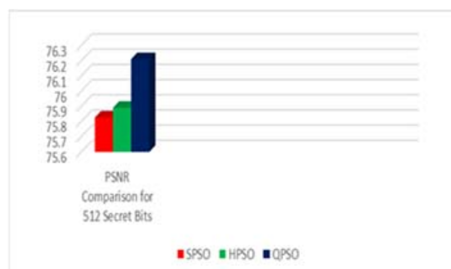
PSNR quality measure of the proposed method for (Lena) stegocover with 256 Secret Bits

PSNR quality measure of the proposed method for (Lena) stegocover with 512 Secret Bits

Baboon

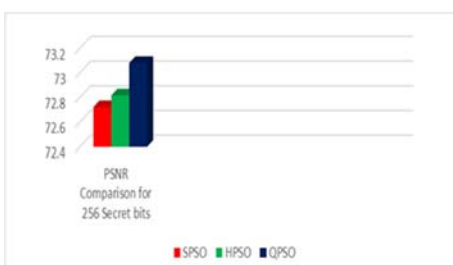


PSNR quality measure of the proposed method for (Baboon) stegocover with 256 Secret Bits

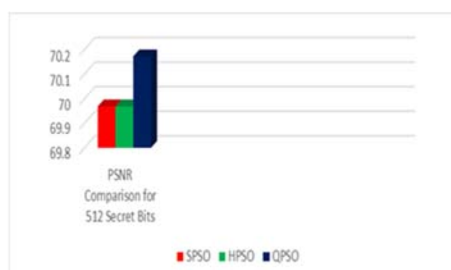


PSNR quality measure of the proposed method for (Baboon) stegocover with 512 Secret Bits

Kid



PSNR quality measure of the proposed method for (Kid) stegocover with 256 Secret Bits



PSNR quality measure of the proposed method for (Kid) stegocover with 512 Secret Bits

Figure10: Comparison of PSNR Quality Metric of the Proposed Method

6. CONCLUSION AND FUTURE WORK

In this paper, we have defined a new framework For evaluating the behavior of PSO algorithm classically, quantitatively and humanly using image steganography. The three types of PSO algorithm are used as powerful swarm intelligence search technique for finding the best hiding positions in the cover image to hide a secret messages. The experimental results indicate that quantum behavior of PSO algorithm obtained best performance than classical, and human behaviors of PSO in the field of image steganography. In a future research, using these three types of PSO in another applications such as feature extraction, 3D watermarking. Also, another types of behaviors of PSO will be investigated.

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