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Multilevel Thresholding based Image Segmentation using Whale Optimization Algorithm

Basu Dev Shivahare, S.K.Gupta

Abstract: ***Whale Optimization Algorithm (WOA) was proposed by Seyedali Mirjalili and Andrew Lewis in 2016. WOA is nature-inspired, meta-heuristic (randomization and deterministic) algorithm, which is being used to solve various single objective, multi objective and multi-dimensional optimization problems. To determine threshold value for image segmentation Otsu, kapur, thresholding etc. methods are used. In this paper multilevel threshold values are computed using WOA and these multilevel threshold values are used for image segmentation. Fitness is computed using Otsu thresholding. Minimum fitness score is considered as best optimal value. WOA has capability to explore, exploit the search s pace and avoid local optima. In multilevel thresholding, complex images are segmented into L+1 levels for multiple threshold values L =2, 3 etc. This paper addresses about performance of Whale Optimization Algorithm (WOA) and Particle Swarm Optimization (PSO) for various benchmark objective functions such as unimodel, multimodel, fix dimension multimodel based on their convergence curves for different number of iterations400,500 600 and compute multilevel threshold values for various level image segmentation using Whale Optimization Algorithm.***

Keywords: ***Nature inspired algorithm, Whale Optimization Algorithm (WOA), multilevel thresholding, image segmentation***

I. INTRODUCTION

Image segmentation is process of splitting of image in parts so that objects, boundaries of objects can be identified and meaningful information can be extracted from segmented image. There are many methods of image segmentation, such as histogram thresholding, threshold segmentation ,edge detection , region extraction , clustering algorithms [1][2] **,**nature inspired meta heuristic algorithm such as genetic algorithm, particle swarm algorithm, whale optimization algorithm(Seyedali Mirjalili and Andrew Lewis ,2016)[3][4].threshold value can be obtained by using any image segmentation method .Thresholding is categorized in two parts: bi-level. Thresholding and multilevel thresholding. In bi-level thresholding, image is segmented in two levels .two groups of objects are produced.

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***** Correspondence Author
Basu Dev Shivahare*,Research Scholar, AKTU, Lucknow, Uttar Pradesh, IndiaEmail:basuiimt@gmail.com
S.K.Gupta , Associate Professor, BIET, Jhansi ,Uttar Pradesh, India
Email: guptask_biet@rediffmail.com

Multilevel thresholding have multiple threshold value and hence overcome limitation of bi-level thresholding
Multilevel threshold values can be obtained by optimization technique such as Genetic Algorithm GA, PSO [7], Otsu [11] WOA [3] etc. To compute multilevel threshold values for various level image segmentation PSO (Kennedy J, Eberhart R, 1995) [7], Modified PSO and OTSU (Fayçal Hamdaoui et al ,2014)[11] are previously used .In this paper WOA is used to compute multiple threshold values in term of best positions of search agents for design variable Dim in successive iterations. Dim is a variable which represents number of thresholds.
In WOA, objective is to find best solution for searching target prey. Best solution means best position which is near to prey and get optimal cost to search prey. WOA has been widely used for multilevel image segmentation (M.A.El Aziz et al, 2018) [4], clustering applications [5], design of low pass filter [10] etc.

II. LITERATURE REVIEW

WOA is nature-inspired, meta-heuristic algorithm proposed by Seyedali Mirjalili and Andrew Lewis in 2016. (Seyedali Mirjalili and Andrew Lewis, 2016)[3].WOA has capability to work on combination of exploration and exploitation to get optimal or best solution and get rid of local minima (Hardi M.Mohammed,Shahla et al,2019)[6]
In exploration, search space is explored by different solutions and find global optimal or best solution.
Exploration is achieved in WOA, by generating a random position of whale or search agent. Exploration is done by the randomness of the A vector, |A| >=1 while searching for the prey. Exploration is for global optimal search for prey . Exploitation is local search.exploitation which is performed by the bubble-net attacking technique.
In this paper, working mechanism of WOA is explained in two steps (Seyedali Mirjalili and Andrew Lewis, 2016; Hardi M. Mohammed, Shahla et al, 2019) [3][6]

A.Bubble-net Attacking Technique :(Exploitation phase)

a. Encircling Prey: in this phase best position of search agent in n dimension is identified. We presume that target prey is best position or is best candidate solution of leader .we get best position of leader which is near to target prey and optimal cost to search target prey. In successive iteration. leader position or best position may be change. Vectors A and C are computed.

A=2*a*r1-a; equation1
C=2*r2; equation2

r1 and *r*2 are random vectors in [0, 1].

To apply **shrinking encircling mechanism**, value of a is linearly decreasing from 2 to 0 and a2 is linearly decreasing from -1 to -2 in successive iteration and vector A varies in computation. value of A should be in the range (-1, 1) and updated positions of search agent is determined using equation no 3 ,4.now depending upon variation of p and vector A, other search agents update their positions in direction of finest search agents

p<0.5, |A| < 1 %case 1-b

D1= abs(C*Best_position (j) - P (i, j)) equation3

D1 is distance vector between best position of leader X^* and current search agent position P (i, j) in current iteration t. Best_position or leader position is X^* which is near to optimal solution

Updated position

Updated position P (i, j) = Best_position (j)-A*D1equation4

OR

Updated position P (i, j) = X^*(j)-A*D1

b.Spiral Updating Position:

p>=0.5, %**case2**

D2 = abs (Best_position (j)-P (i, j)); equation5

Or

D2 = X*(j) – P (i, j)

Best_position (X^*) is best position which is near to target prey, P (i, j) is current whale position

After computation of D2, spiral shape movement of humpback whale is emulated by following equation

Updated position P (i j) = D2*exp (b.*l).* cos(l.*2*pi)+Best_position (j); equation6

Best_position is X^* which is near to optimal solution.

where constant value b is used to identify logarithmic spiral shape and random number l is in interval of [−1,1]. chance for selection between the spiral model and shrinking encircling mechanism is 50 %.

B.Search for prey (Exploration phase):

Exploration phase helps to overcome local optimum problem and performs global search.

Rank_index plays very important role due to dynamic nature. search agent discovers random position X_rand after getting random position X_rand rather than getting best position or leader position in exploitation phase, search agent position is updated using equation 9 and 10.

p <0.5, |A| >=1 % case 1-a

Rank_index = floor (SearchAgents_no*rand ()+1);equation7

X_rand= P (Rank_index, :); equation8

Find value of X_rand (j)

Distance_X_rand=abs(C*X_rand (j)-P (i, j)); equation9

P (i, j) =X_rand (j)-A*Distance_X_rand; equation10

Seyedali Mirjalili and Andrew Lewis tested 29 mathematical benchmark fuctions (unimodel[F1 to F7] ,multimodel [F8 to F13],fix dimension multimodel[F14 to F23] and composite [F24 to F29]) using Whale optimization AlgorithmWOA[3], Differential Evolution(DE) (Stron.R,PriceK,1997)[12], Fas t Evolutionary Algorithm(FEP)(Yao X et al,1999) [13], Particle Swarm Optimization(PSO) (KennedyJ,Eberhart R,1995)[7] ,Gravitational Search Algorithm(GSA) (Rashedi E et al,2009)[9] and find best optimal value of each benchmark objective function for every algorithm.

Each algorithm is executed 30 times with population size 30 and 500 iteration in each run. In each run, the best leader with best optimal value of each benchmark objective function for every algorithm is computed. Best optimum value is optimal fitness value.

In Table 1, **Leader** optimal value of each benchmark objective function for every algorithm is average solution of best optimal value after 30 times simulation of each algorithm. Algorithm which has minimum or optimal average Leader optimal value for benchmark function is assigned as rank 1.

Table1

Rank based on average solution of 30 runs							
Type	Function	Criteria	WOA	DE	FEP	PSO	GSA
UNIMODEL	III. F1	Ave	1 .41E −30	8 .2E −14	**0 .00057**	0 .000136	2 .53E −16
		Rank	1	3	5	4	2
	F2	Ave	1 .06E −21	1 .5E −09	0 .0081	0 .042144	0 .055655
		Rank	1	2	3	4	5
	F3	Ave	5 .39E −07	6 .8E −11	0.016	70.12562	896.5347
		Rank	2	1	3	4	5
	F4	Ave	0 .072581	0	0.3	1 .086481	7 .35487
		Rank	2	1	3	4	5
	F5	Ave	27 .86558	0	5.06	96 .71832	67 .54309
		Rank	3	1	2	5	4
	F6	Ave	3 .116266	0	0	0.000102	2 .5E −16
		Rank	4	1	1	3	2
	F7	Ave	0 .001425	0 .00463	0 .1415	0 .122854	0 .089441
		Rank	1	2	5	4	3
M	F8	Ave	−5080.76	−11080.1	−12554.5	−4841.29	-2821.07
		rank	3	4	5	2	1

ULTIMODEL	F9	Ave	0	69 .2	0 .046	46 .70423	25.96841
		rank	1	5	2	4	3
	F10	Ave	7 .4043	9 .7E −08	0 .018	0.276015	0.062087
		rank	5	1	2	4	3
	F11	Ave	0.000289	0	0 .016	0.009215	27.70154
		rank	2	1	5	3	5
	F12	Ave	0.339676	7 .9E −15	9 .2E −06	0.006917	1.799617
		rank	4	1	2	3	5
	F13	Ave	1 .889015	5 .1E −14	0 .0 0016	0.006675	8 .899084
		rank	4	1	2	3	5
FIXD	F14	Ave	2 .111973	0 .998004	1 .22	3 .627168	5 .859838
		rank	3	1	2	4	5
IM	F15	Ave	0.000572	4 .5E −14	0 .0005	0.000577	0.003673
		rank	3	1	2	4	5
EN	F16	Ave	−1 .03163	−1 .03163	−1 .03	−1 .03163	−1 .03163
		rank	2	2	1	2	2
SI	F17	Ave	0 .397914	0 .397887	0 .398	0 .397887	0 .397887
		rank	2	1	3	1	1
ON	F18	Ave	3	3	3 .02	3	3
		rank	1	1	2	1	1
MU	F19	Ave	−3 .85616	N/A	−3 .86	−3 .86278	−3 .86278
		Rank	1		2	3	3
LT	F20	Ave	−2 .98105	N/A	−3 .86	−3 .26634	−3 .31778
		Rank	1		4	2	3
IM	F21	Ave	−7 .04918	−10 .1532	−5 .52	−6 .86513	−5 .95512
		Rank	4	5	1	3	2
OD	F22	Ave	−8 .18178	−10 .4029	−5 .53	−8 .45653	−9 .68447
		Rank	2	5	1	3	4
EL	F23	Ave	−9 .34238	−10 .5364	−6 .57	−9 .95291	−10 .5364
		Rank	2	4	1	3	4
			WOA	DE	CMA-ES	PSO	GSA
COMPOSITE	F24	Ave	0 .568846	6 .75E −2	100	100	6 .63E −17
		Rank	2	3	4	4	1
	F25	Ave	75 .30874	28 .759	161.99	155 .91	200 .6202
		Rank	2	1	4	3	5
	F26	Ave	55 .65147	144 .41	214 .06	172 .03	180
		Rank	1	2	5	3	4
	F27	Ave	53 .83778	324 .86	616 .4	314 .3	170
		Rank	1	4	5	3	2
	F28	Ave	77 .8064	10 .789	358 .3	83 .45	200
		Rank	2	1	5	3	4
	F29	Ave	57 .88445	490 .94	900 .26	861 .42	142 .0906
		Rank	1	3	5	4	2

From Table 1, we can see that WOA has 1st rank for 10 benchmark functions out of 29 benchmark functions i.e. WOA has 1st rank for 35 % benchmark function while WOA has 2nd rank for other 10 benchmark functions out of 29 benchmark functions approx. 35 % benchmark function. Hence WOA gets 1st and at least 2nd rank to solve most of optimization problems rather than other optimization techniques.

IV. EXPERIMENTAL RESULTS

Experimental results are explained in two parts, part1 and part2

In part 1, Whale Optimization Algorithm (WOA) and Particle Swarm optimization (PSO) are tested for unimodel(F5,F7),multimodal (F9,F11) and fix dimension multimodal (F17,F21) benchmark functions for different number of iterations and find which optimization technique has faster convergence nature towards optimum value using Mat lab 2016 software .

In part 2, multilevel threshold values for three and four level image segmentation using WOA is calculated. various images from berkely image dataset are taken .we can see multilevel image segmentation using WOA is performed.

Experimental Result: Part 1

Benchmarks functions (Seyedali and Andrew, 2016) [3] which are being tested in this paper are shown in Table 2.

Table2

Benchmark function description	Number of design Variable (Dim)	Range of Variables [lower bound,upper bound]	F_{min} Optimum value
F5(x)= $\sum_{i=1}^{n-1}[100(x_{i+1} - x_i^2)^2+ (x_i-1)^2]$	30	[-30,30]	0
F7(x)= $\sum_{i=1}^{n} i\, x_i^4$ + random [0,1)	30	[-1.28,1.28]	0
F9(x)= $\sum_{i=1}^{n} [x_i^2 - 10\cos(2\pi x_i) + 10]$	30	[-5.12,5.12]	0
F11(x)=$\frac{1}{4000}\sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n}\cos(\frac{x_i}{\sqrt{i}}) + 1$	30	[-600,600]	0
F17(x)= $(x_2 - \frac{5.1}{4\pi^2}x_1^2 + \frac{5}{\pi}x_1 - 6)^2 + 10(1 - \frac{1}{8\pi})\cos x_1 + 10$	2	[-5,5]	0.398
F21(x)= $-\sum_{i=1}^{5}[(X - a_i)(X - a_i)^T + c_i]^{-1}$	4	[0,10]	-10.1532

For execution of WOA and PSO, population size/search agent is set 30 and different number of iterations 400,500, 600 are taken .lower bound, upper bound and Dim are set for objective functions in Table 2.Dim represents position of search agent. positions of search agent for Dim = n is initialized. Fitness is computed in successive iterations .if new Fitness value is optimal than previous Fitness value then best position and best score of search agent are updated.

minimum fitness value i.e.$Fitness_{min}$ is best score or best optimal value .best position or best solution with design variable Dim and best score or best optimal value of search agent for different number of iterations for various benchmark objective functions are shown in Table 3.

Table3

S.N.	Function Name	Iterations	Results
1	F5 Dim =30	400	**best position** obtained by WOA is : 0.50528 0.24687 0.045201 0.005492 0.016602 0.0019057 0.0099919 0.012972 0.0023576 0.013147 0.0076254 0.0038373 0.015205 0.0080534 0.0086143 0.0060847 0.016852 0.0069004 0.030317 0.00010189 0.0026856 0.012509 0.0093206 0.017487 0.02362 0.0028331 0.0056447 0.0098532 0.0084411 0.013911 **best score** for objective function F5 obtained by WOA is : **27.6359** **best position** obtained by PSO is : 0.45632 0.2026 0.012443 0.010262 0.0025055 0.0075559 0.012754 0.010251 0.014393 0.054742 0.42711 0.67198 0.8175 0.90128 0.93948 0.95514 0.95539 0.9456 0.9093 0.83628 0.70187 0.50046 0.25255 0.085062 0.012991 0.011866 0.010573 0.011731 0.012373 -0.00043401 **best score** for objective function F5 obtained by PSO is : 79.6217

2	F5 Dim =30	500	best position obtained by WOA is : 0.45564 0.20237 0.012377 0.013429 0.0062213 0.0043437 0.013181 0.0099655 0.013286 0.0057833 0.023581 0.0015588 0.01272 0.0082615 0.0019926 0.012307 0.016594 0.02167 0.019034 0.010648 0.017678 0.018948 0.0086508 0.01047 0.0095943 0.0033613 0.012504 0.0083381 0.0020514 -9.2166e-05 best score for objective function F5 obtained by WOA is : **27.8223** best position obtained by PSO is : -0.89099 0.80458 0.65281 0.44263 0.20823 0.053903 0.012956 0.010209 0.0067074 0.010155 0.010205 0.010206 0.010193 0.010263 0.010221 0.010238 0.010155 0.010197 0.010203 0.010169 0.0097364 0.010199 0.010207 0.010205 0.010257 0.010198 0.010209 0.010202 0.010003 0.00010001 best score for objective function F5 obtained by PSO is : 28.3983
3	F5 Dim =30	600	best position obtained by WOA is : 0.56643 0.31853 0.079464 0.00059192 0.013498 0.011541 0.0026197 0.015309 0.0053064 0.00036463 0.019167 0.019539 0.015117 0.005353 0.0074335 0.01617 0.001746 0.014487 0.027454 0.012831 0.0012655 0.00062834 0.023489 0.013799 0.00096995 0.0093432 0.020712 0.012473 0.019413 0.0027771 best score for objective function F5 obtained by WOA is : **27.449** best position obtained by PSO is : 0.65441 0.42214 0.20103 0.091719 0.23789 0.5234 0.73844 0.85776 0.92587 0.95922 0.97313 0.99021 1.0023 1.0255 1.0147 1.0103 1.0123 1.0202 0.99309 0.96187 0.91256 0.82606 0.67971 0.45733 0.20038 0.0058249 0.010502 -0.013072 0.01085 0.00057623 best score for objective function F5 obtained by PSO is : 72.458
4	F7 Dim =30	400	best position obtained by WOA is : -0.047469 0.061427 0.017428 0.012768 -0.030446 -0.078833 0.033254 0.00034455 -0.020222 0.036744 -0.076836 0.017055 0.039737 0.029814 -0.034137 -0.0074221 -0.02537 -0.00080047 -0.048005 -0.028679 -0.037416 0.076089 -0.029319 0.013284 -0.047083 0.047315 -0.030771 -0.030165 0.01607 -0.0010737 best score for objective function F7 obtained by WOA is : **0.0020384** best position obtained by PSO is : -0.10558 -0.044512 -0.21388 -0.10359 -0.19062 -0.13604 0.040628 0.075119 0.010371 0.079156 -0.10207 0.0016923 -0.090965 -0.011092 -0.012001 -0.025283 -0.032121 0.059146 -0.0027738 0.048022 0.0091449 -0.069054 0.023913 0.0083457 -0.017767 0.056088 -0.088191 -0.036257 0.031627 0.13385 best score for objective function F7 obtained by PSO is : 0.032123
5	F7 Dim =30	500	best position obtained by WOA is : -0.016825 0.00055651 -0.079418 0.0021085 -0.028408 0.0089314 0.0016393 0.0093043 -0.0033816 0.0054527 0.0019162 0.0047991 0.0063925 0.0014308 0.0066369 -0.011648 0.010043 0.0061538 0.011707 -0.0055366 -0.00074377 0.0079396 -0.025329 0.00012671 0.0041324 -0.018326 -0.0075601 0.0015546 0.0061986 0.0037851 best score for objective function F7 obtained by WOA is : **0.00018173** best position obtained by PSO is : 0.003906 -0.1279 -0.14383 0.11189 0.09405 -0.051373 -0.099247 0.056869 0.055898 0.052682 0.040225 -0.036497 0.12158 -0.022656 0.027253 0.089572 0.096339 0.083622 0.053067 0.12026 -0.012242 0.017521 0.046923 -0.12065 0.062498 -0.016237 -0.036029 -0.030655 0.028254 -0.039031 best score for objective function F7 obtained by PSO is : 0.020398
6	F7 Dim =30	600	best position obtained by WOA is : -0.0051769 -0.017324 -0.085006 0.0016572 0.00075368 0.012118 0.004937 -0.0068388 0.026702 -0.02815 0.023688 -0.0012229 0.021584 0.03043 0.013649 0.027123 -0.065138 -0.010662 0.0011931 -0.037026 -0.057745 -0.044401 -0.0061475 0.023747 -0.0014018 0.0041424 0.019264 -0.013544 -0.041133 -0.0060735 best score for objective function F7 obtained by WOA is : **0.0010252** best position obtained by PSO is : -0.23443 -0.13073 -0.043655 -0.026515 0.12071 -0.1067 0.089194 0.059974 0.031021 -0.059926 0.060271 -0.014129 0.06336 -0.010556 0.03205 0.117 0.087134 0.058543 0.042585 0.027924 -4.7858e-05 0.031951 0.07449 -0.092496 -0.023377 -0.023151 0.0021438 0.0074285 -0.030854 -0.013974 best score for objective function F7 obtained by PSO is : 0.013314

7	F9 Dim =30	400	best position obtained by WOA is : -7.4658e-10 -9.4035e-11 -3.9699e-09 -3.5575e-09 -1.8399e-09 -8.3337e-10 -1.5981e-10 -3.5393e-09 -6.8222e-10 -1.8255e-09 1.7776e-08 -1.021e-09 -8.0516e-09 -1.9801e-09 -3.7628e-09 -9.9914e-10 -7.8757e-09 -7.9623e-09 -9.6187e-10 -1.8438e-09 -3.8185e-09 -4.0431e-09 -4.0132e-09 -1.8972e-09 -1.0587e-09 -3.6127e-09 -1.1041e-09 -7.8514e-09 -7.7379e-09 -4.7799e-09 best score for objective function F9 obtained by WOA is : **5.6843e-14** best position obtained by PSO is : -1.9899 -1.7882e-10 -1.9899 0.99496 9.013e-09 -0.99496 -1.9899 1.9899 -1.9541e-07 0.99496 1.0384e-09 3.0529e-08 -5.5328e-09 -0.99496 0.99496 1.3255e-08 3.9798 0.99496 -1.9899 -2.8393e-09 -1.9899 -0.99496 -0.99496 -0.99496 0.99496 0.99496 -5.4608e-09 -0.99496 7.4458e-09 -1.4272e-08 best score for objective function F9 obtained by PSO is : 51.7377
8	F9 Dim =30	500	best position obtained by WOA is : 5.8565e-10 -5.223e-12 -1.6662e-09 1.3533e-08 -2.7094e-09 -4.7061e-10 -4.0869e-11 3.2242e-09 -6.4391e-10 -3.7359e-09 6.2802e-09 2.0198e-09 4.5779e-09 1.6493e-09 4.2768e-09 3.6727e-09 3.3027e-09 1.5056e-09 -1.0809e-09 -1.327e-10 3.4494e-10 -3.6088e-10 2.4744e-11 -1.2164e-11 -1.0407e-10 2.8254e-10 -3.3717e-09 -1.4364e-09 -2.025e-10 5.7388e-09 best score for objective function F9 obtained by WOA is **: 0** best position obtained by PSO is : -0.99496 -2.8175e-05 -0.99496 -1.9471e-09 1.9899 2.9849 0.99496 -0.99496 -0.99496 9.2076e-09 -1.9899 0.99496 -0.99496 -1.8797e-08 2.9849 -8.6829e-09 0.99496 1.9899 2.9849 -1.9899 0.99496 -1.9899 2.9849 -1.9899 9.3071e-08 0.99496 -2.7154e-08 -0.99496 0.99495 -0.99496 best score for objective function F9 obtained by PSO is : 72.6319
9	F9 Dim =30	600	best position obtained by WOA is : 8.5761e-10 -4.9003e-11 -4.0021e-10 -4.1762e-10 7.0688e-09 5.1103e-12 1.6299e-09 -5.8349e-11 -6.1221e-10 -1.2215e-10 -7.3758e-10 -1.7715e-10 -8.1559e-10 1.9068e-10 -8.241e-09 4.5946e-10 -1.1314e-09 -1.1241e-09 -3.1253e-10 -9.5853e-10 -1.4092e-09 2.0663e-09 -1.8589e-09 -3.1072e-10 3.3488e-10 5.2812e-10 -1.4013e-09 -7.7555e-10 7.4238e-09 5.7178e-10 best score for objective function F9 obtained by WOA is **: 0** best position obtained by PSO is : -0.99496 0.99496 -0.99496 0.99496 0.99496 7.2434e-09 1.9899 0.99496 0.99496 0.99496 1.2622e-08 1.555e-09 2.9849 -0.99496 -1.2592e-07 0.99496 -0.0011142 0.99496 -1.933e-07 0.99496 1.9899 0.99496 1.0553e-08 0.99496 0.99496 2.9849 0.99496 -0.99496 7.7178e-09 0.99496 best score for objective function F9 obtained by PSO is : 43.7784
10	F11 Dim =30	400	best position obtained by WOA is : -4.6901e-09 -1.0427e-08 1.158e-08 8.7882e-10 -1.1518e-08 6.8618e-09 -2.6911e-08 -8.1232e-11 1.2373e-08 2.1569e-08 2.1273e-08 -1.1958e-09 3.0988e-09 -3.3668e-08 3.2214e-09 -1.4222e-10 3.6975e-08 -1.4918e-08 -9.5076e-09 -3.6306e-09 3.2328e-08 -6.0381e-09 1.0076e-08 -1.007e-08 1.5719e-09 5.5274e-09 1.1342e-08 6.9004e-09 1.2679e-08 -3.8209e-09 best score for objective function F11 obtained by WOA is : **0** best position obtained by PSO is : -3.14 2.665e-06 -5.4332 -2.5806e-06 1.6172e-06 8.3873e-07 3.044e-07 -4.9618e-06 5.278e-07 3.2533e-06 3.4775e-06 -9.7165e-07 0.017453 -4.2611e-06 0.0031378 -3.6106e-07 -2.1316e-05 1.0495e-06 4.728e-07 0.00046102 2.7419e-05 2.1264e-06 -6.051e-06 1.686e-06 6.1267e-05 -2.329e-06 -4.5065e-07 3.6268e-05 5.3881e-07 -2.3971e-06 best score for objective function F11 obtained by PSO is : 0.0098694

11	F11 Dim =30	500	best position obtained by WOA is : 1.4922e-09 -1.7774e-11 2.6135e-10 1.2331e-08 -8.7562e-11 8.623e-10 -2.3156e-10 1.5674e-09 1.0173e-08 8.5763e-09 -6.5361e-09 4.3585e-09 1.5778e-08 -2.2672e-08 2.967e-08 -2.1309e-09 3.052e-08 2.1114e-08 -1.4797e-08 -7.4911e-09 -1.8852e-08 2.7925e-08 4.6885e-08 -2.236e-08 3.3654e-08 8.8488e-10 2.1032e-08 -2.8889e-09 -2.1339e-08 1.4991e-08 best score for objective function F11 obtained by WOA is : **0** best position obtained by PSO is : 6.8051e-10 -1.6323e-07 -3.4939e-09 7.7533e-09 -2.4593e-05 9.404e-09 -1.5733e-08 2.3649e-08 -2.1444e-06 -4.2354e-09 2.0994e-08 1.3148e-08 3.6621e-08 -1.3449e-06 6.7647e-08 2.4429e-08 4.639e-06 4.3236e-09 -4.5211e-08 -2.9417e-07 1.879e-08 -4.1968e-08 -3.7095e-05 -4.8532e-09 -2.6422e-08 -2.9695e-09 -2.5928e-06 -2.8265e-08 -1.6857e-09 8.0693e-05 best score for objective function F11 obtained by PSO is : 2.0214e-10
12	F11 Dim =30	600	best position obtained by WOA is : 4.4241e-10 1.0324e-09 1.2455e-08 1.5757e-09 2.1337e-09 2.0738e-09 -1.8182e-09 -8.7231e-10 2.5997e-10 -2.5583e-08 -1.1149e-09 1.2195e-08 2.5348e-09 -2.6922e-09 1.0028e-08 4.1945e-08 -2.1377e-09 -3.3733e-09 1.2528e-08 -3.9888e-09 -9.7013e-09 -8.068e-09 -3.4276e-09 -5.0435e-10 2.5464e-10 -1.8716e-08 -3.2926e-09 1.4683e-08 3.6265e-11 -4.5404e-10 best score for objective function F11 obtained by WOA is : **0** best position obtained by PSO is : -1.26944e-08 1.349e-08 -5.43325 1.24887e-08 -1.82605e-08 -1.00326e-07 -8.28287 -8.85035 -2.13268e-08 -1.12108e-07 -0.000676691 -10.8179 -2.76826e-08 1.79236e-08 -7.00215e-05 0.000192537 -4.13376e-08 7.59145e-08 -3.06263e-05 3.74787e-08 -1.13162e-08 4.07854e-08 -2.86289e-08 3.55804e-07 4.82748e-08 -4.37063e-08 7.1863e-08 0.000589797 2.27224e-08 1.35886e-08 best score for objective function F11 obtained by PSO is : 0.073695
13	F17 Dim =2	400	best position obtained by WOA is : -3.13867 12.2658 best score for objective function F17 obtained by WOA is : 0.39793 best position obtained by PSO is : 3.1416 2.275 best score for objective function F17 obtained by PSO is : **0.39789**
14	F17 Dim =2	500	best position obtained by WOA is : 3.1413 2.276 best score for objective function F17 obtained by WOA is : 0.39789 best position obtained by PSO is : 3.1416 2.275 best score for objective function F17 obtained by PSO is : 0.39789
15	F17 Dim =2	600	best position obtained by WOA is : 3.1415 2.2753 best score for objective function F17 obtained by WOA is : 0.39789 best position obtained by PSO is : 3.1416 2.275 best score for objective function F17 obtained by PSO is : 0.39789
16	F21 Dim =4	400	best position obtained by WOA is : 1.0065 1.0034 0 1.0023 best score for objective function F21 obtained by WOA is :-0.88198 best position obtained by PSO is : 5.9987 6.0003 5.9987 6.0003 best score for objective function F21 obtained by PSO is : **-2.6829**
17	F21 Dim =4	500	best position obtained by WOA is : 3.9933 3.9867 4.0043 4.0159 best score for objective function F21 obtained by WOA is :**-10.1041** best position obtained by PSO is : 3.0018 6.9983 3.0018 6.9983 best score for objective function F21 obtained by PSO is : -2.6305
18	F21 Dim =4	600	best position obtained by WOA is : 0.99977 0.99879 1.0006 1.0014 best score for objective function F21 obtained by WOA is : **-5.0551** best position obtained by PSO is : 5.9987 6.0003 5.9987 6.0003 best score for objective function F21 obtained by PSO is : -2.6829

Table 4 addresses about which optimization technique performs better for different number of iterations in terms of best optimal value or best score.

S.N.	Objective Function Name	Optimization technique performs better for different iterations in terms of best optimal value (faster convergence towards zero)		
		Iteration =400	Iteration =500	Iteration =600
1	F5	WOA	WOA	WOA
2	F7	WOA	WOA	WOA
3	F9	WOA	WOA	WOA
4	F11	WOA	WOA	WOA
5	F17	PSO	WOA	WOA
6	F21	PSO	WOA	WOA

For objective functions F5,F7,F9,F11 WOA achieves faster convergence towards optimum value for different number of iterations 400,500,600.For objective functions F17 and F21 PSO achieves faster convergence towards optimum value for iteration =400.when number of iterations are increased 500 ,600 then WOA achieves faster convergence towards optimum value for objective function F17 and F21.

Hence WOA performs better for iterations >= 500 to achieve faster convergence rate towards best optimum value ($F_{minimum}$) for most of objective functions.

We can see the performance of WAO and PSO for various objective functions with different number of iterations in following convergence curve figures.

Figure 1 to Figure 18 shows convergence curve of WOA and PSO for various objective functions.

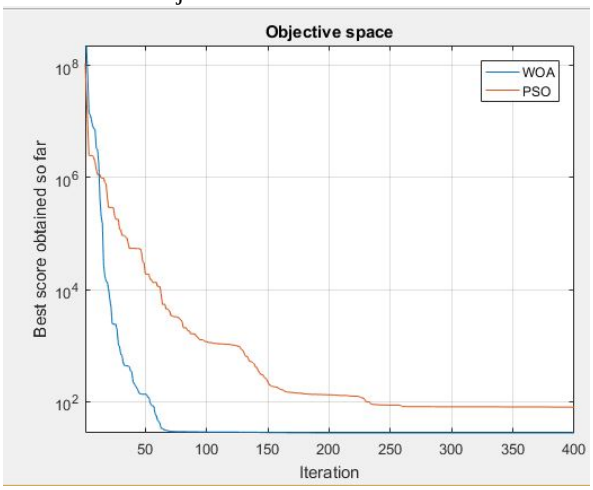


Figure1:F5(400 iteration)

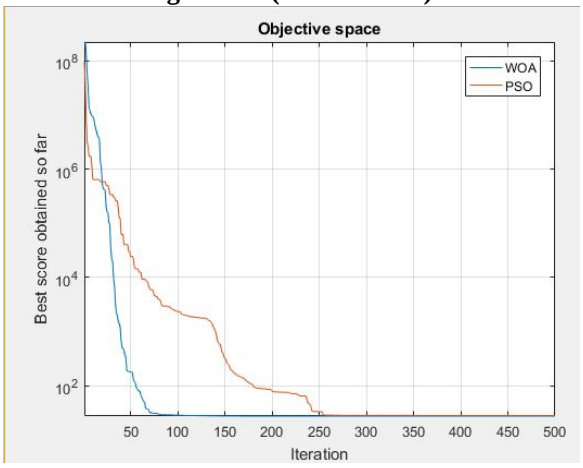


Figure2:F5(500 iteration)

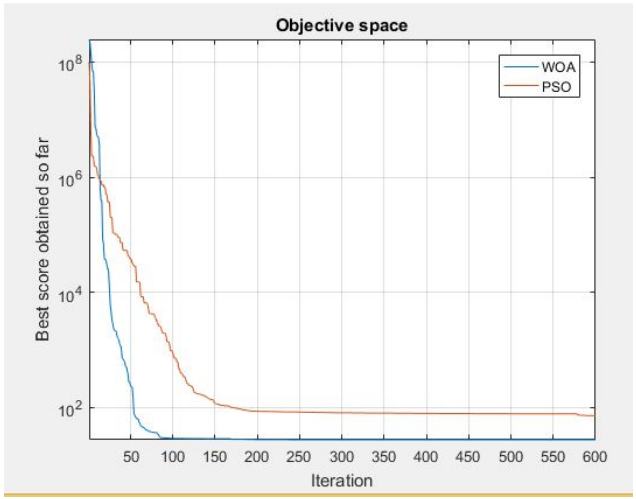


Figure3:F5(600 iteration)

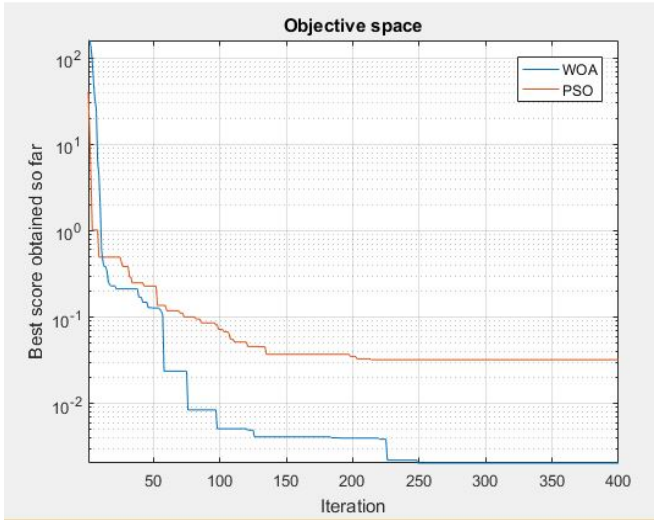


Figure4:F7(400 iteration)

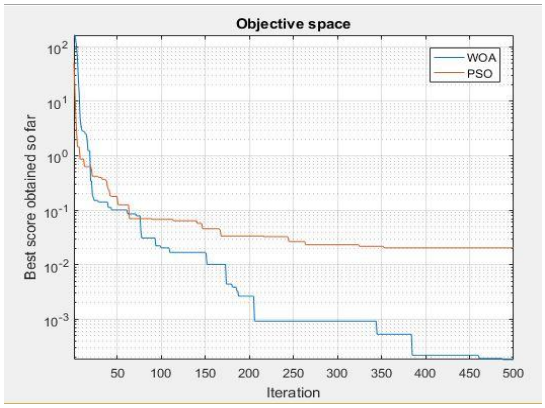


Figure5:F7(500 iteration)

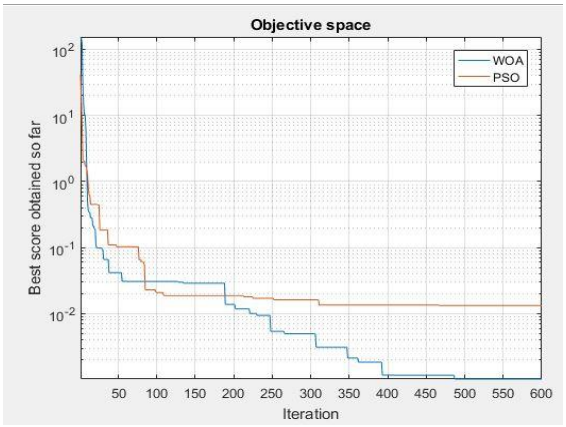


Figure6:F7(600 iteration)

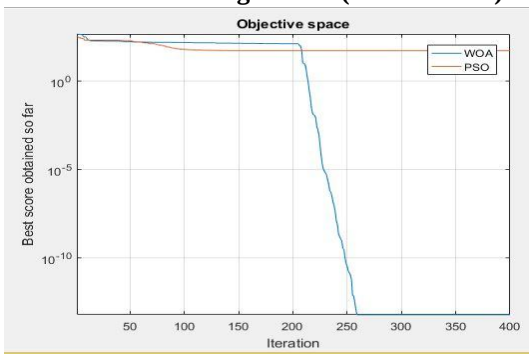


Figure7:F9(400 iteration)

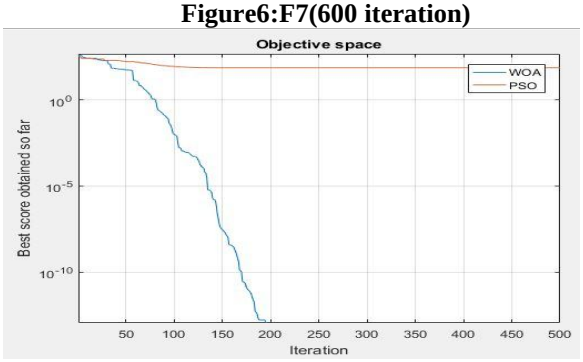


Figure8:F9(500 iteration)

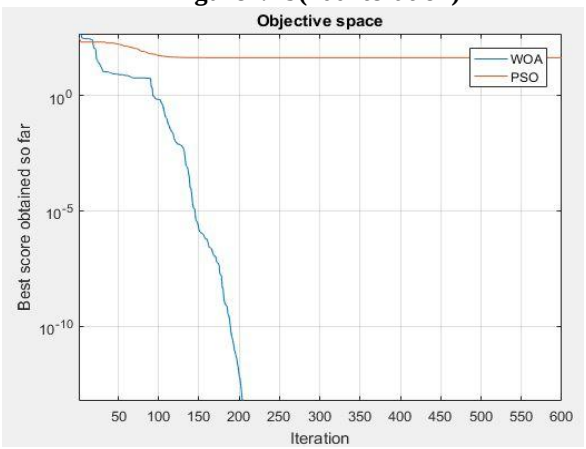


Figure9:F9 (600 iteration)

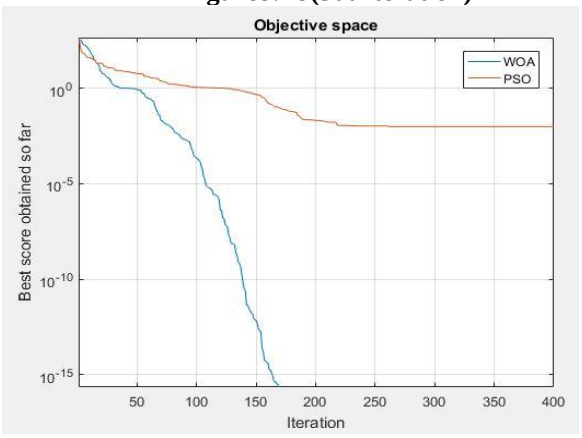


Figure10:F11 (400 iteration)

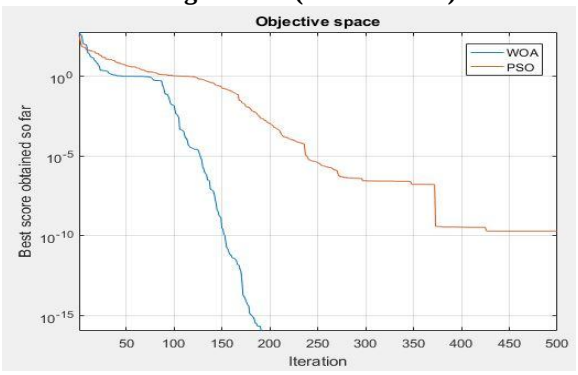


Figure11:F11 (500 iteration)

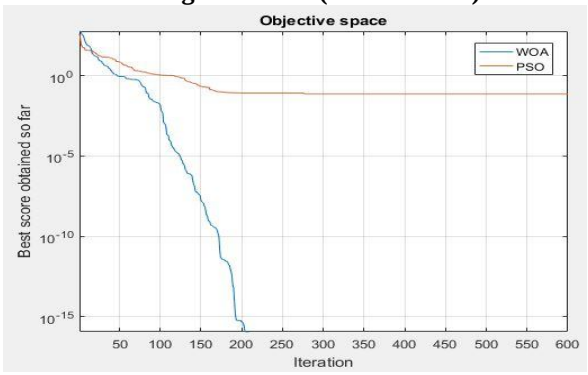


Figure12:F11(600 iteration)

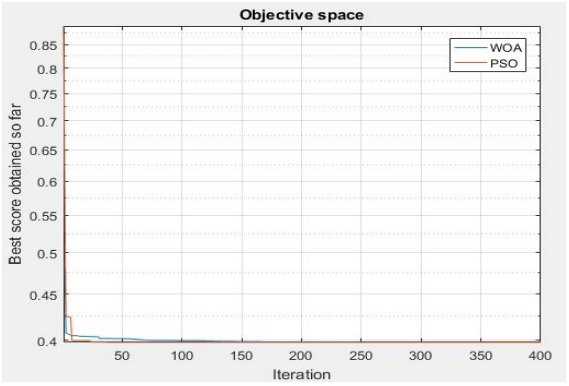


Figure13:F17 (400 iteration)

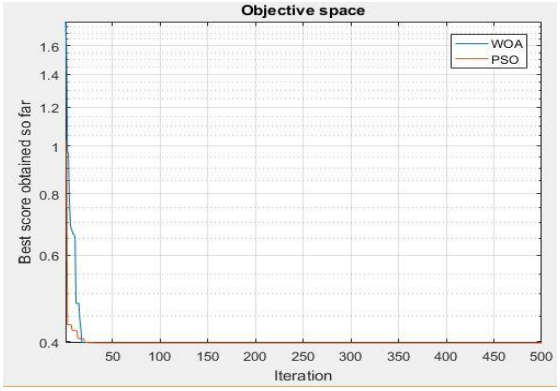


Figure14:F17 (500 iteration)

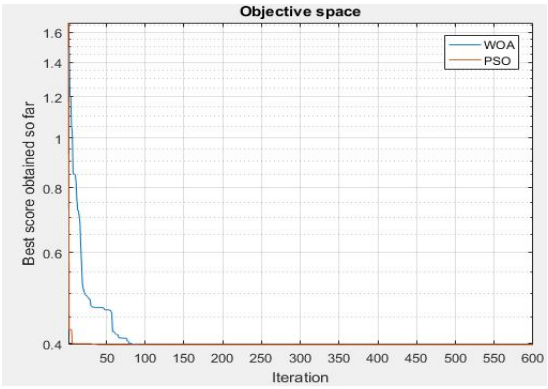


Figure15:F17 (600 iteration)

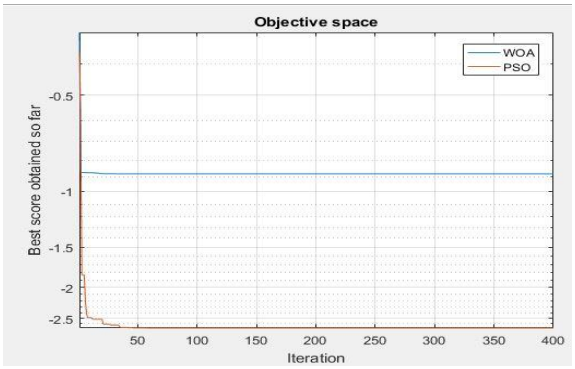


Figure16:F21 (400 iteration)

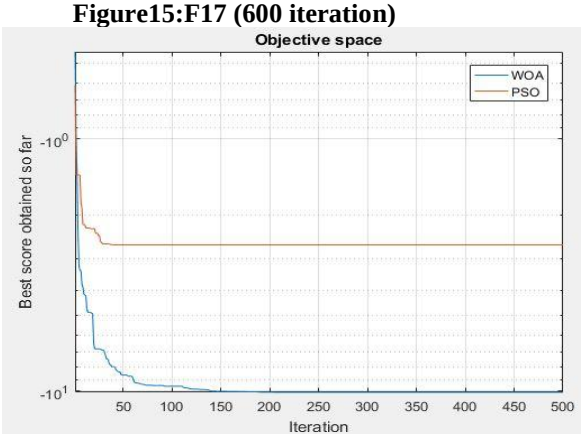


Figure17:F21 (500 iteration)

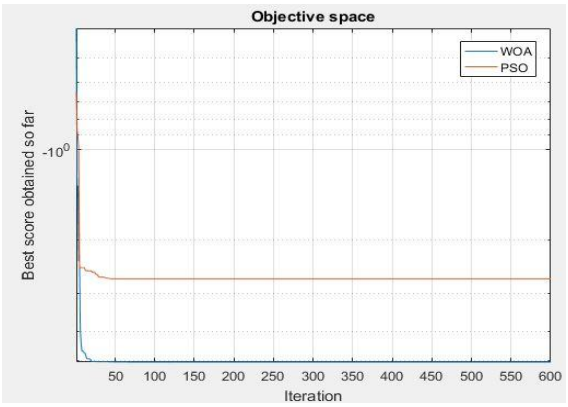


Figure18:F21 (600 iteration)

Experimental Result: Part 2

In part2, Multiple threshold values using WOA are computed and these multiple threshold values are used for image segmentation .05 benchmark images (320 X 214) of Berkeley image dataset are taken to calculate multiple threshold values for three and four level image segmentation using WOA .WOA (Seyedali Mirjalili and Andrew Lewis ,2016) is used to find best position and best score or fitness of a search agent from population in successive iterations. Best position of search agent is number of position in n dimension .to find two threshold values [T1, T2], Dim =2 and for three threshold values [T1, T2, T3], Dim =3 are set for an image. weight and variance are calculated using otsu algorithm. Dim represents number of threshold values for splitting an image.

Best position or Best leader among population size or search agent for Dim =2, 3 represents threshold values. variance represents best score or Fitness.

Multiple threshold values are calculated for population size or search agent =30, maximum iterations are 500 under 1st run.Lower_bound and Upper bound are taken as follows.

Lower_bound = zeros (1, Dim);
Upper_bound = 254*ones (1, Dim);
SearchAgents_no = 30; % Number of search agents
Max_iteration = 500; % Maximum numbef of iterations

For Dim =2, two threshold values [T1, T2] are generated and [0, T1, T2] will be set as pixel intensity p(i,j) in gray level image for three level image segmentation after satisfying the conditions.

a.(p(i,j) >=0 && p(i,j) < T1) set 0 in p(i,j)
b.(p(i,j) >= T1 && p(i,j) < T2) set T1 in p(i,j)
c.(p(i,j) >=T2 && p(i,j) < 255) set T2 in p(i,j)

these new pixel intensities are treated as super pixel labels of an image. for Dim =3 ,thress threshold values [T1,T2,T3] are generated and four threshold values [0,T1,T2,T3] will be set pixel intensity p(i,j) in gray level image for four level image segmentation. imagename.mat file from berkely dataset is loaded using Matlab and refImage(320 X214) is generated. refImage is used as ground truth image. refImage and superpixellabels image are used to to compute mean square error(MSE) and peak Signal to noise ratio(PSNR).superpixellabels image is converted into label2rgb() for display image in various levels.
Threshold values, MSE, PSNR for three level and four level image segmentation are shown in Table5.

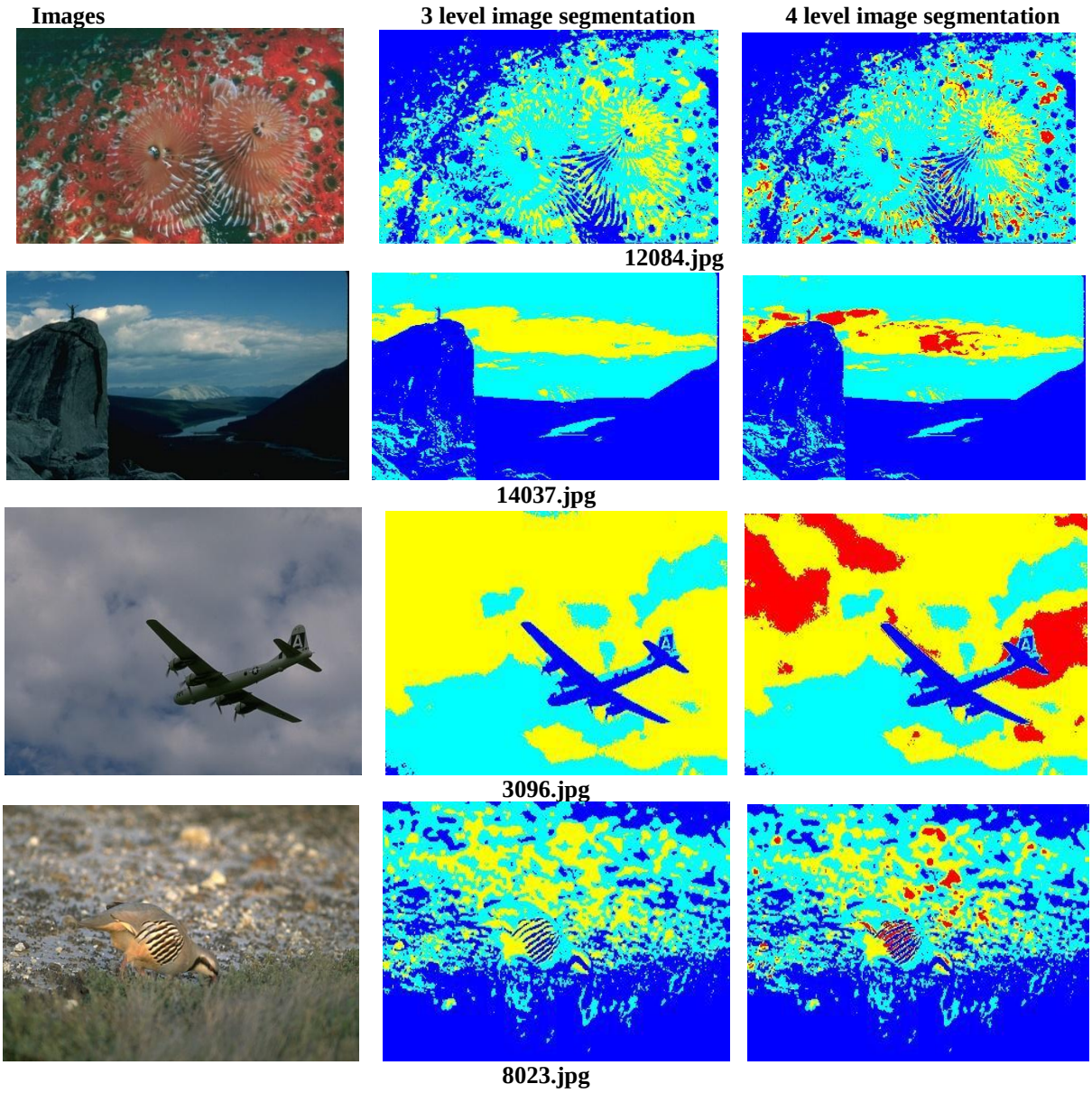
Threshold values for Three level and Four level image segmentation Using WOA

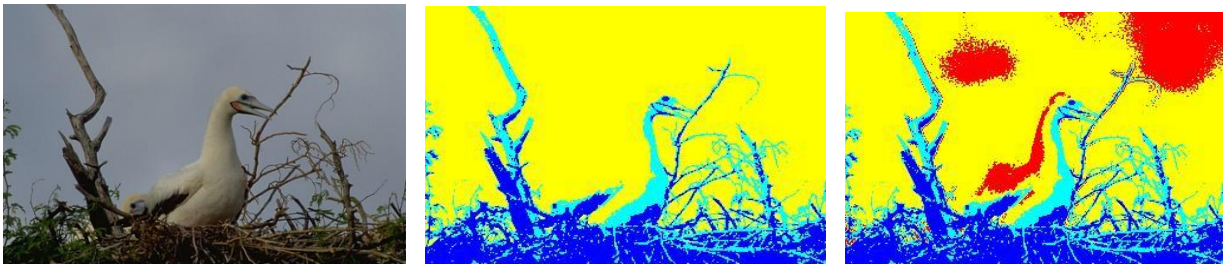
S.N.	Image Name	Threshold values	MSE	PSNR	Threshold values	MSE	PSNR
		[T1,T2] (Dim =2)			[T1,T2,T3] (Dim =3)		
1	12084.jpg	79,123	1576.546	16.15374	79,123,166	1469.3	16.45581
2	14037.jpg	61,128	1193.682	17.3615	61,128,176	1097.679	17.72605
3	3096.jpg	67,118	630.3699	20.13485	67,118,137	536.5064	20.83505
4	8023.jpg	108,146	4097.288	12.0057	108,146,192	4028.8	12.07825
5	8049.jpg	53,108	892.8195	18.62317	53,108,143	676.6051	19.82745

Table 5

Figures of segmented image based on threshold values for dim =2 (three level image segmentation) and dim =3 (four level image segmentation) are shown below.

Segmented Images: Three level and Four level image segmentation





8049.jpg

V. CONCLUSION

Image segmentation techniques are widely used in medical images, satellite images ,military image system, etc. Images are segmented into various levels by using multiple threshold values .multilevel thresholding method overcomes limitation of bi level thresholding. bilevel thresholding method segments an image in two parts only. multilevel thresholding methods segment the images into various levels so that user can get meaningful information from segmented images. In this paper multiple thresholds are obtained using Whale Optimization Algorithm (WOA).WOA is Meta heuristic nature inspired algorithm and widely used in various applications such as multilevel image segmentation (M. A. El Aziz et al,2018)[4], clustering applications(J. Nasiri ,F. M.Khiyabani,2018)[5] and design of low pass filter(Adrika Mukherjee et al 2017) [10].In this paper, performance of WOA and PSO are also discussed by showing their convergence curve behavior based on various objective functions for different number of iterations using Whale Optimization Algorithm WOA is tested on various benchmark functions and has faster convergence rate than gravitational search algorithm and particle swarm optimization PSO (Seyedali & Andrew,2016)[3].

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AUTHORS PROFILE

Basu Dev Shivahare completed B.Tech.(CSE) from UPTU,Lucknow,(UP) in 2006 ,M.Tech (CS) from BIT MESRA ,Ranchi in 2012 .currently he is pursuing Phd(CSE) from AKTU,Lucknow,Uttar Pradesh ,India. He has published 10 research papers in peer review international journal and conferences. His research area is Image Processing .His area of interest is Big Data, Hadoop, Data Structure & Algorithms. He is UGC-NET qualified.

Dr. S.K. Gupta is an Associate Professor in Department of computer science and Engineering at Bundelkhand Institute of Engineering & Technology (BIET) Jhansi, Uttar Pradesh, India .He completed B.Tech(CSE) from HBTI, Kanpur, M.Tech(CSE) from MNREC Allahabad ,Phd(CSE) in 2010 from Bundelkhand University Jhansi(UP),India .His area of interest is Image Processing , Compiler Design, Operating System. He has published more than 30 Research papers in International journals and Conferences. He Worked as Joint Controller of Examination, Mahamaya Technical University (MTU), Noida, UP (INDIA)-284128, since March 24, 2011 to December 26, 2013. He guided more than 10 PhD Students. He has more than 25 years of teaching experience. He is member of ISTE.