A Hybrid Particle Whale Optimization Algorithm with application to workflow scheduling in cloud–fog environment

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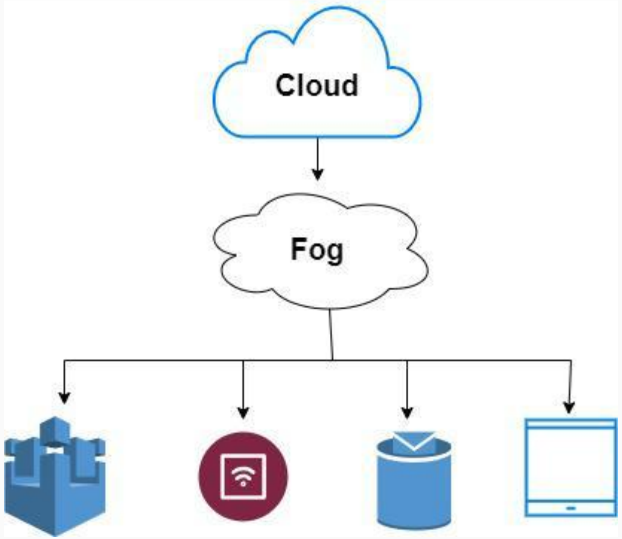
Introduction

Problem statement:

- limited number of scientific processes;
- a limited number of performance indicators.



Cloud-fog computing

Fitness Function

$\text{Fitness(F1)}= \text{Total execution cost} \quad (\text{TEC})$

$$\text{TEC} = \sum_{j=0}^{nV\ M-1} C[j] * (LET[j] - LST[j])$$

LST	Least start time
LST[j]	Least start time of j_{th} virtual machine
LET	Least end time
LET[j]	Least end time of j_{th} virtual machine

$\text{Fitness(F2)}= \text{Total Execution Time(TET)}$

$$\text{TET}_w = \max\{CT_i \mid i = 1, 2, 3, 4 \ldots\ldots m\}$$

CT	Completion time
CT_i	Completion time of job T_i's

Global best and particle best values

- global best (gbest)
- particle best (pbest)

Update particles velocity and next position

$$V_i(iter + 1) = w * V_i(iter) + c_1 * r_1 * (pbest - x_i(iter)) + c_2 * r_2 * (gbest - x_i(iter)) \ldots\ldots\ldots$$

r_1, r_2	[0,1]	Factor to control social influence of swarm
c_1	2	Inertia makes the particle move in the same direction and with the same velocity
c_2	2	Random variable to be assigned in [0,1] interval on every iteration

WOA

$$\vec{D} = \left| \vec{C} . \overrightarrow{X^*}(t) - \vec{X}(t) \right|$$

$$\vec{X}(t+1) = \overrightarrow{X^*}(t) - \vec{A} \cdot \vec{D}$$

t indicates the current iteration

X^* is the position vector of the best solution

$$\vec{A} = 2\vec{a} \cdot \vec{r} - \vec{a}$$

$$\vec{C} = 2 \cdot \vec{r}$$

$\vec{a}$ is linearly decreased from 2 to 0 over the course of iterations

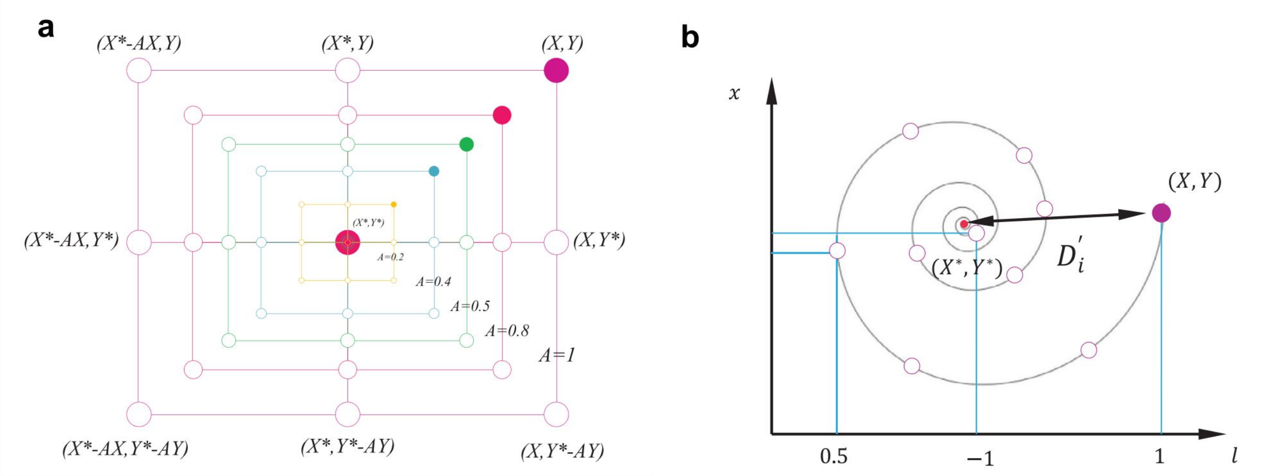
$\vec{r}$ is a random vector in [0,1].

WOA

Bubble net attacking method (exploitation phase)

$$\vec{X}(\text{iter}+1)=\begin{cases}\vec{X}^{*}(\text{iter})-\vec{A}\cdot\vec{D} & \text{if } p<0.5\\ D' * e^{bl} * \cos(2\pi l)+\vec{X}^{*}(\text{iter}) & \text{if } p\geq 0.5\end{cases}$$

where ‘p’ is a random number in the range [0,1].



Bubble-net search mechanism implemented in WOA (X∗ is the best solution obtained so far):

(a) shrinking encircling mechanism and

(b) spiral updating position

WOA

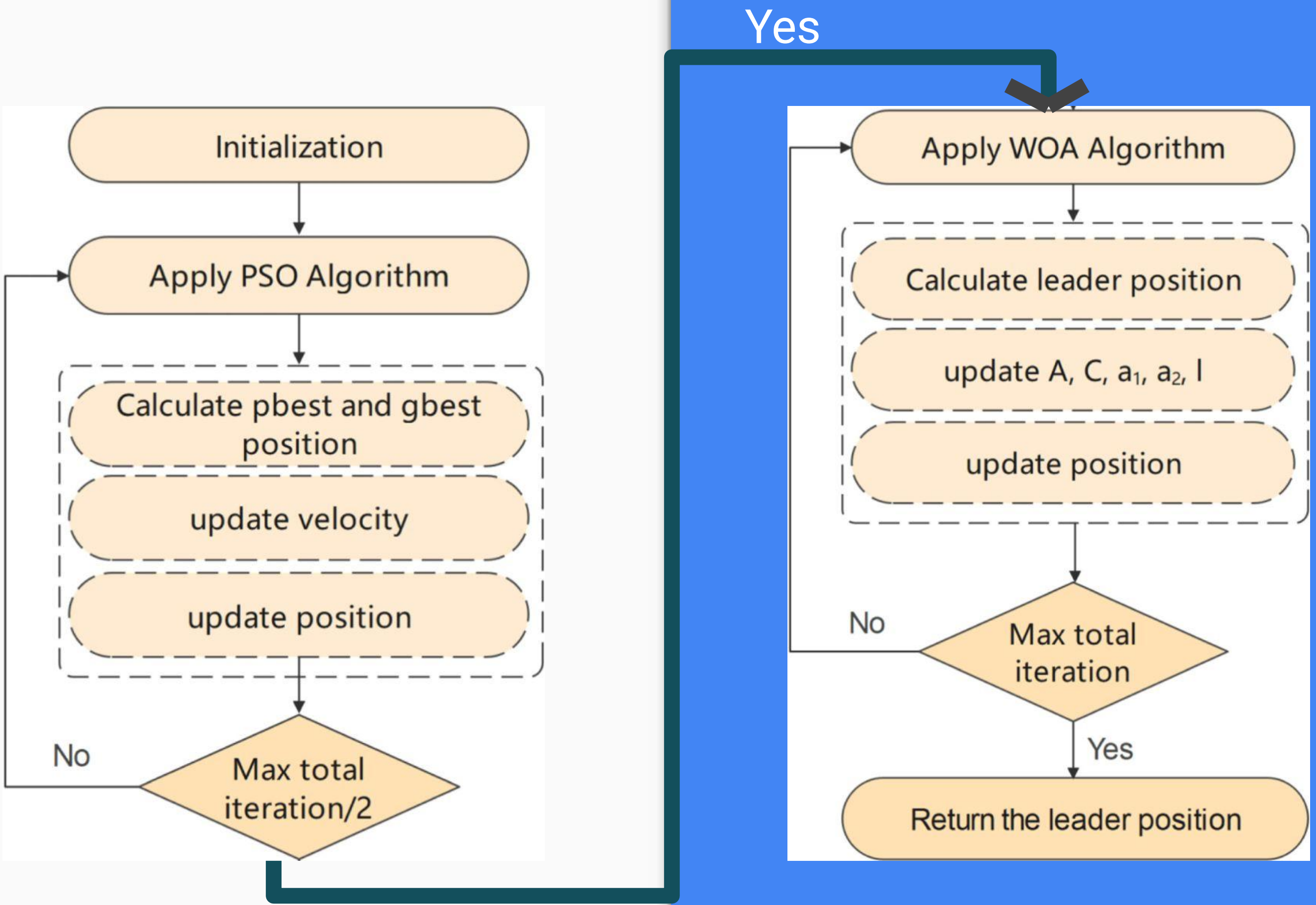
Search for prey (exploration phase)

$$\vec{D} = \left| \vec{C} \cdot \overrightarrow{X_{rand}} - \vec{X} \right|$$

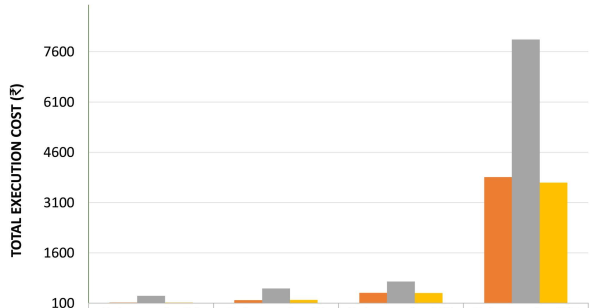
$$\vec{X}(t+1) = \overrightarrow{X_{rand}} - \vec{A} \, . \, \vec{D}$$

where $\overrightarrow{X_{rand}}$ is a random position vector (a random whale) chosen from the current population.

Proposed PWOA algorithm

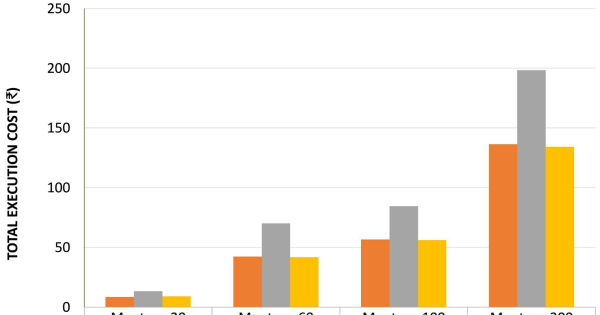


Results



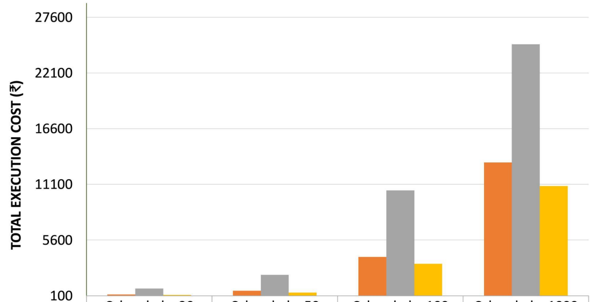
	Epigenomics 24	Epigenomics 47	Epigenomics 100	Epigenomics 997
PSO	117.40	190.73	402.25	3861.87
WOA	316.72	536.01	742.21	7961.67
PSO+WOA	115.29	192.78	397.12	3695.91

NUMBER OF ITERATIONS



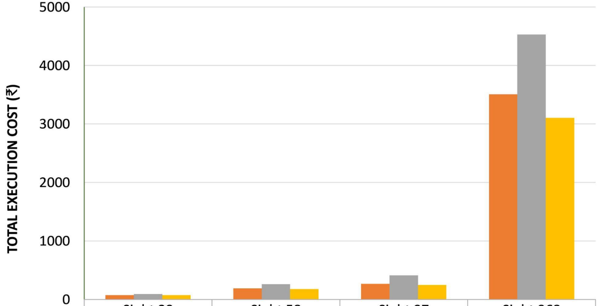
	Montage 20	Montage 60	Montage 100	Montage 300
PSO	8.43	42.25	56.63	136.37
WOA	13.355	70.09	84.39	198.31
PSO+WOA	8.95	41.76	56.14	134.109

NUMBER OF ITERATIONS



	Cybershake 30	Cybershake 50	Cybershake 100	Cybershake 1000
PSO	230.89	578.67	3927.26	13270.35
WOA	810.71	2160.42	10497.37	24935.72
PSO+WOA	171.85	405.57	3247.67	10932.23

NUMBER OF ITERATIONS

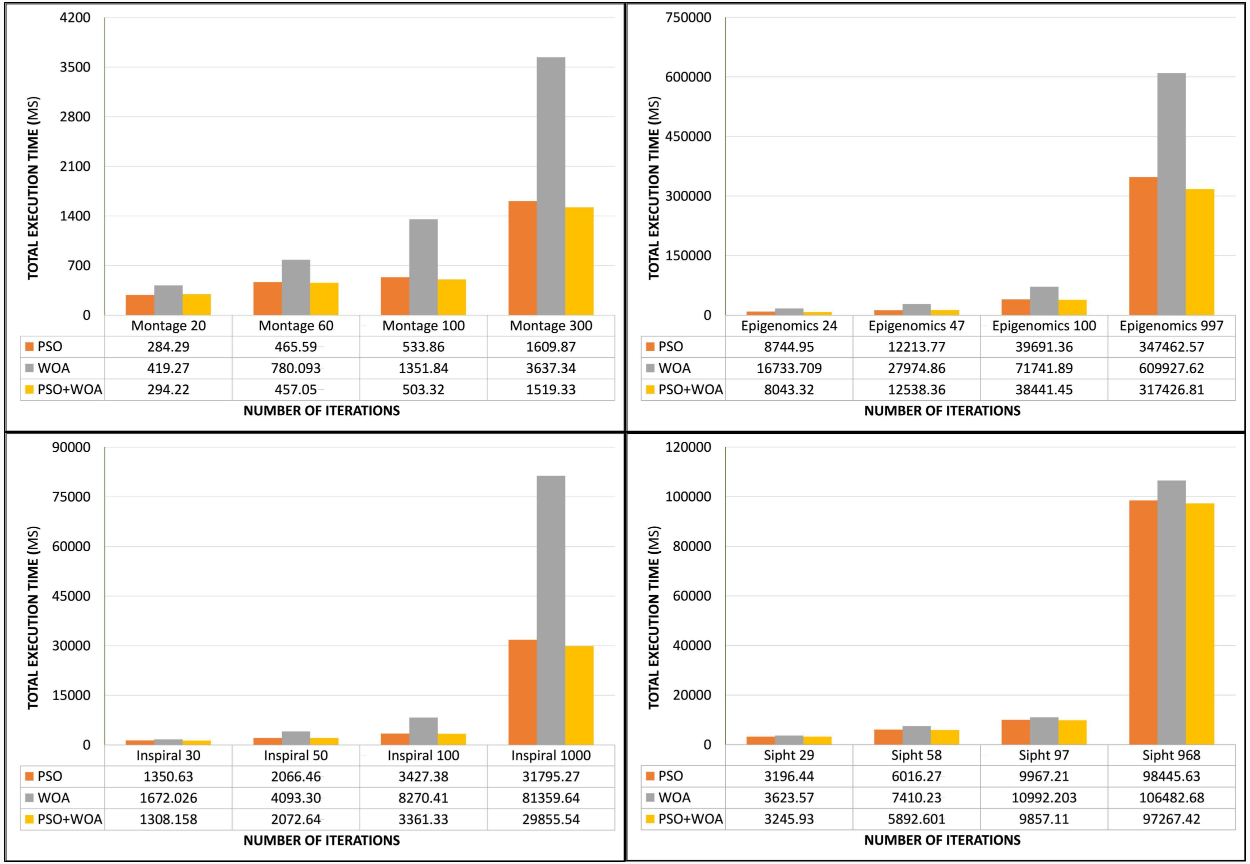


	Sipht 29	Sipht 58	Sipht 97	Sipht 968
PSO	73.41	190.09	267.26	3506.07
WOA	92.65	259.98	413.52	4530.24
PSO+WOA	75.93	176.81	247.16	3105.58

NUMBER OF ITERATIONS

TEC:
-Better than PSO from 1.23% to 22.6%
-Better than WOA from 30.43% to 71.31%

Results



	Montage 20	Montage 60	Montage 100	Montage 300
PSO	284.29	465.59	533.86	1609.87
WOA	419.27	780.093	1351.84	3637.34
PSO+WOA	294.22	457.05	503.32	1519.33

	Epigenomics 24	Epigenomics 47	Epigenomics 100	Epigenomics 997
PSO	8744.95	12213.77	39691.36	347462.57
WOA	16733.709	27974.86	71741.89	609927.62
PSO+WOA	8043.32	12538.36	38441.45	317426.81

	Inspiral 30	Inspiral 50	Inspiral 100	Inspiral 1000
PSO	1350.63	2066.46	3427.38	31795.27
WOA	1672.026	4093.30	8270.41	81359.64
PSO+WOA	1308.158	2072.64	3361.33	29855.54

	Sipht 29	Sipht 58	Sipht 97	Sipht 968
PSO	3196.44	6016.27	9967.21	98445.63
WOA	3623.57	7410.23	10992.203	106482.68
PSO+WOA	3245.93	5892.601	9857.11	97267.42

TET:
-Better than PSO from 1.45% to 7.73%
-Better than WOA from 12.47% to 50.37%

Conclusion

This article introduces a new meta-heuristic algorithm called Particle Whale Optimization Algorithm (PWOA) for workflow optimization. PWOA combines two existing algorithms to reduce Total Execution Time (TET) and Total Energy Consumption (TEC) in various workflows like Cybershake, Montage, Epigenomics, Sipht, and Inspiral.

PWOA outperforms standard Particle Swarm Optimization (PSO) and Whale Optimization Algorithm (WOA). For example, PWOA reduces TEC by 22.60%, 71.31%, 2.46%, 56.92%, and 6.08% compared to PSO for Cybershake, Epigenomics, Inspiral, Montage, and Sipht, respectively. It also reduces TET by 7.73%, 17.75%, 6.60%, 50.37%, and 3.72%.

Thanks for your attention