

algorithm,algpseudocode

Algorithm 2: ControlledLISTENMode Optimization Algorithm

[1]

Input: Objective function $f(x)$, bounds $[lb, ub]$, dimension D , number of agents N , iterations T

Output: Best solution $x^*, f(x^*)$

Initialize roles: Initiators, Duelists, Controllers, Sentinels based on ratio;
 Initialize positions $X_i \sim U(lb, ub)$ for $i = 1 \dots N$;
 Evaluate fitness $F_i = f(X_i)$ and set global best $x^* = \arg \min F_i$;

for iteration $t = 1$ to T **do**

- Compute population standard deviation and step scale;
- Compute progress factor $p = t/T$ and Lévy probability $\rho = 0.2 - 0.1p$;
- Initialize hotspot list $H = \emptyset$;
- foreach** Initiator i **do**

 - Compute adaptive step $\sigma = \sigma_1 \cdot \text{step_scale} \cdot (0.3 + 0.7(1 - p))$;
 - if** $\text{rand}() < \rho$ **then**
 - $| \quad \text{step} \leftarrow 0.8 \cdot \text{LevyFlight}(\beta)$;
 - else**
 - $| \quad \text{step} \leftarrow \sigma \cdot \mathcal{N}(0, I)$;
 - end**
 - $X_i \leftarrow \text{clip}(X_i + \text{step})$;
 - Add X_i to hotspots H ;

- end**
- Evaluate $f(h)$ for each $h \in H$;
- Select top-k best hotspots as target set T_H ;
- foreach** Duelist d **do**

 - Select random target $t \in T_H$;
 - Compute $lf = \text{LevyFlight}(\beta)$;
 - $step \leftarrow \sigma_2(t - X_d) + 0.5\beta \cdot lf$;
 - $X_d \leftarrow \text{clip}(X_d + step)$;

- end**
- foreach** Controller c **do**

 - Determine active set $A = \text{initiators} \cup \text{duelists}$;
 - if** $|A| > 0$ **then**
 - $| \quad \text{Select } k \propto (1 - p) \text{ samples from } A$;
 - $| \quad centroid \leftarrow \frac{1}{k} \sum X_i, \forall i \in A$;
 - else**
 - $| \quad centroid \leftarrow \text{random agent}$;
 - end**
 - $step \leftarrow \eta(centroid - X_c) + 0.1\mathcal{N}(0, I)$;
 - $X_c \leftarrow \text{clip}(X_c + step)$;

- end**
- if** Controller(s) exist **then**
- $| \quad C_{mean} = \text{mean of controller positions}$
- end**
- foreach** Sentinel s **do**

 - if** global best x^* exists **then**
 - $| \quad step \leftarrow \lambda(x^* - X_s) + 0.2(C_{mean} - X_s)$;
 - $| \quad X_s \leftarrow \text{clip}(X_s + step)$;
 - end**
 - if** $\text{rand}() < 0.05$ **then**
 - $| \quad X_s \leftarrow \text{clip}(X_s + 0.02\mathcal{N}(0, I))$;
 - end**

- end**
- if** $\text{variance} < 10^{-3}$ **then**
- $| \quad \text{Randomly reinitialize one sentinel}$;
- end**
- /* Evaluate and Archive Elites */
- Evaluate all $F_i = f(X_i)$;
- Update global best $x^*, f(x^*)$;
- Store top-5 elites in archive;

end

return $x^*, f(x^*)$
