State Adaptive Slime Mold Fractional Order Ant System (SASFAS) for Optimal Path Planning

1. Introduction

The State Adaptive Slime Mold Fractional Order Ant System (SASFAS) is a hybrid bio-inspired optimization algorithm designed for complex path planning problems, such as UAV routing and Traveling Salesman Problems (TSP). It combines the exploration ability of the Slime Mold Algorithm (SMA), the path-finding capability of Ant Colony Optimization (ACO), memory-aware dynamics from Fractional Calculus, and adaptive control of parameters based on convergence state.

2. Components of SASFAS

2.1 Slime Mold Algorithm (SMA)

The position update mechanism in SMA is inspired by the oscillatory behavior and mass transfer dynamics of slime molds:

$$X_i^{t+1} = \begin{cases} X_{\text{best}}^t + v_b(W_i \cdot X_i^t - X_j^t), & r < p \\ X_i^t + r\left(\frac{X_k^t - X_j^t}{2}\right), & r \geq p \end{cases}$$

where X_i^t is the current position, X_{best}^t is the best found solution, X_j^t, X_k^t are random individuals, v_b is a vibration coefficient, W_i is a weight factor, and p is a probability threshold.

2.2 Fractional Order Dynamics

Fractional derivatives model memory effects. The Caputo derivative is defined as:

$$D_t^\alpha f(t) = \frac{1}{\Gamma(n-\alpha)} \int_0^t \frac{f^{(n)}(\tau)}{(t-\tau)^{\alpha+1-n}} d\tau, \quad n-1 < \alpha < n$$

In optimization, the fractional order update becomes:

$$X_i^{t+1} = X_i^t + \eta \cdot D_t^\alpha X_i(t)$$

where η is a learning rate and α is the fractional order (e.g., 0.7).

2.3 Ant Colony Optimization (ACO)

ACO is used to construct and refine solutions using probabilistic decision rules:

$$P_{ij} = \frac{[\tau_{ij}]^\alpha [\eta_{ij}]^\beta}{\sum_{k \in \text{allowed}} [\tau_{ik}]^\alpha [\eta_{ik}]^\beta}$$

$$\tau_{ij}^{t+1} = (1-\rho)\tau_{ij}^t + \Delta\tau_{ij}$$

where τ_{ij} is the pheromone level, $\eta_{ij} = 1/d_{ij}$ is the heuristic based on distance, and ρ is the evaporation rate.

2.4 State Adaptive Control

Parameters such as inertia, probability, or pheromone evaporation are adjusted based on the state of convergence:

$$w(t) = w_{\min} + (w_{\max} - w_{\min}) \cdot \left(\frac{t_{\max} - t}{t_{\max}} \right)$$

$$p(t) = \frac{1}{1 + e^{-k(t-t_0)}}$$

3. Combined Update Equation

The combined update rule for each agent in SASFAS is:

$$X_i^{t+1} = \mathrm{SMA}(X_i^t, W_i^t, X_{\text{best}}^t) + \eta \cdot D_t^\alpha X_i(t) + \text{ACO\_path\_update}(P_{ij})$$

4. Applications

- UAV path planning
- Multi-Depot Multiple Traveling Salesman Problems (MDMTSP)
- Sensor clustering in WSNs
- Image segmentation
- Dynamic scheduling and routing

5. Conclusion

SASFAS is a promising hybrid algorithm for solving complex path planning problems by effectively combining global and local search strategies, incorporating memory-aware dynamics, and dynamically adjusting parameters.