Design of optimal fuzzy controller using grey Gaussian bare-bones differential evolution

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Abstract

This project attempts to propose the grey Gaussian barebones differential evolutions (GBDEs) with two newly grey-based Gaussian mutation strategies to improve the search performance of GBDE algorithm. The proposed two grey GBDE were applied to optimize Takagi-Sugeno (T-S) type fuzzy controller to observe and compute their control performances. The simulation results show that the proposed methodology has a good control performance.

Grey GBDE Algorithms

1. Gaussian mutation strategy

- Grey-based arithmetic recombination strategy
  \[ v_{i,G+1} = \alpha_{i,1} \cdot v_{i,G+1} + \alpha_{i,2} \cdot v_{i,G} \]
  \[ g_{i} = g(x_{best,G} + x_{i,G}) \]
  \[ g_{i} = g(x_{best,G} - x_{i,G}) \]

- Current-type Gaussian mutation strategy
  \[ v_{i} = \text{Normal}(\mu, \sigma), \quad \mu = (x_{best,G} + x_{i,G})/2 \]
  \[ \sigma = |x_{best,G} - x_{i,G}| \]

- Random-type Gaussian mutation strategy
  \[ v_{i} = \text{Normal}(\mu, \sigma), \quad \mu = (x_{best,G} + x_{r,G})/2 \]
  \[ \sigma = |x_{best,G} - x_{r,G}| \]

2. Hybrid crossover strategy

- Hybrid crossover strategy
  \[ u_{i,G+1} = \begin{cases} f(v_{j,G}), & \text{if } (rand_{j} \leq Cr) \text{ or } (j = f rand) \\ x_{j,G}, & \text{otherwise} \end{cases} \]
  \[ f(v_{j,G}) = \begin{cases} v_{j,G}, & \text{if } \rho_{G} \leq 0.5 \\ (1-w_{G}) \cdot x_{j,G} + w_{G} \cdot x_{j,best,G}, & \text{otherwise} \end{cases} \]

- \[ \rho_{G} = \text{rand}(0,1) \cdot w_{G} = 0.5 \cdot \text{rand}(0,1) \]

3. Selection strategy

- \[ x_{i,G+1} = \begin{cases} u_{i,G}, & \text{if } f(u_{i,G+1}) \leq f(x_{i,G}) \\ x_{i,G}, & \text{otherwise} \end{cases} \]

4. Main procedure:

Mutation ⇒ Crossover ⇒ Selection

Simulation Results

Objective function

\[ J(t) = \int_{t}^{t_{f}} [w_{1} \cdot e(t) + w_{2} \cdot u^{2}(t)] dt + w_{d} \cdot \Delta y(t), \text{ if } \Delta y(t) \geq 0, \]
\[ \int_{t}^{t_{f}} [w_{2} \cdot e(t) + w_{1} \cdot \Delta y(t)] dt + w_{d} \cdot \Delta y(t), \text{ if } \Delta y(t) < 0. \]
\[ \Delta y(t) = y(t) - y(t-1) \]

- \[ w_{1} = 0.999, \quad w_{2} = 0.001, \quad w_{d} = 2.0, \quad w_{d} = 50 \]

Controlled plant \[ G(S) = \frac{1.6}{s^{2} + 2.584s + 1.6} \]

Form of target vector

- PID controller: \[ x_{i,G} = (P_{i}, I_{i}, D_{i}) \]
- Fuzzy controller:
  - Fuzzy rule: \[ x_{1} = e, \quad x_{2} = \dot{e} \]
  - Rule \( t \): If \[ x_{1} \in A_{1} \text{ and } x_{2} \in A_{2} \]
  Then \[ u_{i} = \alpha_{0} x_{1} + \alpha_{1} \cdot x_{1} + \alpha_{2} x_{2} \]

- Target vector

System responses

Related paper: