Abstract-This study focused on the development of a new population-based evolutionary optimization algorithm for the design of fuzzy systems. The new designed algorithm, mutation-aided elite continuous ant colony optimization (MECACO) initializes the ant colony in more concentrative region follow by an elites-continuous ACO with the dynamic mutation technique to exploit and explore the solutions. One example of TSK-type fuzzy system optimized by the MECACO is presented. More results and performance superiority of fuzzy systems designed by the MECACO are detailed in [1]. The results of MECACO deigned fuzzy system for pedelec control determining the applied electric voltage to assisted motor for compensating for the changes of the road gradients and human pedal torques will be shown in the technical report.

Method
The flow chart of the proposed MECACO algorithm [1] is shown in Figure 1. All ant solutions are initialized randomly in the range [0.45,0.55] assuming the parameters of fuzzy system are considered in [0,1]. The mutation probability for each new solution component is proportional to the biased standard deviation of all the ant components of the same position. The Elite ACO_R mixes, in scanning manner starting from the first solution component, the first two best elites uniformly in probability to form a directional solution. Then Gaussian sampling procedure around the directional solution for further exploitation is employed to generate a new candidate solution. The operation of dynamic mutation is given by

\[
s_i^n(t+1) = s_i^n(t) + s_i^n(t) \cdot 0.05 \cdot U[-1,1], \quad \text{if } s_i^n(t) \leq 0.5, \\
s_i^n(t+1) = s_i^n(t) + (1 - s_i^n(t)) \cdot 0.05 \cdot U[-1,1], \quad \text{if } s_i^n(t) > 0.5,
\]

\(n\): random integer in [1,N].
\(U[-1,1]\): random number in [-1,1]

Results
Nonlinear plant track control example:

\(y(k + 1) = \frac{y(k)y(k - 1)y(k) + 2.5}{1 + y^2(k) + y^2(k - 1)} + u(k), -1.2 \leq y \leq 1.2\)

\(y_r(k + 1) = 0.6y_r(k) + 0.2y_r(k - 1) + r(k), 0 \leq k < 250,\)

\(r(k) = 0.2 \sin(2k\pi/25) + 0.4 \sin(k\pi/32),\)

Objective function

\[SAE = \sum_{j=1}^{5} ||y_j(k) - y(k)||\]

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>ACO_R (q=0.01)</th>
<th>ACO_R (q=10)</th>
<th>RCACO [2]</th>
<th>MECACO</th>
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</thead>
<tbody>
<tr>
<td>Average SAE</td>
<td>9.63</td>
<td>2.32</td>
<td>1.92</td>
<td>1.75</td>
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<tr>
<td>STD</td>
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<td>1.33</td>
<td>1.06</td>
<td>0.86</td>
</tr>
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</table>

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References