Sensor-Based Path Planning and Intelligent Steering Control of Nonholonomic Mobile Robots

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Summary

This paper presents a control scheme for autonomous navigation of intelligent mobile robots under unstructured environments. First, using a simple genetic algorithm, the path planning module generates an obstacle-free path as a sequence of control vectors of orientation, considering kinematic constraints in steering control of nonholonomic wheeled mobile robots. To reduce the length of code of the gene, the change of orientation is restricted to 5 values from 45 deg to -45 deg (Fig. 1).

The fitness value of a chromosome, or planned path is a weighted sum of the following three terms: 1) the ratio of distance of the planned path to that of the straight line, both to the goal position, 2) the sum of distance between via-points and the nearest obstacles (Fig. 2), and 3) the deviation from the goal orientation (Fig. 3). If the 2nd term of the fitness function is large, the planned path is free from obstacles. The 3rd term is the special term for the proposed path planning algorithm. If the robot approaches the goal from a counter direction, the variable $f$ becomes minus and the path is rejected.

Conventional GA operators such as combined roulette and elite selection, one-point crossing over, and point mutation were applied. For real-time consideration, the total generation number is fixed at the value required for the convergence of the fitness value. Path planning is re-initiated before the robot reaches the final control points to perform smooth movements without stopping. Examples of planned path reveal the effect of the 3rd term of the fitness function (Fig. 4). The GA parameters are listed in Table 1. The mean processing time for path planning was 0.48 sec using SunUltra60 (300 MHz UltraSparc2 CPU).

Table 1 GA parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Population size</td>
<td>20</td>
</tr>
<tr>
<td>Generation number</td>
<td>100</td>
</tr>
<tr>
<td>Gene number</td>
<td>8</td>
</tr>
<tr>
<td>Crossover probability</td>
<td>0.8</td>
</tr>
<tr>
<td>Mutation probability</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Then, the tracking control module calculates the references for motion control of the mobile robot using a sensor fusion network (Fig. 5). An experimental procedure for teaching the sensor fusion network is introduced, and basic characteristics of the internal and external sensors during straight-line and circular movements on the floor with black-striped markers are measured using our experimental small robot to show the feasibility of the proposed control scheme. The experimental results explain relations between the robot movement and the sensor outputs.