Intelligent Planning of Tourism Scenic Routes Based on Genetic Algorithm in Coal WANBEI Mining Subsidence

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Abstract
Aiming at the problem of tourism scenic route planning, this paper studies and analyzes the combined influence of terrain slope and surface properties on vehicle route planning. The "window moving method" is introduced to carry out early slope calculation and traffic ability analysis for the terrain, roughness evaluation index is established respectively for wheeled and tracked vehicles and the "preponderant area method" is used to rasterize the surface properties. By setting up the tabu list, the constraint influence of slope and roughness is superposed to reduce the search scope and improve the search efficiency. The evaluation function is constructed to improve the genetic algorithm and combined with Expand list, Open list, Closed list and Path list, route optimization algorithm is designed for considering the constraints of slope and roughness. The simulation results show that the algorithm can quickly and effectively realize the tourism scenic route planning of the real terrain environment.

Keywords: Genetic algorithm; Tourism scenic route planning; Slope; Surface properties; Roughness

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1. Introduction
Under the tourism scenic environment, vehicle route planning is faced with great challenges: (1) complex surface properties form various delay or hindrance to vehicle travel; (2) variable terrain slope severely limits or affects the vehicle travel; (3) real vehicle is used for practice, which not only consumes lots of human, physical and financial resources, but also is difficult to guarantee the safety of personnel and vehicles, so it is necessary to study a tourism scenic route planning method consistent with actual terrain environment [1-5].

Genetic algorithm is a classical heuristic global search algorithm, which is the shortest route search algorithm based on Dijkstra and BFS algorithm. Aiming at slow search speed of traditional genetic algorithm and not optimized return route, Peng Song et al. have improved the global route planning algorithm for lunar vehicle and used binary search to optimize the route planning strategies for concave obstacle [6-9]. Ren Bo et al. have comprehensively considered integrating the smoothing technique of digital map for constraint conditions such as terrain slope limitation, vehicle overload limit and safe flight elevation limit into the route optimization to achieve the optimal track close to terrain [10-13].

This paper takes the vehicle under the tourism scenic environment as the research object and uses the improved genetic algorithm to study and analyze the problem of tourism scenic route planning. The experimental results show that the improved genetic algorithm has stronger reality and superior search ability [13-16].

2. Data Pre-Processing
2.1. Establishment of Slope List
Elevation data of the terrain is derived from 5m x 5m grid and assumed that projected area of vehicle is just a grid unit. According to four vertices (corresponding elevation as \(Z_{i,j} \), \(Z_{i+1,j} \), \(Z_{i+1,j+1} \), \(Z_{i,j+1} \)) in grid unit \((i,j)\), work out the elevation \(Z'_{i,j}\) in the grid center point \(P'_{i,j}\) as follows:
\[ Z_{i,j}' = \left( Z_{i,j} + Z_{i+1,j} + Z_{i+1,j+1} + Z_{i,j+1} \right) / 4 \]

Slope (slope) represents the vector of inclination degree of this point on the terrainal surface, which is composed of two factors such as slope size and direction. Assumed that the slope size suitable for vehicle passing is 0°-30°, when the vehicle is ready to move down to next grid, it needs to calculate the slope size in real-time in the moving direction to judge the traffic ability between two grids.

"Window moving method" is introduced into the algorithm and the coordinate sequence of the grid center point is represented as this grid unit to calculate the slope size of the current grid and its 8 adjacent grids. "Window moving method" adopts 3x3 window, as shown in Figure 1.

![Figure 1. 8 Adjacent slopes of grid center point](image)

With counter-clockwise director as the sequence, successively calculate the slope size \( G_{i,j,k} \) of adjacent grids relative to the current grid center point, in which \( 1 \leq k \leq 8 \). Specific formulas are as follows:

\[
\begin{align*}
G_{i,j,1} & = \frac{Z_{i+1,j} - Z_{i,j}}{5\sqrt{2}} \\
G_{i,j,2} & = \frac{Z_{i,j+1} - Z_{i,j}}{5} \\
G_{i,j,3} & = \frac{Z_{i+1,j+1} - Z_{i,j}}{5\sqrt{2}} \\
G_{i,j,4} & = \frac{Z_{i,j+1} - Z_{i,j}}{5} \\
G_{i,j,5} & = \frac{Z_{i+1,j+1} - Z_{i,j}}{5\sqrt{2}} \\
G_{i,j,6} & = \frac{Z_{i+1,j} - Z_{i,j}}{5} \\
G_{i,j,7} & = \frac{Z_{i,j+1} - Z_{i,j}}{5} \\
G_{i,j,8} & = \frac{Z_{i+1,j+1} - Z_{i,j}}{5\sqrt{2}} \\
\end{align*}
\]

Establish Slope list: when \( G_{i,j,k} \in \left[ -\frac{\pi}{6}, \frac{\pi}{6} \right] \), \( \text{Slope}(i,j,k) = 1 \), which represents passable between two grids; on the contrary, \( \text{Slope}(i,j,k) = 0 \), which represent impassable; as shown in Figure 2, grids with "X" are impassable.

![Figure 2. Slope Information in three-dimensional terrain](image)
2.2. Establishment of Roughness List

*Roughness* is defined as the ratio of actual travel speed and normal travel speed of vehicle after being influenced by surface properties such as subgrade, soil texture, vegetation and water system, so there is $0 \leq \text{Roughness}(i, j) \leq 1$. The paper approximately transforms the influence of the surface property on vehicle travel into the increase in traveling distance, namely, the smaller the roughness is and the more difficult the vehicle travel is, the longer the traveling distance of vehicle is.

Establish *Roughness* list and assumed that the hard pavement roughness is $\text{Roughness}(i, j) \leq 1$. For soil pavement, grassland, sandy land, forest, swamps and so on, the roughness declines in turn until 0. Reference to experimental data of wheeled and tracked vehicles and expert experience, we can know that the traffic ability of tracked vehicles is better than that of wheeled vehicles. As a result, the roughness of the wheeled and tracked vehicles is set respectively as 6 grades as follows, as shown in Table 1.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Surface property</th>
<th>Roughness (wheeled vehicle)</th>
<th>Roughness (tracked vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hard pavement</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Soil pavement</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>Grassland</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>Sandy land</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>Forest</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>Swamp/lake</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Aiming at the surface properties of influencing route planning, in order to realize one-to-one mapping of terrain grid and roughness, take its projection on the grid and use the “preponderant area method” to screen out and mark grids with all levels of surface properties, and rasterization of surface properties is as shown in Figure 3.

2.3. Establishment of Tabu List

*Tabu* list is a tabu list for passage of marked grid relative to adjacent grids. When the grid unit $(i, j)$ meets $\text{Slope}(i, j, k) = 0$, $1 \leq k \leq 8$, or $\text{Roughness}(i, j) = 0$, assume that $\text{Tabu}(i, j) = 0$, which represents impassable; on the contrary, assume that $\text{Tabu}(i, j) = 1$. The superposition of *Slope* list and *Roughness* list is as shown in Figure 4.
3. Algorithm Construction

3.1. Design of Evaluation Function

Assume that the vehicle can only move through a grid every time, adjacent grid moving is independent of time and the vehicle can not repeatedly travel through the grid that is already passed.

Evaluation function of genetic algorithm improved by the definition is

\[ f(i, j) = g(i, j) + h(i, j) \]

and meets

\[
\text{Tabu}(i, j) = \begin{cases} 
1 & \text{if grid } (i', j') \text{ is passable unit adjacent to } (i, j), \\
g(i, j) = g(i', j') + \frac{\Delta D}{\text{pass}(i, j)} & \text{otherwise,}
\end{cases}
\]

Where, grid \((i', j')\) is passable unit adjacent to \((i, j)\), \(g(i', j')\) is the actual distance from initial point to grid \((i', j')\), \(\Delta D\) is the actual distance from grid \((i', j')\) to \((i, j)\), \(\text{pass}(i, j)\) is the roughness of grid \((i, j)\) and \(h(i, j)\) is European heuristic distance from \((i, j)\) to end point.

3.2. Establishment of Expand List

Establish Expand list for real-time inspection of adjacent traffic ability of current grid. Data structure of Expand list is defined as \(\{i, j, g, h, f\}\), respectively representing coordinate sequence of \(X, Y\) axis of the current grid center point and the actual value, heuristic value and estimated value of its corresponding evaluation function.

3.3. Establishment of Open List

Open list stores grids to be inspected and data structure is \(\{t, i, j, Parent_i, Parent_j, g, h, f\}\), of which \(t = 1/0\), when \(t = 1\), it represents that this point has not yet been chosen, subject to further inspection and judgment; when \(t = 0\), it represents that this point has been chosen, without further inspection and has entered the Closed list; \(Parent_i, Parent_j\) represents the parent grid coordinate sequence of \((i, j)\). For the current grid, the input process of Open list is shown in Figure 5.
If \((i, j)\) meets
\[
\begin{align*}
\text{Open}(m, 1) &= 1 \\
g(i, j) > g(i', j') + \frac{\Delta D}{\text{pass}(i, j)}
\end{align*}
\]
where \(m\) is line number of grid \((i, j)\) corresponding to Open list, \(\text{Open}(m, :)\) list of \((i, j)\) shall be updated as follows.

\[
\begin{align*}
\text{Open}(m, 2) &= i \\
\text{Open}(m, 3) &= j \\
\text{Open}(m, 4) &= i' \\
\text{Open}(m, 5) &= j' \\
\text{Open}(m, 6) &= g(i', j') + \frac{\Delta D}{\text{pass}(i, j)} \\
\text{Open}(m, 7) &= h(i, j) \\
\text{Open}(m, 8) &= \text{Open}(m, 6) + \text{Open}(m, 7)
\end{align*}
\]

3.4. Establishment of Closed List

Closed list stores all grids that are not needed to be inspected again and its data structure is defined as \([i, j]\). Initially, the grid of \(\text{Tabu}(i, j) = 0\) is added to Closed list, so that the impassable barrier grid can be precluded through the initial Closed list to reduce the search space and improve the search efficiency, and avoid repeated traversal through grids that are already passed.

3.5. Establishment of Path List

Path list represents the optimal path searched finally and its data structure is defined as \([i, j]\). With the data (i.e. coordinate sequence at the end point) in the last line of Closed list as the data Path\((1,:))\) of its first line, work out its Path\((2,:))\) in the second line by seeking for parent grid of Path\((1,:))\) in Open list, analogizing in turn until the initial point is searched out.
4. Results and Analysis

4.1. Steps of Algorithm

The specific steps of the algorithm are as follows:

1. Data pre-processing. Read the elevation data, determine the grid size and number of partition and establish Slope list, Roughness list and Tabu list.
2. Add initial point into Open list and add impassable grids in Tabu list into Closed list.
3. Judge whether the current grid is the end point; if it is, finish the search and output results.
4. Reference to Closed list, add passable grids of the current grid into Expand list and calculate the corresponding $g, h, f$ values.
5. Input and update of Open list reference to process of Figure 5.
6. Search for the smallest grid of $f$ value in Open list, if it is the end point, finish the search and output results; if not, the grid shall be set as the current value and calculate $g, h, f$ values in Open list, and at the same time, it shall be marked with having been selected and added into Closed list, returning to (3).
7. Form Path list through parent grid in the Open list, finish the search and output results.

4.2. Experimental Comparison and Analysis

The improved genetic algorithm of this paper adopts Matlab 2007b to realize simulation and the spatial scope of terrain is 200 $m \times 200 \times 200$, which is divided into 40x40 grids after pre-processing; $X, Y$ serial number of the initial grid is (14,28) and the end point is (26,20). Figure 6 shows the route planning of wheeled vehicle based on genetic algorithm; (1) is the unconstrained planning; (2) is the planning in consideration of slope and roughness.

![Route planning effect picture of wheeled vehicle based on genetic algorithm](image)

(1) Unconstrained planning, distance: 91.50238, time: 0.04688  
(2) Planning in consideration of slope and roughness, distance: 353.6155, time: 0.7813

Figure 6. Route planning effect picture of wheeled vehicle based on genetic algorithm

The specific experimental data are shown in Table 2, from which we can know that a tourism scenic route adapting to actual topography and landforms can be planned properly by the improved genetic algorithm under the circumstances where increase in computing time is little.
### Table 2. Comparison of experiment value under different constraint conditions

<table>
<thead>
<tr>
<th>Type of constraint</th>
<th>Wheeled vehicle</th>
<th>Tracked vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Route value/m</td>
<td>Time/s</td>
</tr>
<tr>
<td>Non-restraint</td>
<td>91.5024</td>
<td>0.0469</td>
</tr>
<tr>
<td>Slope</td>
<td>197.6963</td>
<td>0.2031</td>
</tr>
<tr>
<td>Roughness</td>
<td>95.1909</td>
<td>0.6094</td>
</tr>
<tr>
<td>Slope + Roughness</td>
<td>353.6155</td>
<td>0.7813</td>
</tr>
</tbody>
</table>

Table 3 is experiment made by using Dijkstra and improved genetic algorithm in consideration of the constraint conditions of slope and roughness, and the results show that the improved genetic algorithm has shorter search time under the circumstances where the optimal route searched out is the same.

### Table 3. Comparison of experiment value of different algorithms

<table>
<thead>
<tr>
<th>Name of algorithm</th>
<th>Wheeled vehicle</th>
<th>Tracked vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Route value/m</td>
<td>Computing time/s</td>
</tr>
<tr>
<td>Dijkstra</td>
<td>353.6155</td>
<td>0.8438</td>
</tr>
<tr>
<td>Improved genetic</td>
<td>353.6155</td>
<td>0.7813</td>
</tr>
</tbody>
</table>

### 5. Conclusion

The paper researches the problem of tourism scenic route planning of vehicle by using the improved genetic algorithm, analyzes the influence of terrain slope and surface properties on route planning through introducing of slope list and roughness list, designs the route optimization algorithm in consideration of slope and roughness constraints. The simulation results show that this algorithm can quickly and effectively achieve tourism scenic route planning. The next step is to study out a relatively complete set of equipment for different roughness classification method and quantitative system specific to different equipment through analysis and comparison and further improve the evaluation function of genetic algorithm.

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