Research on Generating for Train Paths in Traffic Interruption Conditions on China Railway Network

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Abstract

When railway emergency lead to traffic interruption for some sections, it is indispensable for railway administration to take some urgent processing measures for transporting detained passengers and trains. This paper focuses on the method of generating train paths in traffic interruption conditions and proposed the idea that signal system compatibility is a considerable factor in the procedure of searching paths. On the basis of this idea, it was designed that the algorithm of generating train path in terms of adequate capacity strategy. The core of the algorithm is recursive dijkstra algorithm. Finally, we confirmed the practicability of algorithm through an example. The result showed that the proposed algorithm for generating train feasible paths provides references to the organization of railway traffic organization in traffic interruption conditions.

Keywords: railway transportation; signal system compatibility; recursive dijkstra algorithm; train feasible path; emergency

1. Main text

Railway system is usually disturbed by emergency which cause traffic interruption, such as natural disasters, equipment failure, driving accident and so on. At the moment, railway administration will take a variety of measures for adjustment to deal with the emergency. Detouring is a crucial adjustment measure, which can guarantee train to bypass the interruption section and run back to the original path in a relatively short time. The core and foundation

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are reselecting and generating the feasible paths set for the sake of finishing the task of arranging trains to detour. Therefore, it is practical significance for railway traffic organization in traffic interruption conditions to researching on detouring and selecting the paths set.

Most of related researches [1-6] is to minimize the mileage or time as the objective according to limited mileage or adequate capacity as a basic strategy and search paths by K-shortest algorithm. However, on account of characteristic that there are complicated railway track type, different devices and facility in China’s current railway network, a train path usually consists of sections which are different speed grading and signal mode. On the basis of the objective network condition, it is essential for analyzing the degree of compatibility which is between signal system and trains which are different speed grading and arranged to detour in the procedure of generating train paths in emergency for the purpose of providing supports of decision with train dispatching personnel who are responsible for adjusting transportation in traffic interruption conditions.

2. The Generating for train paths in emergency

2.1. The analysis of signal system compatibility for train paths in emergency

The train paths consist of a number of sections. It is dependent up on the sections which are characterized by highest level of CTCS that signal system compatibility for train path in emergency.

1. Its signal system can be compatible with different speed rating trains if the train path in emergency consist of sections whose level of CTCS are CTCS-0/1 and speed are less than 160km/h. On the basis of characteristic of downward compatibility for locomotive signal equipment, bullet train can run on the railway whose level of CTCS are CTCS-0/1 by switching signal mode because its’ locomotive signal equipment corresponds to signal system whose rating is CTCS-2/3.

2. The bullet train can run on it if the train path in emergency comprises the sections whose level of CTCS are CTCS-2/3. For general speed train, its’ locomotive signal equipment is not compliant with CTCS-2/3 signal system. For this reason, it has to be switched block system for the sake of running on the CTCS-2/3 railway section. For one thing, the operation of general speed train can be controlled by LKJ system whose functions are recording and monitoring statistics and running state of train when the CTCS-2/3 railway is equipped with ground signal. Its’ signal mode for operation is CTCS-0/1. The operation of general speed train has to be dependent on telephone block system when the CTCS-2/3 railway sections is not equipped with ground signal. So, if general speed train runs on the train paths which includes CTCS-2/3 railway sections, its’ operation will obstruct bullet train and increase the security risks as well as difficulty of circuitous operation in emergency.

In conclusion, all speed rating train can run on the path whose rating of CTCS is CTCS-0/1. General speed train is not allowed to run on the path which includes CTCS-2/3 railway section.

2.2. The proceed of generating train paths set in emergency

The core of generating paths is computing the K-shortest paths. According to the graph theory, every path in $G(V, E)$ is the shortest path for $G(V, E')$ which is the sub-graph of graph $G$. So, the algorithm for generating paths is designed in terms of recursive dijkstra algorithm which was proposed by CHAI Deng-feng and Zhang Deng-rong [7] and adequate capacity strategy.

According to the content of 2.1, it is necessary to distinguish the level of CTCS of path in the procedure of iteration in algorithm. Although the sum of capacity for paths set is able to meet the quality of trains which are organized to detour in emergency, it is impracticable for general speed trains to run on the circus path if the level of CTCS of all paths are CTCS-2/3. So, the adequate capacity strategy needs to be adjusted. There are two end conditions in the algorithm. In the first place, the sum of capacity for paths must meet all trains. In the second place,
the capacity also needs to run up to the quality of general speed trains which are included with all trains. The
algorithm will end if the capacities of paths set meet the two conditions at the same time. The following is procedure
of the algorithm for generating train paths set in emergency.

 Initialization of all parameters:  
 1. $N_1$ denotes the target value of capacity for meeting all trains.  
 2. $N_2$ denotes the target value of capacity for meeting general speed trains.  
 3. $k$ denotes the iterations and is equal to 1 by initialing.  
 4. $M$ denotes the array which is used as memorizing the sequence of sub-graphs and is equal to $G$ by initialing.  
 5. $D$ denotes the array which is used as memorizing the length of paths and is equal to zero vector by initialing.  
 6. $L$ denotes the array which is used as memorizing the paths and initialized as null.  
 7. $y$ is equal to 1 and denotes the number of sub-graph when the algorithm goes into next iteration.  
 8. $t$ is equal to $y-1$ and denotes the number of sub-graph when it is extracted from $M$ that the sub-graph which is able to generate the $k$th shortest path.  
 9. $SC_1$ denotes the sum of capacity of paths set and $SC_2$ denotes the capacity which meets the general speed train when the $k$th iteration ends.

 Calculating the shortest path by dijkstra algorithm for every sub-graph in $M$ and the length of the paths are sorted by ascending order when the $k$th iteration begins.

 Calculating the $C_{k1}$ which denotes capacity value of $k$th shortest path, which is used as meeting all trains. It is equal to the least value of sections whose capacity is the minimum value among whole sections which constitutes the path.

 Calculating the $C_{k2}$ which denotes capacity value of $k$th shortest path, which is used as meeting general speed trains. Distinguishing the level of CTCS for the $k$th shortest path: if it is equal to CTCS-0/1, $C_{k1} = C_{k2}$; else $C_{k2} = 0$.

 Calculating the $SC_1$: The following is method of calculation.
  a. If $C_{k1} \neq C_{(k-1)1}$, $SC_1 = SC_1 + C_{k1}$;
  b. If $C_{k1} = C_{(k-1)1}$, recognizing whether the same section decides the capacity of $k$th shortest path and $(k-1)$th shortest path. If true, $SC_1$ remains the value of $(k-1)^{th}$ iteration; If false, $SC_1 = SC_1 + C_{k1}$.

 Calculating the $SC_2$: The method is corresponding to $SC_1$.

 Distinguishing the end condition. If $SC_1 \geq N_1$ and $SC_2 \geq N_2$, the algorithm ends; else the program continues to step 8, $k = k + 1$.

 Extracting the sub-graph from $M$, which generated the $(k-1)$th shortest path. The number of the rest part $t$ is equal to $y-1$. It consists of $m$ sections. Construct a group of sub-graph by deleting every section respectively. The group can be expressed as $G_1, G_2,..., G_m$.

 Updating the $M$: It can be expressed as $M = G_1, G_2,..., G_{m+t}$ by adding $G_1, G_2,..., G_m$ to $M$.

 Checking whether the null graph or repeated non-null sub-graph are in $M$. If true, deleting them, return to step 2; If false, $y = m + t$, return to step 2.

 3. Example

 Geological disasters caused traffic interruption of the section from $v_3$ to $v_6$ and section from $v_6$ to $v_{10}$. At the moment, the railway administration takes the urgent and emergency measures to arrange affected train to detour the blocked section. Section $v_3 - v_6$ and $v_6 - v_{10}$ belong to 300-350km/h high-speed railway, and the rating of CTCS is CTCS-3. The section from $v_8$ to $v_{10}$ belong to 200-250km/h high-speed railway, and the rating of the line CTCS is CTCS-2. Other sections’ speeds are less than 160km/h and rating of CTCS is CTCS-0. (Note: the railway network and section data are selected from the 4th reference; Table 1 shows the mileage and capacity of section in network)
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<table>
<thead>
<tr>
<th>Section</th>
<th>Mileage(km)</th>
<th>Capacity</th>
<th>Section</th>
<th>Mileage(km)</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_1 - v_3$</td>
<td>30</td>
<td>12</td>
<td>$v_2 - v_3$</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>$v_2 - v_3$</td>
<td>95</td>
<td>10</td>
<td>$v_3 - v_4$</td>
<td>80</td>
<td>6</td>
</tr>
<tr>
<td>$v_3 - v_4$</td>
<td>50</td>
<td>0</td>
<td>$v_4 - v_5$</td>
<td>80</td>
<td>3</td>
</tr>
<tr>
<td>$v_4 - v_7$</td>
<td>60</td>
<td>4</td>
<td>$v_8 - v_{10}$</td>
<td>95</td>
<td>6</td>
</tr>
<tr>
<td>$v_5 - v_6$</td>
<td>45</td>
<td>4</td>
<td>$v_9 - v_{10}$</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>$v_6 - v_{10}$</td>
<td>100</td>
<td>0</td>
<td>$v_7 - v_{10}$</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>$v_7 - v_8$</td>
<td>30</td>
<td>7</td>
<td>$v_9 - v_{10}$</td>
<td>60</td>
<td>11</td>
</tr>
<tr>
<td>$v_8 - v_{11}$</td>
<td>75</td>
<td>6</td>
<td>$v_9 - v_{10}$</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>$v_9 - v_{11}$</td>
<td>35</td>
<td>13</td>
<td>$v_{11} - v_{12}$</td>
<td>140</td>
<td>8</td>
</tr>
<tr>
<td>$v_{11} - v_{12}$</td>
<td>30</td>
<td>12</td>
<td>$v_2 - v_3$</td>
<td>20</td>
<td>9</td>
</tr>
</tbody>
</table>

The information of trains is as follows.

- **EMU:** G301 G305 G109 D3;
- **Express Train:** T5;
- **Fast Train:** K31 K37;
- **Pukuai Train:** 1203, 1311, 1101.

Ductility coefficient is set as 1.5. Therefore, the capacity $N_1$ is equal to 15, which is used as meeting the quality of all trains. The capacity $N_2$ is equal to 7, which is used as meeting the quality of general speed trains. According to the algorithm program which was given in the 2.2, the paths set is as shown in table 2. $SC_1 = 19$  $SC_2 = 10$. 
Table 2. the set of feasible paths

<table>
<thead>
<tr>
<th>Number</th>
<th>Path</th>
<th>mileage</th>
<th>CTCS</th>
<th>Capacity (SC1)</th>
<th>Capacity(SC2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$v_3 - v_2 - v_8 - v_{10}$</td>
<td>175</td>
<td>CTCS-2</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>$v_3 - v_4 - v_7 - v_{10}$</td>
<td>180</td>
<td>CTCS-0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>$v_3 - v_2 - v_8 - v_9 - v_{10}$</td>
<td>205</td>
<td>CTCS-0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>$v_3 - v_4 - v_5 - v_{10}$</td>
<td>255</td>
<td>CTCS-0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

The CTCS of first path is CTCS-2, so its’ signal system cannot be compliant with locomotive equipment for general speed train. The rest paths of set are able to meet demand of detouring for all trains because their rating of signal system is CTCS-0.

4. Conclusion

Detouring is the significant adjustment measure for transportation in emergency and its’ foundation is generating feasible train paths. This paper analyzed signal system compatibility of paths and designed the algorithm of generating train path in terms of adequate capacity strategy. Its’ core is recursive dijkstra algorithm. Finally, we analyzed an example and confirmed the practicability of algorithm. On the basis of generating paths set, we can continue to research on the selection and distribution for the sake of make it more comprehensive that the space adjustment which is involved in train paths in emergency.

References