Research on the optimal strategy of desert crossing game under known weather conditions

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Abstract. The "Crossing the Desert" mini-game needs to consider a variety of mutually restrictive factors. Players must coordinate funding and path issues to find the optimal strategy to reach the end within the specified time. Based on the study of crossing the desert when the weather conditions are known, this paper establishes a topology model, and uses priority search and game theory to solve the player's optimal strategy for passing through the barriers. First, the entire map is digitized and represented by a general topological map; then, given the map and weather distribution, the highest profit of each path is calculated. Specific calculation details require further analysis to arrive at a more practical and efficient route planning plan. The model proposed in this paper only provides a more effective solution for this problem from the perspective of mathematical modeling.

1. Introduction

In the board game, there is such a small game: the player uses a map to purchase a certain amount of water and food (including food and other daily necessities) with the initial funds, starting from the starting point, and walking in the desert. There will be different weather on the way. You can also replenish funds or resources in mines and villages. The goal is to reach the end within the specified time and keep as many funds as possible. It is necessary to give the optimal strategy for players to cross the desert under normal circumstances when the weather conditions are known. This article will verify the model based on two specific questions.

(1) Assuming that there is only one player and the weather conditions are known in advance during the entire game period, try to give the player's optimal strategy under normal circumstances.

(2) Assuming that there is only one player, and the player only knows the weather conditions of the day, he can decide the action plan for the day based on this, and try to give the best strategy for the player under normal circumstances.

2. Model assumptions

(1) With day as the basic time unit, the start time of the game is the day 0, and the player is at the starting point. The player must reach the end on or before the deadline, and the player’s game ends after reaching the end.

(2) Two resources, water and food, are required to cross the desert, and their smallest unit of measurement is a box. The sum of the quality of water and food that the player has every day cannot exceed the upper limit of the load. If the end is not reached and the water or food is exhausted, the game is deemed to have failed.
(3) The daily weather is one of three conditions: "clear", "high temperature", and "sandstorm". The weather in all areas in the desert is the same.

(4) Every day the player can go from a certain area on the map to another area adjacent to it, or stay in place. You must stay in place on a sandstorm day.

(5) The amount of resources consumed by the player staying in place for a day is called the basic consumption\[1\], and the amount of resources consumed for a day of walking is times the basic consumption.

(6) On the 0th day, the player can use the initial funds to purchase water and food at the base price at the starting point. Players can stay at the starting point or return to the starting point, but cannot purchase resources at the starting point multiple times\[2\]. Players can return the remaining water and food after reaching the end, and the return price of each box is half of the base price.

(7) When the player stays in the mine, he can obtain funds through mining. The amount of funds obtained in a day of mining is called the basic income. If mining, the amount of resources consumed is times the basic consumption; if not, the amount of resources consumed is the basic consumption. Mining is not allowed on the day of arrival at the mine, and mining is also possible on sandstorm days.

(8) Players can purchase water and food at any time with the remaining initial funds or the funds obtained from mining when passing through or staying in the village. The price of each box is twice the base price.

(9) Regional terrain has no significant impact on the player's itinerary.

3. Establish Floyd algorithm model and Topology model

3.1. Floyd algorithm

Each area in the map is abstracted as a node, and the interconnections between the nodes are set as edges to form a network graph. According to the Floyd algorithm, the shortest path between any two points between the village, the starting point, the end point and the mine can be obtained.

From the example constraints, it can be seen that there are restrictions on the total price and weight of the resources that the player can carry at the starting point. Set the amount of water carried as \( x \) and the amount of food carried as \( y \). Based on this, the linear programming function and image can be obtained as follows:

\[
\begin{align*}
3x + 2y &\leq 1200 \\
5x + 10y &\leq 10000
\end{align*}
\]  

(1)

![Figure 1. Linear function graph under the limit of money and weight](image)

Suppose the time limit for going out of the desert is \( n \), the water consumption on the \( i \)th day in the journey is, and the food consumption is, then the total water consumption in the journey \( W \) is

\[
W = \sum_{i=1}^{n} w_i , \text{ The total food consumption } F \text{ is } F = \sum_{i=1}^{n} f_i .
\]

From the requirements and linear analysis, it is known that the purchase of materials at the starting point is the most cost-effective and the amount of materials purchased must be within the linear
programming interval. Assuming that the quantities of water and food purchased at the starting point are \( w_{\text{start}} \) and \( f_{\text{start}} \), then the capital \( Sp \) required to purchase materials is

\[
Sp = (5w_{\text{start}} + 10f_{\text{start}}) + [10(W - w_{\text{start}}) + 20(F - f_{\text{start}})].
\]

Suppose it needs to mine for \( d \) days in the route, the daily income is \( e \), and the initial fund is \( If \). Assuming that the resources are just used up when the player reaches the end point, the remaining amount \( Sp \) of the player upon reaching the end point is

\[
Sp = (5w_{\text{end}} + 10f_{\text{end}}) + [10(W - w_{\text{end}}) + 20(F_{\text{end}})],
\]

Then the required maximum remaining amount \( Sp_{\text{max}} \) is

\[
Sp_{\text{max}} = \max[(If + d * e) - Sp].
\]

Model building:

\[
\begin{align*}
3x + 2y & \leq 1200 \\
5x + 10y & \leq 10000 \\
W & = \sum_{i=1}^{n} w_i \\
F & = \sum_{i=1}^{n} f_i \\
Sp & = (5w_{\text{start}} + 10f_{\text{start}}) + [10(W - w_{\text{end}}) + 20(F - f_{\text{end}})]
\end{align*}
\]

3.2. Algorithm flow

Step 1: The map is abstracted, each area is abstracted as a node, and the relationship between the areas is given;

Step 2: Use Freud's algorithm to calculate the shortest path matrix of all nodes. Use Dijkstra’s algorithm to calculate all the shortest paths between the starting point, the ending point, the mine, and the village as part of the candidate route set from the starting point to the exit, and filter or add some candidate routes according to common sense of life and topic restrictions. combination;

Step 3: Calculate the remaining amount of each path according to the requirements of the model and select the solution with the highest \( Sp \) value as the optimal solution.

3.3. Topology model

Through the Python program, the map that has undergone data quantification processing is topological and the shortest path through the mine is obtained respectively[3], and the cost and income expectations are calculated respectively according to the known conditions.

4. Model solution

4.1. Model solution for problem 1

In response to question 1, the impact of terrain on this question is not considered for the time being, the map uses the Python networkx package to perform topological analysis on the map, and the location of each area of the specific map is abstracted as a point. It can be seen from the map that there are two strategies to choose from: one is to choose the shortest path and go straight to the end; the other is to go through the mine to maximize revenue. Therefore, the shortest path in the two modes can be screened out through the program, and the optimal solution can be obtained by performing partial analysis according to actual requirements and restrictions.

The network map simulation of the map through the Python's own networkx package can respectively obtain the shortest path without considering any factors and the shortest path when passing through the mine \([4]\). At the same time, the calculation of cost consumption shows that the
number of days is sufficient. If you want to maximize revenue, you need to go to the mine to dig as many mines as possible when resources and days allow.

Starting from the starting point with sufficient resources, if the shortest path through the mine to the end is within the time limit, try to mine in the mine as much as possible within the specified number of days to ensure maximum revenue [5], if the situation of the mine is not considered If the shortest path time exceeds the time limit, there will be no optimal solution, and the game will fail.

Starting from the starting point in consideration of the limitations of the resource itself, if the resources cannot enable the player to reach the mining point or the shortest path to the end directly, the game will fail, and there is no optimal solution; if the mining point can be reached and the resources can support mining And other actions (such as the consumption of materials required to exchange materials to and from the village, etc.) are required to increase the proportion of mining time as much as possible within the time limit.

Question one does not consider the shortest path of the mine as 1→25→26→27; when considering the mine, since the shortest return path must pass through the village and the path from the mine to the village is 2, it can be assumed that the player starts from the village before the deadline. The shortest path from the starting point to the mine 12 is 1→25→24→23→21→9→15→13→12; the shortest path from the village 15 to the end point 27 is 15→9→21→27. Since the two routes reach the end point within 30 days, the income gap between reaching the end point and mining is discussed separately.

| Date | Area | Remaining funds | Remaining water | Remaining food |
|------|------|----------------|----------------|---------------|
| 0    | 1    | 9410           | 42             | 38            |
| 1    | 25   | 9410           | 26             | 26            |
| 2    | 26   | 9410           | 10             | 14            |
| 3    | 7    | 9410           | 0              | 0             |

It can be seen from the conditions that if the supplies reach the end, if there is surplus, they will be recovered at the basic price. Therefore, if you want to retain the funds as much as possible, you need to buy supplies at the starting point or the village. Pay attention that the supplies should be used up when they reach the end. Supplies.

The strategy for maximizing revenue in Problem 1 is to start from the starting point and go through 25, 24, 23, 21, and 9 to reach village 15. After the village replenishes resources, go to the mine to dig until the 19th day. After 14 to the village 15 to replenish resources and reach the end.

It can be seen from Figure 2 that after sufficient materials are prepared at the starting point, the mine will be sent to the mine. During this period, a certain amount of consumption will be consumed every day. On the 9th and 22nd days, the village will fill up the materials required for subsequent mining and return trips. The materials just run out, maximizing resource utilization.
Figure 3. The amount of remaining funds

From Figure 3, it can be seen that the capital curve does not change due to the consumption of no funds but the consumption of materials from 1 to 7 days. On the 8th day, replenishment is carried out in the village, so the funds are reduced. On the 11th to 19th days, mining is carried out except for sandstorms. Return to the village one day, and return to the end point after purchasing materials that can be returned to the end point in the village.

In summary, the optimal path through the first problem is shown in Figure 4.

4.2. Model solution for problem 2

Problem two does not consider the shortest path of the mine 1→2→3→4→5→13→22→30→39→47→56→64. After calculating the problem two, the profit maximization strategy is to start from the starting point and follow 2, 3, 4, 5, 13, 22, 30, 39, 46, 55 to reach mine 55, arrive at the village on the 19th day for replenishment, arrive at the next mine on the 22nd day to continue mining, and return from the mine on the 29th day to the end.

After preparing sufficient materials at the starting point, proceed to the mine. During this period, there will be a certain amount of consumption every day. On the 10th and 19th days, the village will make up the materials needed for subsequent mining and return trips. When reaching the end, the materials will be consumed. Exhaust, maximize resource utilization.

In summary, the optimal path through the second problem is shown in Figure 5.

5. Summary

5.1. Model evaluation

Using this model, the shortest path problem can be quickly calculated. Compared with other algorithms, it has strong versatility in terms of solution performance, but the shortest path obtained
under different constraints has different benefits, and it needs to be judged. If the parameters are set incorrectly, the solution speed may be slow and the quality of the solution obtained may be poor. However, the slow convergence speed of this model is not conducive to finding better solutions; the amount of calculation will be greatly increased when facing more complicated maps, and the solution will take longer \(^6\).

5.2. Model improvement
When solving the optimal path, the selection and integration of local paths are not considered, which will affect the output of the optimal path to a certain extent. To improve the accuracy of the model, the coordination between the local optimum and the overall optimum should be considered.

In this model, in addition to using Freud and Dijkstra algorithm \(^7\) to jointly search for the optimal path, convolutional neural network and ant colony algorithm can also be used to determine the optimal path, and at the same time in terms of the optimal solution Other algorithms can also be used for calculation.

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