Wilderness path planning based on continuous road network environment

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INTRODUCTION

To improve the feasibility and safety of subject movement in wilderness environments, and address issues of discontinuous road networks and unconsidered subject size, a continuous road network-based path planning algorithm is proposed. The approach involves constructing a Model Continuous Environment with Subject Objective (MCESO) using a fusion expansion strategy, applying a Road Network Priority (RNP) strategy, and improving the classical A* algorithm to create the MCESO-RNP-A* algorithm. Simulation results demonstrate that this algorithm enables smoother path planning, reducing path generation time by about 30% compared to the MCE-A* algorithm, proving its feasibility and effectiveness.

Subject objective continuous environment modeling

To minimize storage, each pixel is represented in 1 bit, so the data values must lie in the range of [0, 255].

$$data(x,y)=m,(m=0,1,2,\dots,255)$$

Used to differentiate between areas that are accessible and those considered obstacles, based on slope or ground object classification.

$$\begin{aligned}&if\ \ data(x,y)=obstacle:\\&\quad data(x,y)=255\end{aligned}$$

Converts slope from degrees to radians for further processing, used to model terrain.

$$rad=\operatorname{int}(ang\times\frac{5\pi}{9}),(ang\le 90)$$

Marks areas with slope greater than max_slope as obstacles to prevent vehicle sideslip.

$$slope(x,y)=\begin{cases}rad(x,y) & rad(x,y)\le \max slope\\ 255 & rad(x,y)>\max slope\end{cases}$$

Processes digital orthophoto map (DOM) data to distinguish between obstacles and roads.

$$classify(x,y)=\begin{cases}1 & dom(x,y)=street\\ 255 & dom(x,y)=obstacle\end{cases}$$

Final decision logic combining slope and classification results to produce the continuous environment model.

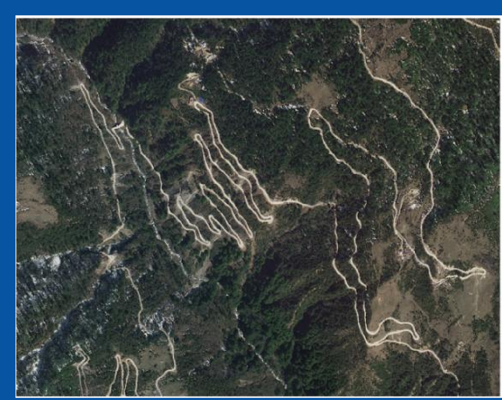
$$accessibility(x,y)=\begin{cases}1 & classify(x,y)=1\\ 255 & classify(x,y)=255\\ slope(x,y) & classify(x,y)=other\end{cases}$$

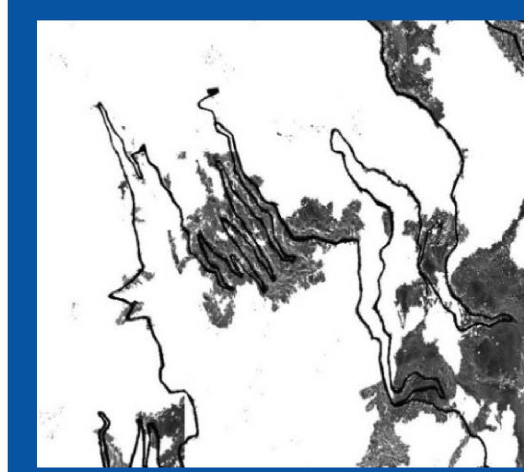
MCESO-RNP-A* path planning algorithm

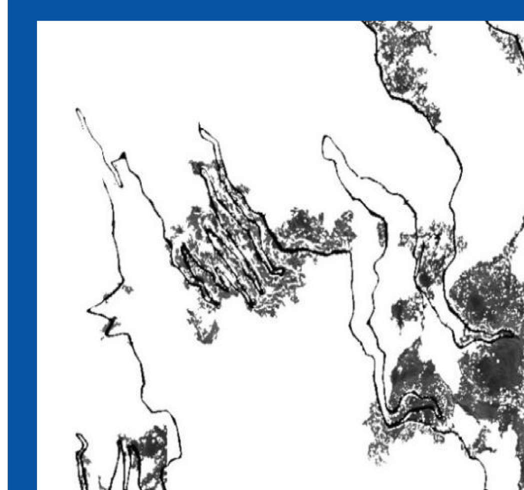
The MCESO-RNP-A* algorithm is an improved A* path planning method that incorporates a subject-oriented continuous environment model and road network information to prioritize road-based navigation. Unlike traditional binary grid modeling in A*, MCESO considers environmental continuity and vehicle size for more realistic planning, forming the MCESO-A* algorithm. To enhance efficiency, road skeleton extraction is applied, resulting in the final MCESO-RNP-A* algorithm.

Simulation experiment and analysis

The experiment utilizes a digital elevation model (DEM) and a digital orthophoto map from a real environment, as shown in Figure 2. These datasets are processed to generate a continuous environment model by fusing a slope map and a ground object classification map (Figure 3), where white indicates obstacles, black indicates roads, and gray represents slope gradients. An expansion kernel based on the vehicle size (4m × 7.5m) is used to account for vehicle dimensions, producing an expanded map (Figure 4). Comparison between Figures 3 and 4 shows that the original model overestimates passable areas due to ignoring vehicle size. Figures 4 and 5 reveal some small unconnected regions, which are removed through connectivity analysis using a threshold of 0.001 of the total area to ensure feasible path planning.







RESULT

Experimental results show that integrating the task entity into environment modeling significantly improves search efficiency. MCESO-A* reduces search time by 37% compared to MCE-A*, and MCESO-RNP-A* further reduces time by 30% due to road network guidance. Additionally, the bidirectional MCESO-RNP-

CONCLUSION

This paper focuses on a subject-objective path planning algorithm within a continuous road network environment. To enhance the use of environmental information beyond traditional binary modeling, a continuous environment model is developed. A subject-objective continuous environment model is further constructed by incorporating the size of the vehicle. Using skeleton