CS447

Potential Field Based Intelligent Vehicle Formation Control for Unstructured Roads

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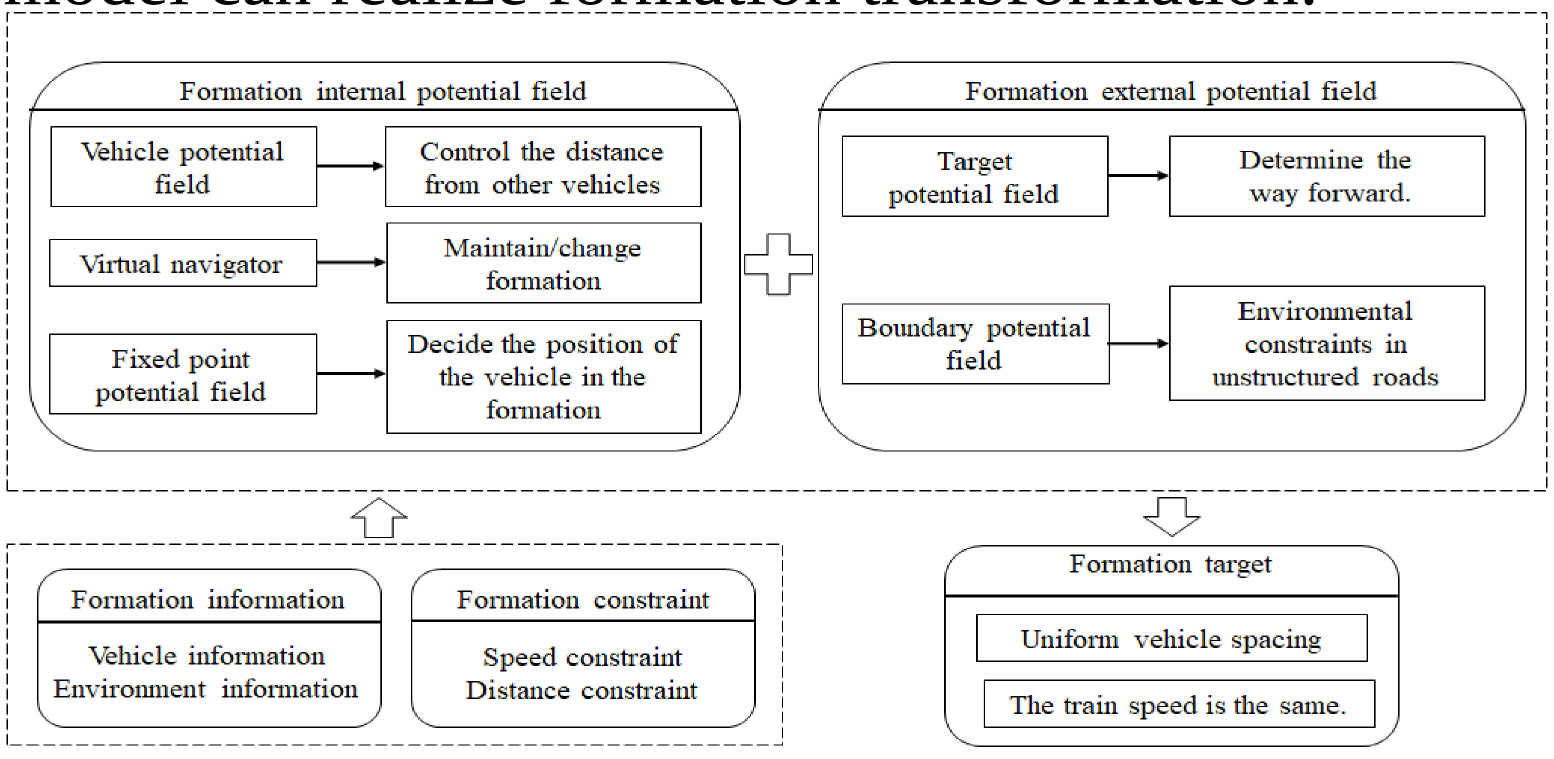
Introduction

This paper studies the formation control of intelligent vehicles on unstructured roads. Firstly, the formation planning framework is put forward. Secondly, by introducing fixed-point potential field, a formation model combining artificial potential field with virtual navigator is established. Based on elasticity theory and boundary potential field model, the R value of virtual navigator is improved. Finally, the simulation shows that the formation model can realize formation transformation.

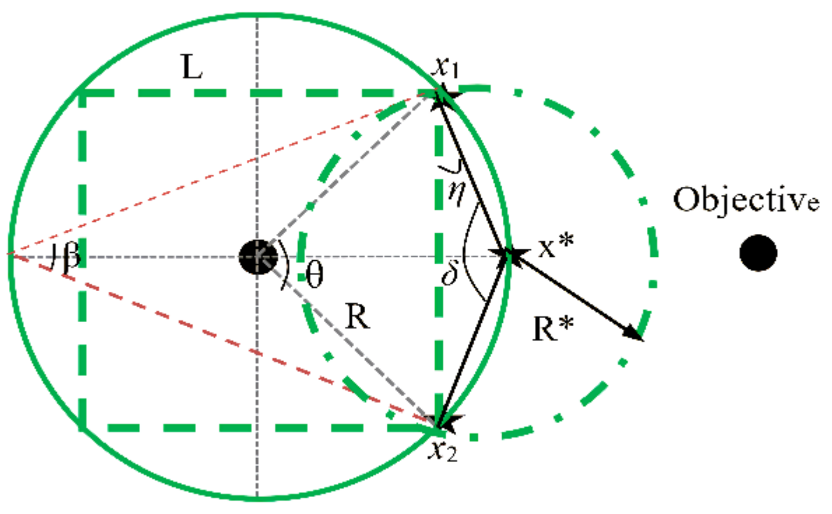


Research Method

1.Determination of the Direction and the Position of Vehicles in the Formation

1)The forward direction of the formation is equivalent to the running direction of the virtual leader.

$$F_{ot} = -\nabla(U_{ot}) = -\nabla(\tfrac{1}{2}k_{at}\,(q_g - q_v))$$



2)The fixed-point potential field is introduced to determine the position of vehicles in the formation.

$$N = \{x \mid \|x - x^*\| < R^*\}$$

$$f_{oi} = -\nabla U_{oi}(q_i)$$

$$U_{oi}(q_i) = \begin{cases} \frac{1}{2}k_{oi}(d_{oi} - L)^2 & if \;\; x_i \in N \\ K & else \end{cases}$$

2.Formation Transformation based on Elasticity Theory

1)Improvement of virtual navigator.

$$U_{vl} = \frac{1}{2}k_{vl}\,(d_{il} - R')^2 \qquad R' = F / K_v$$

2)Improvement of boundary potential field model.

$$U_r(L') = k_r \times \cos(L_f - L') / S_r \times \frac{\pi}{2}$$

$$F = -\nabla U_r(L')$$

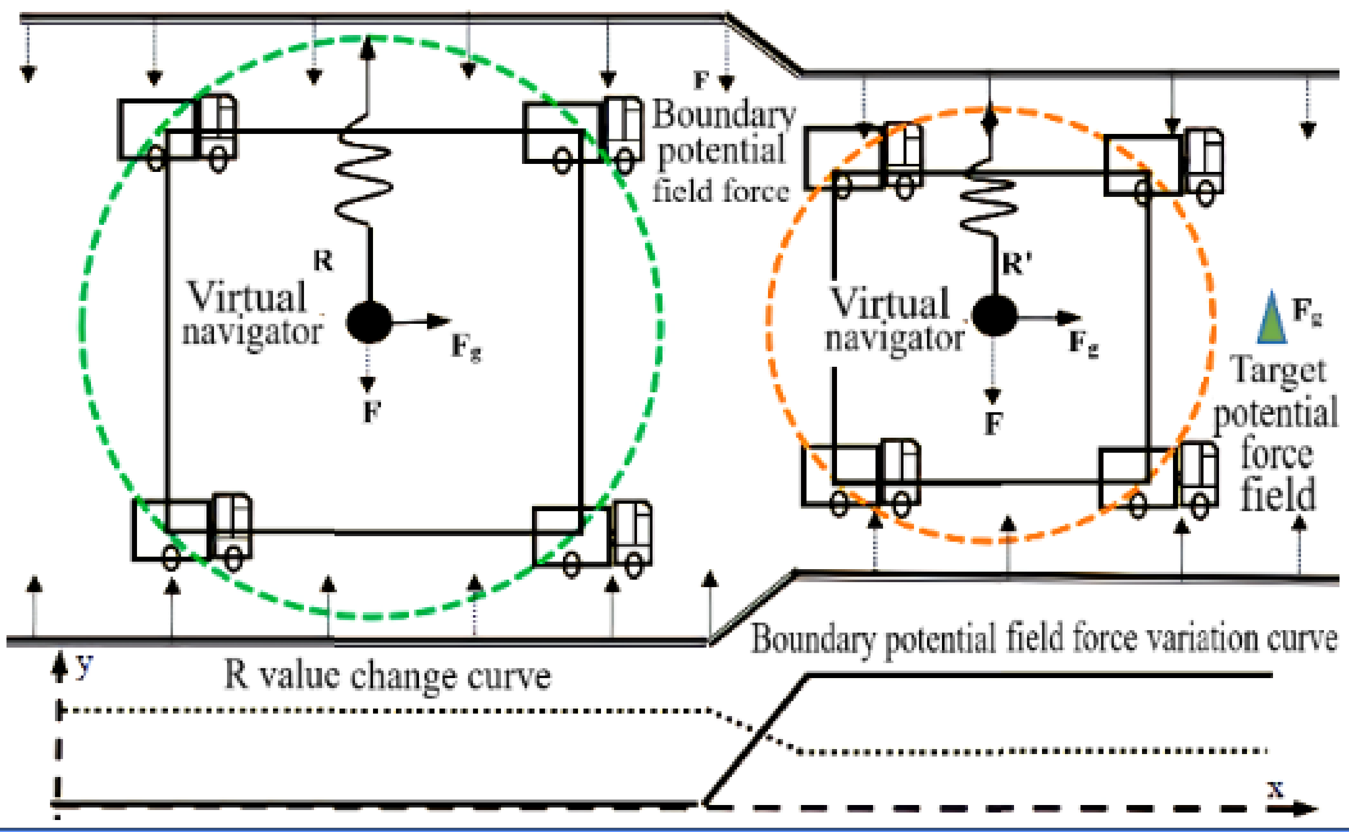
3)Formation Stability Analysis

$$F_{virtual} = \ddot{q}_i = f_{vl} + \sum_{i=1}^{4} f_{vv} + f_{oi} + f_r - b\dot{q}_i$$

$$V = \sum_{i=1}^{4}\left[U_{vl}(d_{il}) + \sum_{j=1,\, j\neq i}^{4} U_{vv}(d_{ij}) + U_{ot}(q_i) + U_r(q_i) + \frac{1}{2}\|\dot{q}_i\|^2\right]$$

$$\dot{V} = -\sum b\|\dot{q}\|^2$$

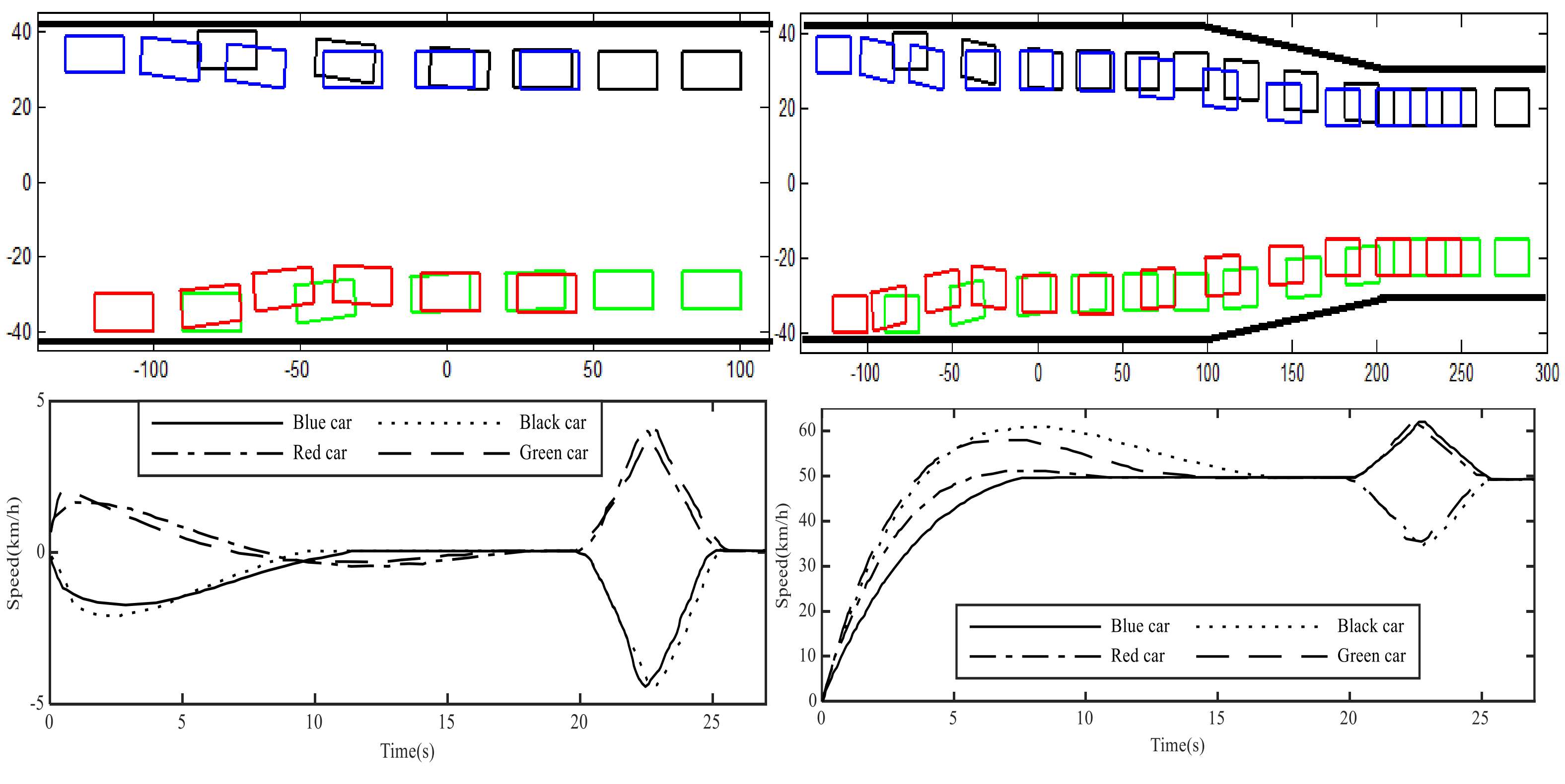
It can be seen from the equation that V is always non-positive.It will reach stability in dissipation-free form.



Results

The simulation results show that four smart cars with different colors form an ideal formation shape under the control of the formation model.

As the vehicle is limited by the maximum longitudinal as well as lateral acceleration of the vehicle, its velocity variation has some differences, but the variation trend is flat, which also meets the vehicle dynamics requirements.



Conclusion

1) By introducing the fixed-point potential field, the target potential field model is established to ensure the accuracy of formation driving.

2) Based on the application of formation transformation, an elastic virtual leader is proposed, and the "road" boundary potential field is established, which avoids the system instability caused by the virtual leader and improves the flexibility of formation. Taking four vehicle formation as an example, the effectiveness of the formation control model is verified by MATLAB.