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MULTI-STEP TRAJECTORY PREDICTION METHOD FOR MARS UAV BASED ON BIDIRECTIONAL GATED RECURRENT UNIT

Abstract

As Mars exploration advances and mission complexity increases, the collaborative operation of multiple Mars Unmanned Aerial Vehicles (UAVs) can significantly enhance the efficiency of Mars exploration and data acquisition. However, the harsh Martian environment poses substantial challenges to UAV flight technology. Atmospheric disturbances such as wind speeds and sandstorms may significantly affect UAV trajectory, leading to deviations from the planned path and increasing the risk of collisions. Therefore, accurate UAV trajectory prediction is essential for real-time flight path adjustments and collision avoidance. This paper proposes a multi-step trajectory prediction method for Mars UAV, leveraging historical flight data to forecast future trajectories. Existing multi-step trajectory prediction approaches for UAV predominantly rely on single-step prediction, where each predicted track point is sequentially appended to historical trajectory data. The model's input is then iteratively updated using a sliding window mechanism to extend the prediction horizon. However, conventional methods suffer from error accumulation, where prediction errors at each step propagate through subsequent iterations, leading to a rapid decline in precision over time. To address this challenge, this paper proposes a multi-step trajectory prediction approach for UAV based on Bidirectional Gated Recurrent Unit (Bi-GRU) network. By leveraging a multi-layer network model, the proposed method extracts essential features from the input sequence and directly predicts the full trajectory in a single forward pass, eliminating iterative updates and effectively mitigating error propagation. First, a UAV dynamics model is developed within simulation platform, incorporating Martian environmental parameters to generate reliable flight data. The UAV's position, attitude angles, and velocity are selected as key features to construct a comprehensive dataset. Subsequently, a three-layer neural network model is designed as the prediction framework for position, attitude, and velocity, respectively. Leveraging the bidirectional propagation mechanism of the Bi-GRU network, the model effectively captures temporal dependencies in both forward and reverse directions, enabling high-precision trajectory prediction. Next, historical trajectory parameters are utilized as input during model training to generate multi-step trajectory predictions. Finally, the prediction accuracy is evaluated using a validation dataset by comparing the predicted and actual trajectories. The results demonstrate that the proposed method outperforms conventional approaches, including CNN, LSTM, and GRU, by achieving the lowest prediction error at the same step length. This validates its effectiveness in meeting the requirements for high-precision multi-step trajectory prediction.