NeuPAN: Direct Point Robot Navigation with End-to-End Model-Based Learning (Abstract Reprint)

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Abstract

Navigating a nonholonomic robot in a cluttered, unknown environment requires accurate perception and precise motion control for real-time collision avoidance. This article presents neural proximal alternating-minimization network (NeuPAN): a real-time, highly accurate, map-free, easy-to-deploy, and environment-invariant robot motion planner. Leveraging a tightly coupled perception-to-control framework, NeuPAN has two key innovations compared to existing approaches: first, it directly maps raw point cloud data to a latent distance feature space for collision-free motion generation, avoiding error propagation from the perception to control pipeline; second, it is interpretable from an end-to-end model-based learning perspective. The crux of NeuPAN is solving an end-to-end mathematical model with numerous point-level constraints using a plug-and-play proximal alternating-minimization network, incorporating neurons in the loop. This allows NeuPAN to generate real-time, physically interpretable motions. It seamlessly integrates data and knowledge engines, and its network parameters can be fine-tuned via back propagation. We evaluate NeuPAN on a ground mobile robot, a wheel-legged robot, and an autonomous vehicle, in extensive simulated and real-world environments. Results demonstrate that NeuPAN outperforms existing baselines in terms of accuracy, efficiency, robustness, and generalization capabilities across various environments, including the cluttered sandbox, office, corridor, and parking lot. We show that NeuPAN works well in unknown and unstructured environments with arbitrarily shaped objects, transforming impassable paths into passable ones.

References

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