CODEI: Resource-Efficient Task-Driven Co-Design of Perception and Decision Making for Mobile Robots Applied to Autonomous Vehicles (Abstract Reprint)

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Abstract

This article discusses the integration challenges and strategies for designing mobile robots, by focusing on the task-driven, optimal selection of hardware and software to balance safety, efficiency, and minimal usage of resources such as costs, energy, computational requirements, and weight. We emphasize the interplay between perception and motion planning in decision-making by introducing the concept of occupancy queries to quantify the perception requirements for sampling-based motion planners. Sensor and algorithm performance are evaluated using false negative rate and false positive rate across various factors such as geometric relationships, object properties, sensor resolution, and environmental conditions. By integrating perception requirements with perception performance, an integer linear programming approach is proposed for efficient sensor and algorithm selection and placement. This forms the basis for a co-design optimization that includes the robot body, motion planner, perception pipeline, and computing unit. We refer to this framework for solving the co-design problem of mobile robots as CODEI, short for co-design of embodied intelligence. A case study on developing an autonomous vehicle for urban scenarios provides actionable information for designers, and shows that complex tasks escalate resource demands, with task performance affecting choices of the autonomy stack. The study demonstrates that resource prioritization influences sensor choice: cameras are preferred for cost-effective and lightweight designs, while lidar sensors are chosen for better energy and computational efficiency.

References

Milojevic, D.; Zardini, G.; Elser, M.; Censi, A.; and Frazzoli, E. 2025. CODEI: Resource-Efficient Task-Driven Co-Design of Perception and Decision Making for Mobile Robots Applied to Autonomous Vehicles. *IEEE Transactions on Robotics*, 41: 2727–2748.