先端科学技術研究科　修士論文要旨

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要旨

Robot navigation has developed from basic perception and obstacle avoidance toward more intelligent systems that can understand environments, reason about spatial relationships, follow human instructions, remember past information, and plan actions according to tasks. This survey reviews this development from the perspective of seven capabilities required for more human-like robot navigation: Environment Understanding, Spatial Reasoning, Instruction Understanding, Task Planning, Generalization, Environment Memory, and Efficiency.

First, the survey reviews how LiDAR, Vision, and Sensor Fusion provide richer environmental information, followed by the development of Semantic Maps and Scene Graphs for representing objects, spatial relations, and scene structure. It then discusses how Hierarchical and Dynamic Scene Graphs, Open-Vocabulary methods, VLMs, and LLMs further support spatial reasoning, language understanding, and task planning. The development of Environment Memory and Task-driven Information Selection is also reviewed to show how robots use historical information while reducing unnecessary memory and computation.

Throughout this development, combining different information and technologies improves robot capabilities but may also introduce trade-offs in Memory, Computation, Latency, Information Loss, and System Complexity. This survey therefore examines not only which capabilities are improved by each technological development, but also what limitations appear as a result. Based on these relationships, the survey discusses how robot navigation may develop from simply adding more capabilities toward coordinating them more effectively. Finally, Shared or Unified Intermediate Representation is discussed as a possible future direction for connecting perception, environment representation, memory, reasoning, and planning, with the goal of achieving a better balance among the capabilities required for human-like robot navigation.