An Autonomous Quadrotor Exploration Combining Frontier and Sampling for Environments with Narrow Entrances

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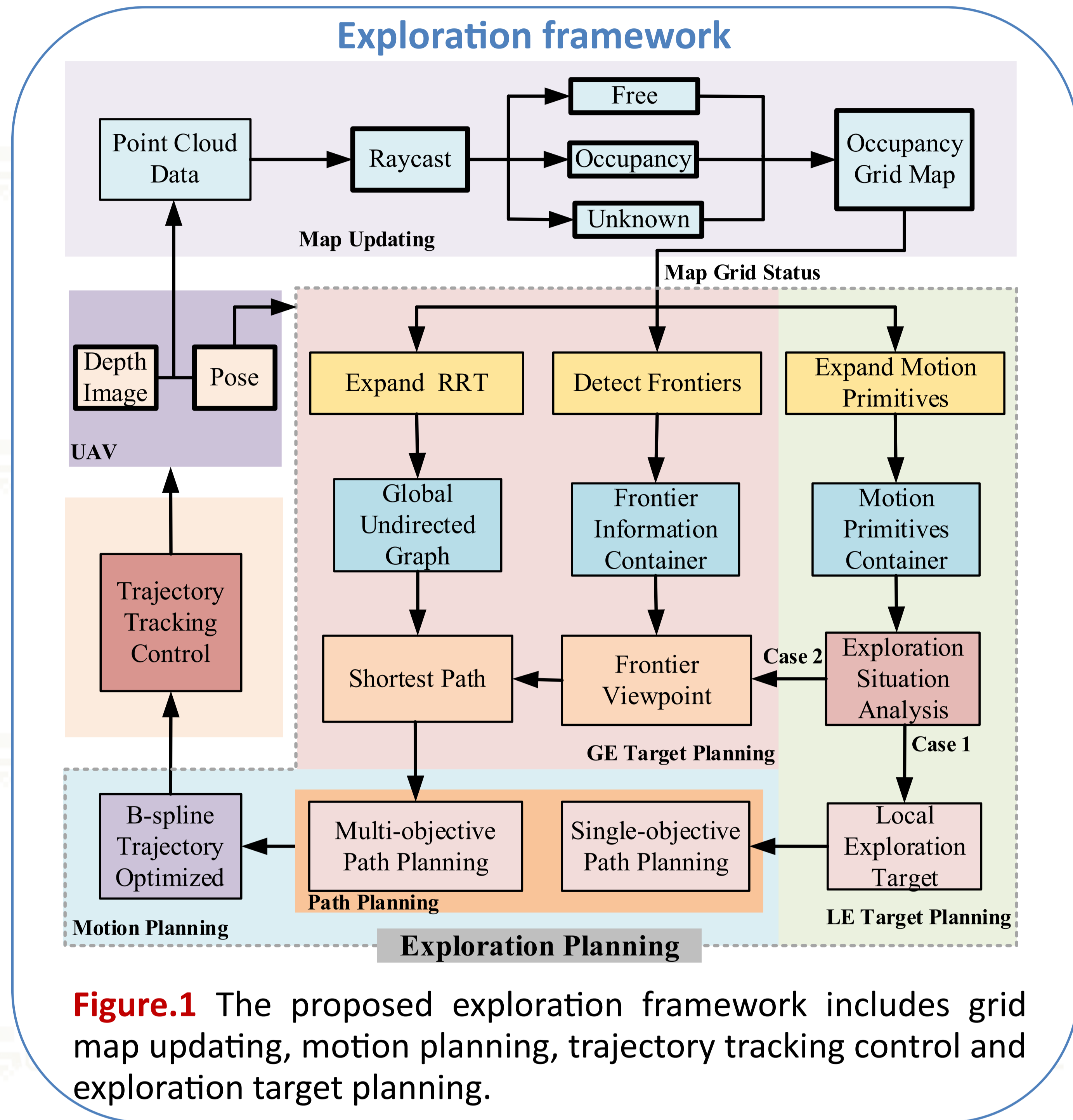1. College of Mechatronics and Control Engineering, Shenzhen University, Shenzhen 518060, China
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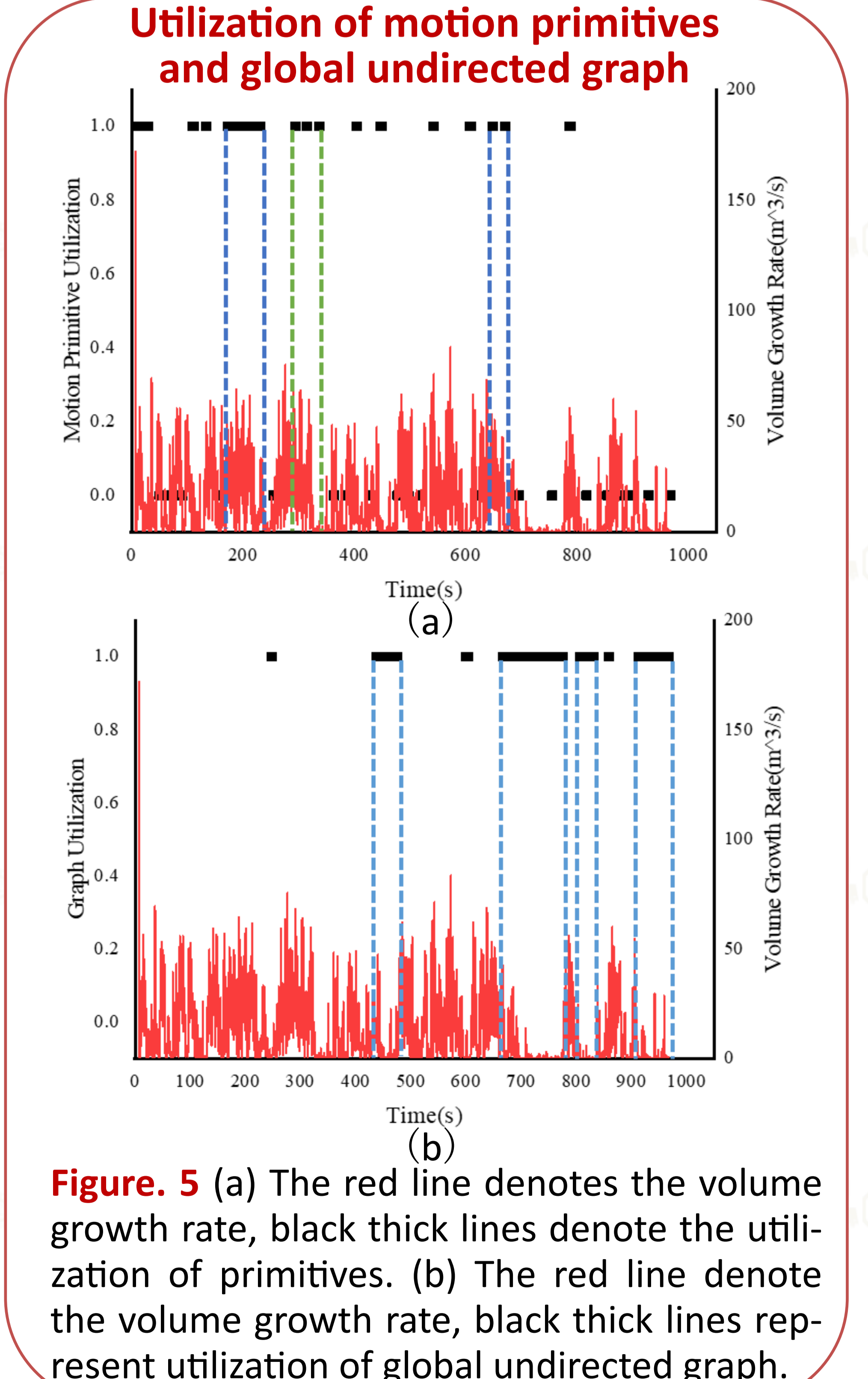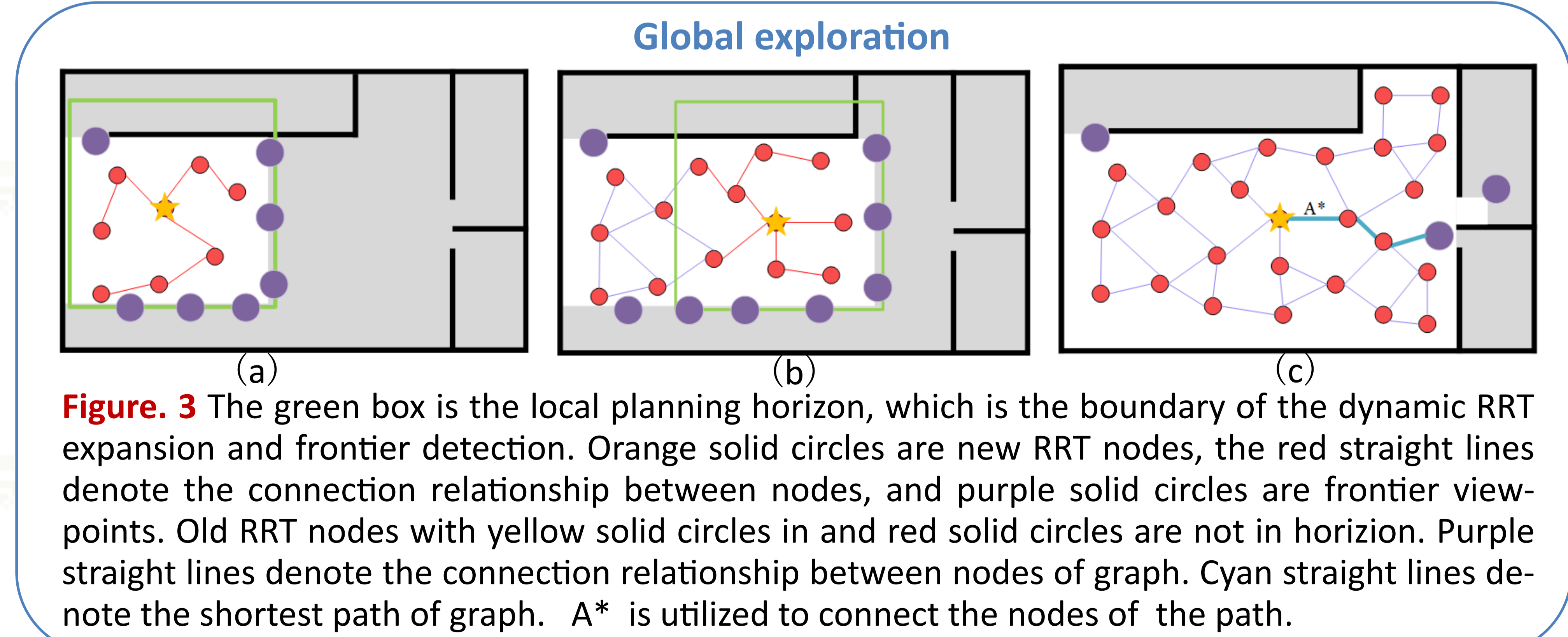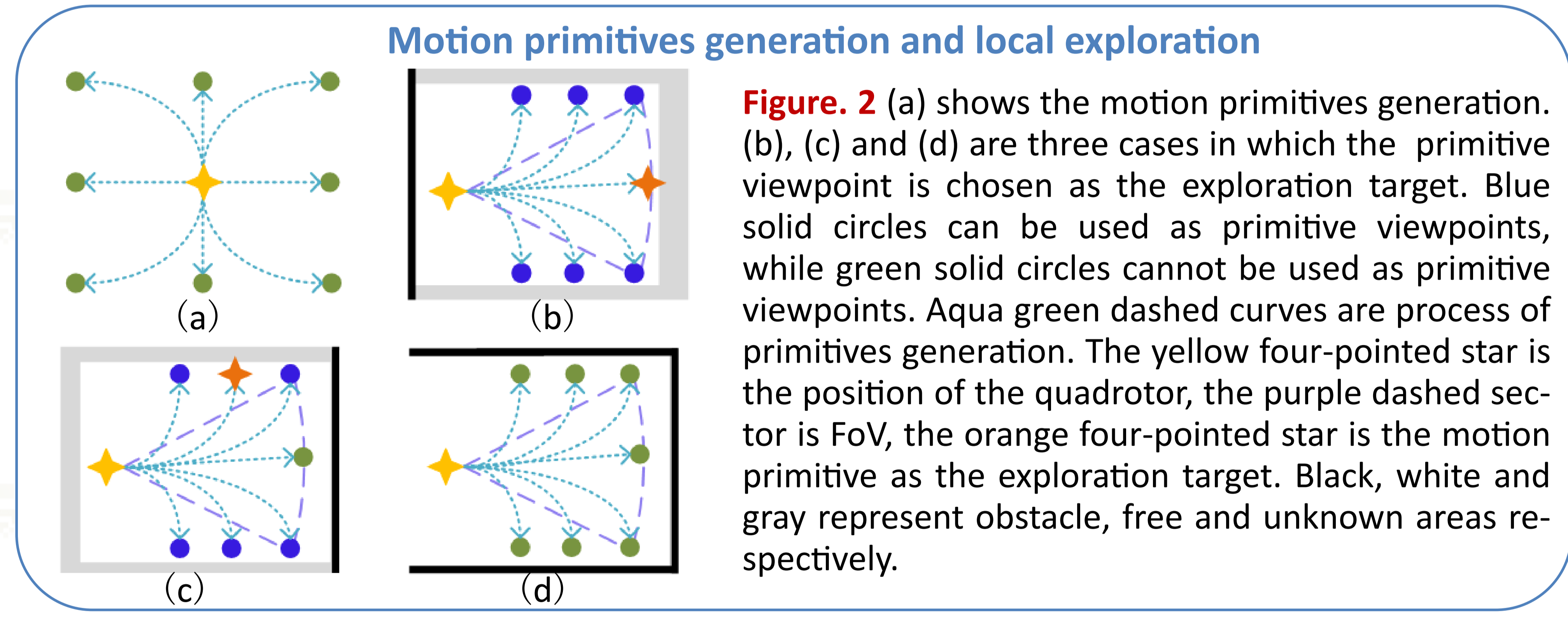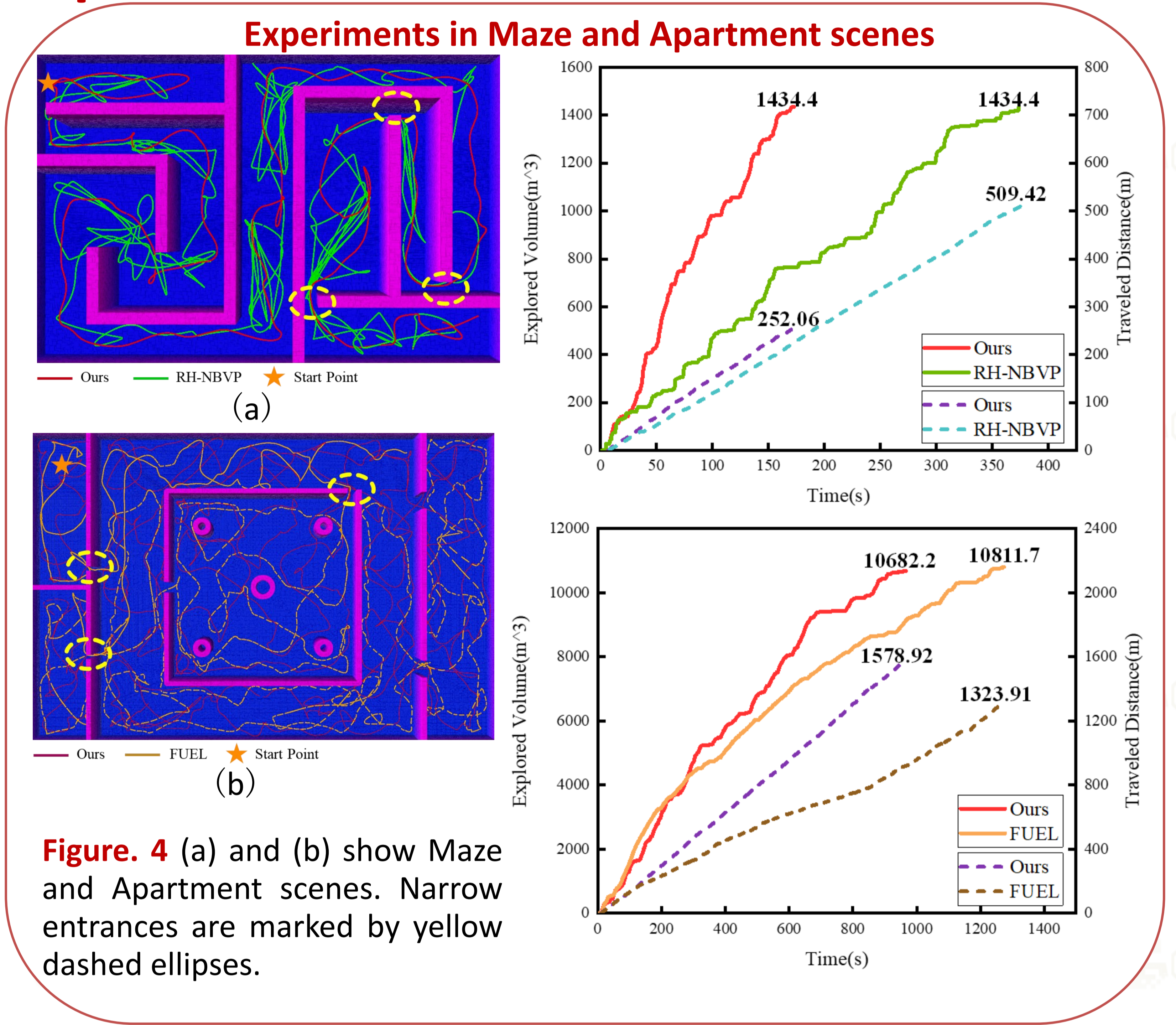
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Abstract:

This paper proposes an autonomous quadrotor exploration method based on frontier and motion primitives for exploring spatial structural environments with multiple narrow entrances. The local region exploration is implemented by expanding the motion primitives in the exploration target selection, while the global exploration is completed by searching frontier viewpoints.

Methods:

Exploration framework

Figure.1 The proposed exploration framework includes grid map updating, motion planning, trajectory tracking control and exploration target planning.

Motion primitives generation and local exploration

Figure. 2 (a) shows the motion primitives generation. (b), (c) and (d) are three cases in which the primitive viewpoint is chosen as the exploration target. Blue solid circles can be used as primitive viewpoints, while green solid circles cannot be used as primitive viewpoints. Aqua green dashed curves are process of primitives generation. The yellow four-pointed star is the position of the quadrotor, the purple dashed sector is FoV, the orange four-pointed star is the motion primitive as the exploration target. Black, white and gray represent obstacle, free and unknown areas respectively.

Global exploration

Figure. 3 The green box is the local planning horizon, which is the boundary of the dynamic RRT expansion and frontier detection. Orange solid circles are new RRT nodes, the red straight lines denote the connection relationship between nodes, and purple solid circles are frontier viewpoints. Old RRT nodes with yellow solid circles in and red solid circles are not in horizion. Purple straight lines denote the connection relationship between nodes of graph. Cyan straight lines denote the shortest path of graph. A* is utilized to connect the nodes of the path.

Experimental Results:

Experiments in Maze and Apartment scenes

Figure. 4 (a) and (b) show Maze and Apartment scenes. Narrow entrances are marked by yellow dashed ellipses.

Utilization of motion primitives and global undirected graph

Figure. 5 (a) The red line denotes the volume growth rate, black thick lines denote the utilization of primitives. (b) The red line denote the volume growth rate, black thick lines represent utilization of global undirected graph.

Conclusion:

We propose a frontier and sampling-based exploration planning framework for exploring unknown environments. The method includes local exploration target planning and global exploration target planning. Results of the simulation experiments demonstrate that the quadrotor effectively enters narrow entrances for full coverage exploration and improves the exploration efficiency.