RB5 Low-Cost Explorer: Implementing Autonomous Long-Term Exploration on Low-Cost Robotic Hardware

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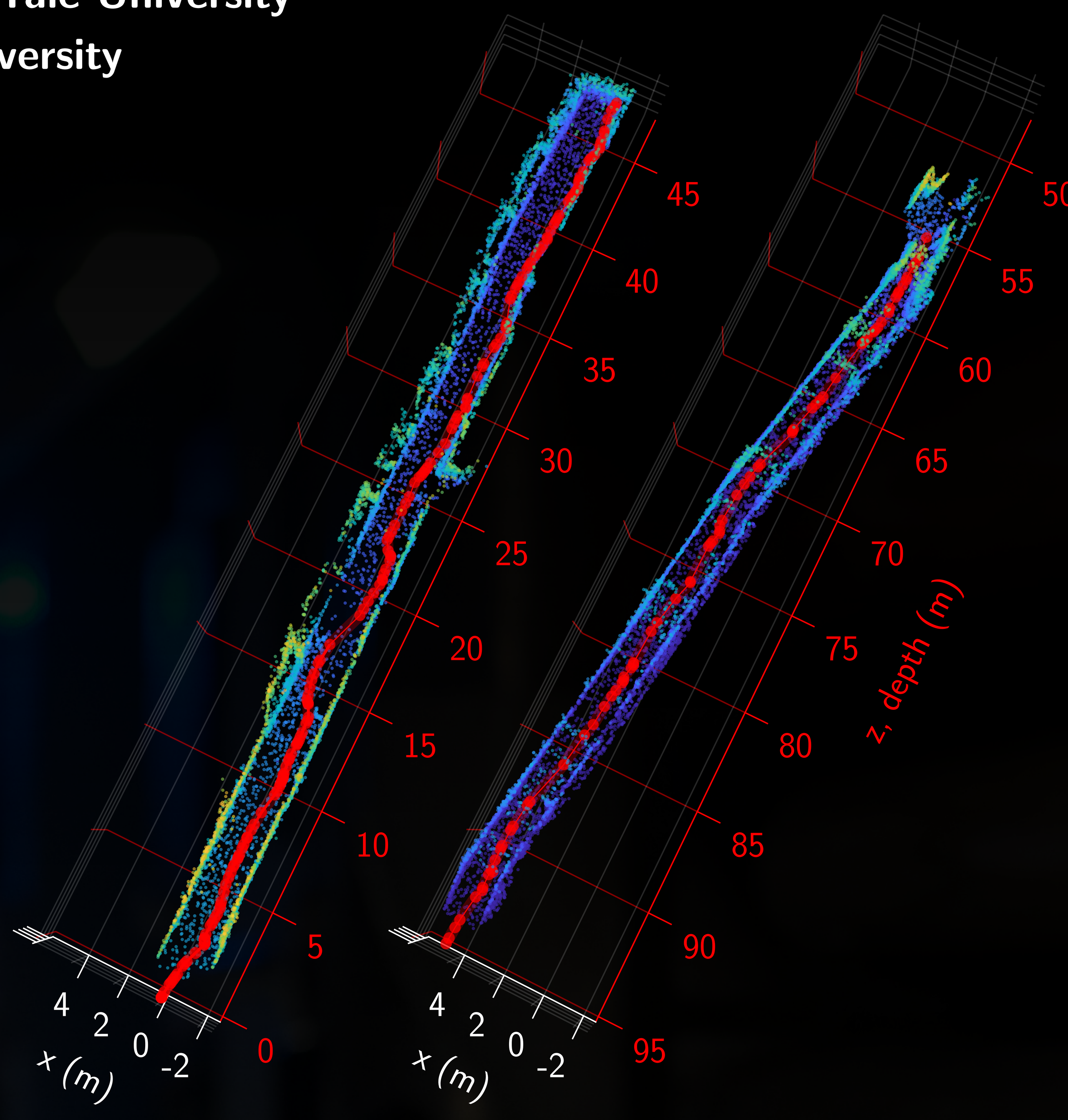
Context

Long-term robotic exploration is currently being restricted in part by the expense of the required sensing, computing, and mechanical hardware. This cost is related to the computational intensity of most common navigation and communication approaches [1, 2], which significantly increases for outdoor terrains.

Addressing this challenge, we design RB5, a low-cost wheeled robotic platform that operates in unknown and GPS-denied environments and on indoor and outdoor terrains, and introduce techniques to reduce update frequencies and enhance the communication capabilities of existing approaches.

By loosening the update frequencies and communication requirements, our methods enable the use of lower-performing and lower-cost hardware while still retaining good autonomous performance.



◀ **Results for a structured environment**. Experimental results are reported for a structured indoor environment, a university hallway composed of four connected corridors for a total length of approximately 80 meters. The view includes the point cloud filtered to report one point every 250. The robot's trajectory is in red and red dots indicate SLAM's registration points.

Systems: Low-cost design

RB5 is a wheeled robot for autonomous long-term exploration with fewer and cheaper sensors. The platform adopts a rocker-bogie suspension system [3] found on NASA's rovers including Sojourner and Curiosity. On either side of the robot, an upside-down V-shaped linkage called the rocker pivots about an axis on the robot frame. The rocker has a wheel at one end and a smaller V-shaped linkage on the other arm. The smaller linkage, called the bogie, can pivot about an axis on the rocker and has two wheels at its tips.

The frame consists of one-inch aluminum extrusions and acrylic sheets, and the rocker and bogie linkages are assembled from aluminum sheets and standoffs.

Systems: Autonomous exploration

Our software stack consists of a mixed approach that combines frontier- and sampling-based methods. Here, with frontiers, we indicate boundaries between known and unknown space [2, 4]. Our approach evaluates local frontiers at each step, samples the environment, and determines feasible candidate path functions ϕ.

The next ϕ is selected so that the frontier is largest. The collection of the candidate path functions forms the coverage. The approach then derives a path-following vector field that points to ϕ at any point and guides the robot utilizing the gradient descent algorithm. This allows the robot to, e.g., follow the coverage path for longer.

Results: Low-cost exploration

We conduct a set of field experiments involving our RB5 experimental robotic platform in a variety of environments, including indoor structured, unstructured underground, and outdoors.

References

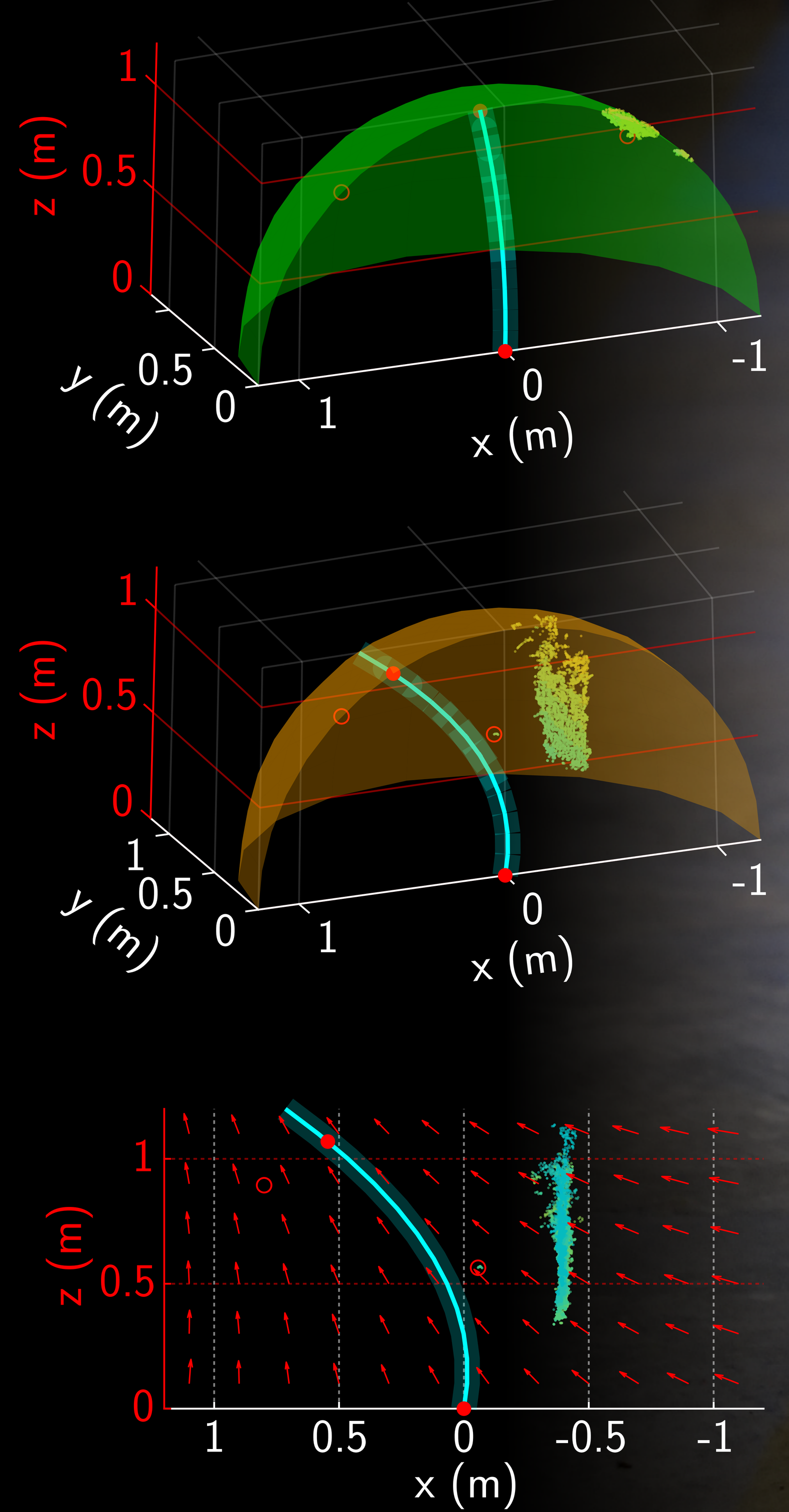
[1] I. Lluvia *et al.*, "Active mapping and robot exploration: A survey," *Sensors*, vol. 21, no. 7, p. 26, 2021.

[2] J. A. Placed *et al.*, "A survey on active simultaneous localization and mapping: State of the art and new frontiers," *IEEE Transactions on Robotics*, vol. 39, no. 3, pp. 1686–1705, 2023.

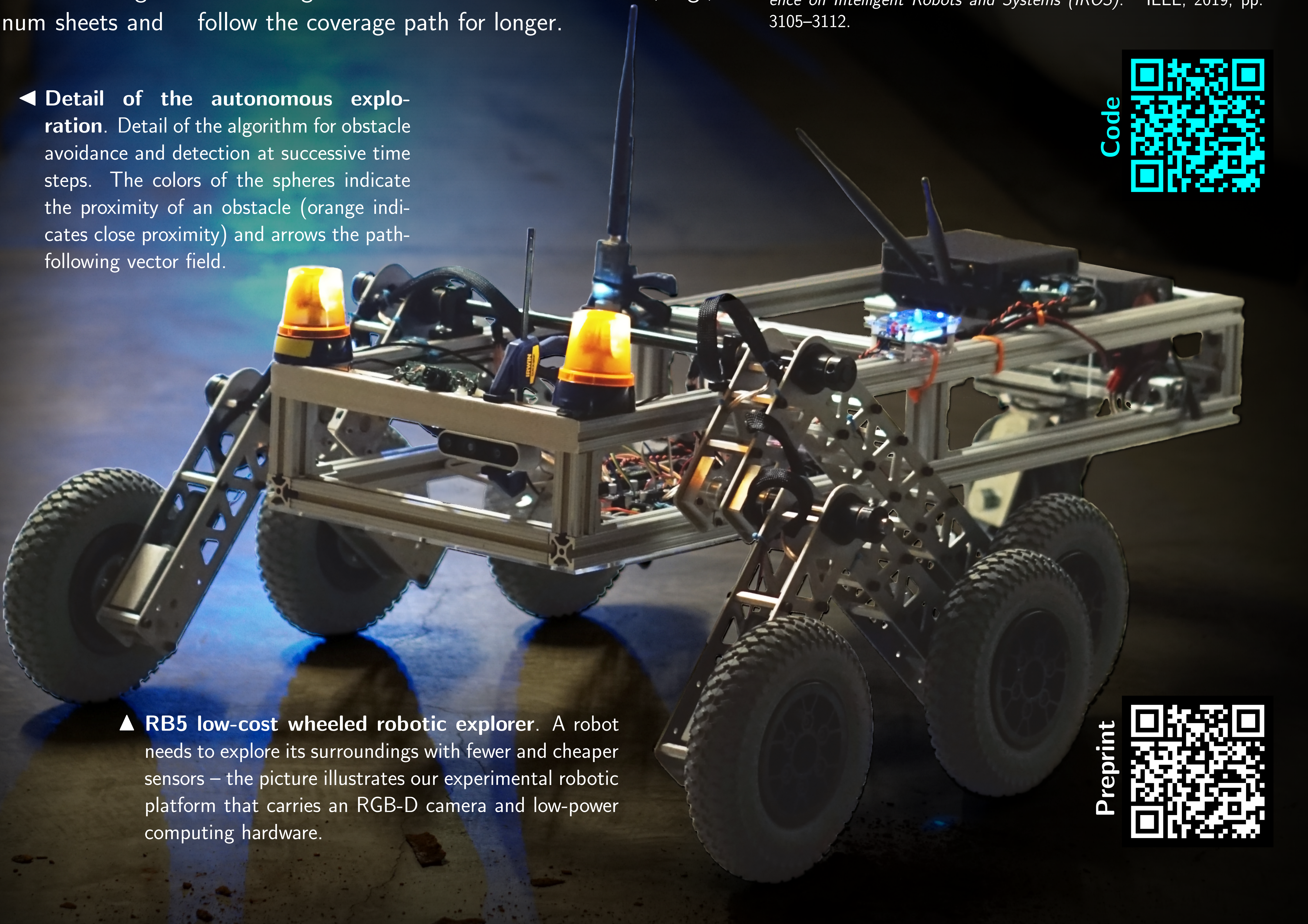
[3] D. B. Bickler, "Articulated suspension system," U.S. Patent 4 840 394, June 20, 1989.

[4] T. Dang *et al.*, "Graph-based path planning for autonomous robotic exploration in subterranean environments," in *International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2019, pp. 3105–3112.

Code



◀ **Detail of the autonomous exploration**. Detail of the algorithm for obstacle avoidance and detection at successive time steps. The colors of the spheres indicate the proximity of an obstacle (orange indicates close proximity) and arrows the path-following vector field.



▲ **RB5 low-cost wheeled robotic explorer**. A robot needs to explore its surroundings with fewer and cheaper sensors – the picture illustrates our experimental robotic platform that carries an RGB-D camera and low-power computing hardware.

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