Quadruped motion planning based on exteroceptive sensing

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Motivation

Automation in Robotics and AI can benefit many industries including: construction fields, oil and gas sites, national security and safety interventions (e.g. in damaged sites after a human-made/natural disaster), or agricultural fields, where efficient navigation is required. In these challenging, hazardous, or extreme environments, quadrupeds have the benefit of using sparse footholds to negotiate 3D terrain in a greater variety of unstructured surfaces compared to traditional robots. To materialise this advantage, quadrupeds need environment cognition and high-level planners that are fast and accurate

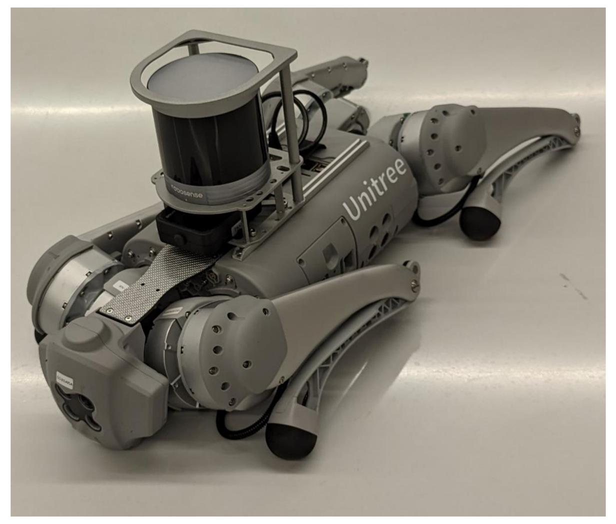

Figure 1. Quadruped robot with 3D LiDAR sensor

Aim

The main aim of the system is to enable safe and fast planning to traverse the aforementioned difficult terrains.

Animals and humans alike both make intelligent choices based on past experiences and the information around us gathered through our eyes. We use this information to avoid risky or challenging areas or to avoid obstacles. By adding a system like this to a quadrupedal robot, it allows it to mimic nature to safely explore.

To be effective, it must be fast and work in simulation and real-world quadrupeds. This allows us to test the system in these challenging environments without needing to transport the robots.

Methodology

Perception

3D scene segmentation is used to take 3D point cloud data and designate each point as belonging to a class. There are different methods for 3D segmentation that involve different sampling techniques and network designs. Many methods cannot perform in real time due to the large size of point clouds. RandLA-Net [2] speeds up training and inference by randomly sampling a point cloud. The method was investigated and identified that performance is not majorly impacted by sampling. The implemented system uses modified code and the authors pretrained models on SemanticKitti LiDAR dataset [3] to create the perception module.

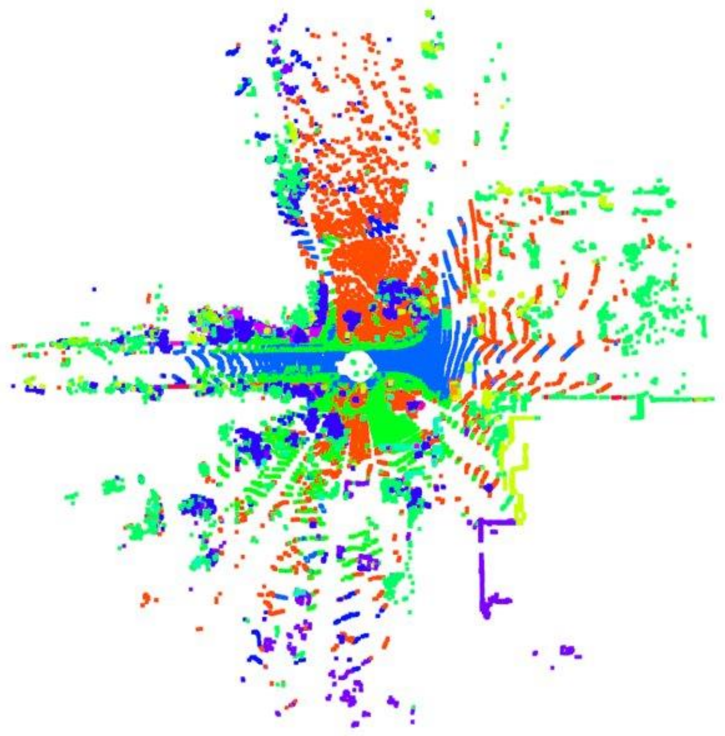

Figure 2. Pointcloud segmentation using RandLA-Net

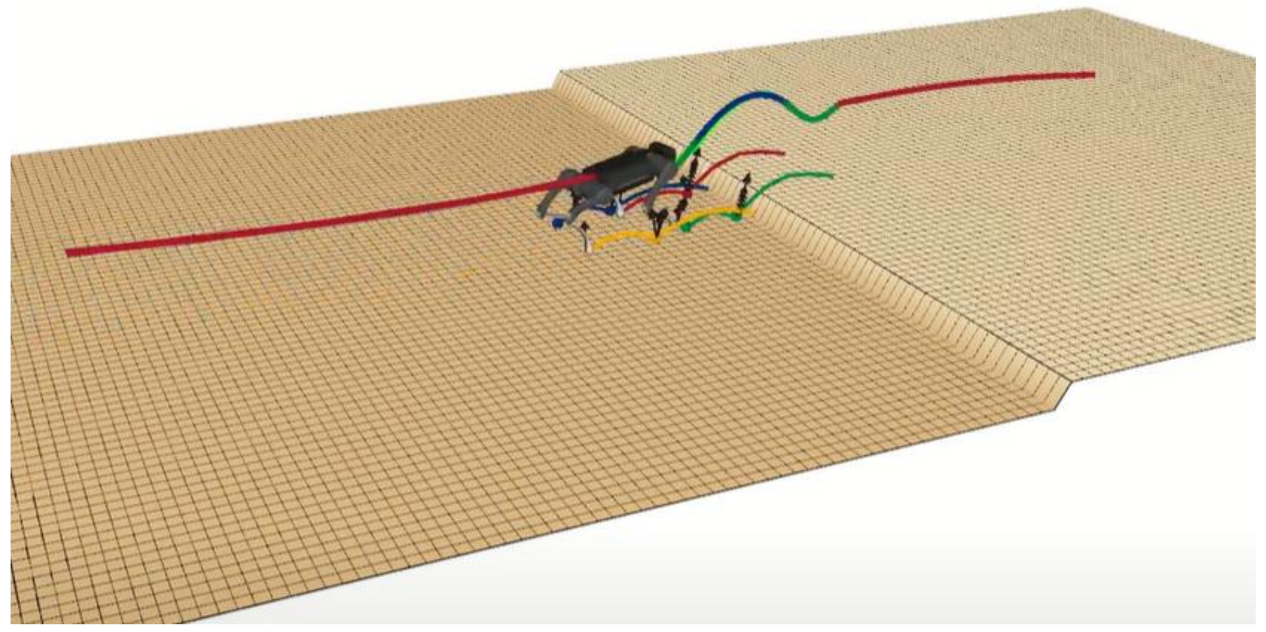

Figure 3. Quadruped robot planning using the QuadSDK framework

Planning

The grid map library presented in [4] is a mapping framework that creates multi-layered maps that can be used for planning. The grid map creates a height map from the point cloud with extra dimensions to incorporate information of the segmentation classes. The classes are hand-crafted to have certain costs to them based on the difficulty to walk on that type of terrain. Traditional cost values are then also calculated including steepness and surface normals. These costs are then combined and produce a risk-mapped grid of the scene which can then be used by the planning system.

The planning systems will find the optimal path to reach the goal, by considering the path cost based on the map as well as the dynamics of the robot. This is currently achieved by utilising the QuadSDK framework[5], where a global body plan is quickly generated by simplifying the dynamics of the quadruped robot to a point mass model [6], and the local body pose, and footstep are then generated based on an NMPC controller and a predetermined gait [5].

Results

Preliminary results demonstrate baseline impleme ntations of the perception and planning pipeline separately on a real quadrupedal robot. The system uses a 3D map that is created from real robot sensors (LiDAR) with the perception system on the robot.

Future Work

Future work will include combining the baseline perception and planning framework, allowing the planning to utilise the metrics generated by the perception pipeline.

This work could also be extended by learning the risk values for classes instead of hard coding the values based on human observations.

Creating/tailoring a dataset toward more appropriate environments would improve the quality of the perception module.

References

[1] J. Lee, J. Hwangbo, L. Wellhausen, V. Koltun, and M. Hutter, "Learning quadrupedal locomotion over challenging terrain," Science robotics, vol. 5, no. 47, p. eabc5986, 2020.

[2] Q. Hu, B. Yang, L. Xie, S. Rosa, Y. Guo, Z. Wang, N. Trigoni, and A. Markham, "Randla-net: Efficient semantic segmentation of large-scale point clouds," 2019.

[3] *Jens Behley, Martin Garbade, Andres Milioto, Jan Quenzel, Sven Behnke, Cyrill Stachniss, Jurgen Gall*; "SemanticKITTI: A Dataset for Semantic Scene Understanding of LiDAR Sequences" in Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV), 2019, pp. 9297-9307

[4] P. Fankhauser and M. Hutter, "A Universal Grid Map Library: Implementation and Use Case for Rough Terrain Navigation", in Robot Operating System (ROS) – The Complete Reference (Volume 1), A. Koubaa (Ed.), Springer, 2016

[5] J. Norby, Y. Yang, A. Tajbakhsh, J. Ren, J. K. Yim, A. Stutt, Q. Yu, N. Flowers, and A. M. Johnson, "Quad-SDK: Full stack software framework for agile quadrupedal locomotion," in ICRA Workshop on Legged Robots, May 2022.

[6] J. Norby and A. M. Johnson, "Fast global motion planning for dynamic legged robots," in 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 3829–3836, IEEE, 2020.