Real-Time Freespace Segmentation Using Deep Learning on Autonomous Robots for Detection of Negative Obstacles

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Detecting negative obstacles (ditches, potholes, ledges, downward stairs, and other dropoffs) is one of the most difficult problems in perception on autonomous robots. Although a significant amount of work has been done on the detection of standing obstacles (solid obstructions), almost no work has been done on the detection of negative obstacles. Detecting these negative obstacles using reliable, cost-effective sensors is crucial for the success of autonomous robots. It is essential to these robots' core functionality that they are able to navigate difficult terrain, requiring advanced perception capabilities. This research developed a method of terrain safety segmentation using deep convolutional neural networks. A custom semantic segmentation architecture was developed to use a single camera as input and creates a freespace map distinguishing safe terrain and obstacles. The network was trained using heavy data augmentation, enabling the network to generalize well, even when using very small hand-labeled datasets. The results showed that the system generalizes well, achieving around 94.9% mIOU accuracy on the validation dataset. The neural network is then deployed to an embedded GPU on an indoor robot. The network, because of its computationally-efficient design, is able to run at 55 fps and create a freespace map that can be used to create a costmap for navigation and obstacle avoidance. Testing with pathfinding algorithms proved the neural network's ability to reliably detect and navigate around both standing and negative obstacles in real-time, using only an RGB camera and the neural network developed in this research.

Awards Won:

Third Award of $1,000

Association for the Advancement of Artificial Intelligence: Third Award of $500

International Council on Systems Engineering - INCOSE: Certificate of Honorable Mention