Remote Surface Classification for Robotic Platforms

Will Roderick, Connor Anderson, Aaron Manheim

wrr@stanford.edu, connora@stanford.edu, manheima@stanford.edu

Motivation

As robots move from controlled lab environments into the outside world, situational awareness and adaptability in uncertain and varying conditions are becoming increasingly important. In many cases, robots must be able to detect, interact with, and navigate around physical surfaces. One such application is air to surface surface locomotion.

Data Collection

Using the aforementioned setup, we collected over 1000 images of 5 surfaces: foliage, tree bark, glass, building exterior, and building interior (representative figures below). These images are sorted for classification with both the flash and no-flash versions. Note the similarity between indoor and outdoor walls.

Models

1. Modified Bag of Words (Modified BoVW)

Raw images were fed to a BoVW classification algorithm implemented in Matlab, which then fed the images of the categories that were hardest to classify to an SVM for more accurate classification.

2. Convolutional Neural Network (CNN)

Raw images were used to train the last layer of the Inception V3 neural network. We had planned to feed in the image processing features in the last layer with the CNN image representation before the final layer, but the CNN was able to perform with high accuracy even without the sensor augmentation.

Given the raw RGB frames for the 5 classes of interest, the CNN was able to achieve 99.9% accuracy.

Discussion

Overall, image enhancement with additional sensor modalities improved the accuracy of the BoVW model. Specifically, reflectance properties improved classification on indoor and outdoor walls. On the other hand, the neural network was able to achieve ~99.9% accuracy with just the raw image frames. These results indicate that while the simple model may not be as accurate as a complex neural network, the simple model, which runs 6 times faster, is suitable for robotic surface classification. These results support that optimizing this model or a simpler neural network could enable real-time classification on small robotic processors.

Future work

Over the next weeks and months, we plan to use this system for robotic applications, including enabling aerial robots to detect viable landing locations. Specifically, we plan to optimize the simpler model for real-time classification on a small processor. Farther into the future, we will focus on adaptability in cluttered environments as well as including a wider range of surfaces and ambient conditions into the classification scheme.

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References