# Vision-Based Obstacle Detection and Avoidance for the CWRU Cutter Autonomous Lawnmower

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This paper describes a cost effective vision-based, single camera obstacle detection and avoidance system used by CWRU Cutter, an autonomous lawn mowing robot, for eventual consumer applications.

CWRU Cutter (pronounced “crew cutter”) is an autonomous lawnmower developed for the annual “Institute of Navigation (ION): Autonomous Lawnmower Competition.” The competition emulates a backyard environment where commercial autonomous mowers could operate. CWRU Cutter also acts as a test-bed for potential commercial sensing and navigation technologies that will be included in future consumer autonomous lawnmowers.

In the past, CWRU Cutter has successfully detected competition obstacles, including a fence, flowerbed, and a mobile obstacle (a stuffed dog mounted on an RC car) using LIDAR. However, LIDAR’s price makes its inclusion in consumer versions of the CWRU Cutter prohibitively expensive. A computer vision-based obstacle detection method is being developed as a cost-effective alternative in the competition environment.

Though significantly more cost-effective, computer vision systems have inherent problems with consistent identification of an object due to changing lighting conditions and shadows. This has kept vision-based obstacle identification methods from being widely adopted in other outdoor consumer products. Though lighting problems can be addressed by computationally intensive processing methods, the CWRU Cutter's onboard computer limits the complexity of algorithms that can be used, since the robot needs to capture and analyze incoming images in real time. Our target speed for algorithm operation is 10Hz or more while the mower is in operation.

CWRU Cutter captures and processes incoming images using a 1.83 GHz Mac Mini running Windows XP with 4GB memory. All algorithms are programmed using National Instruments LabVIEW 8.6 and utilize National Instruments IMAQ vision functions where possible.

This paper discusses the computationally efficient, robust obstacle identification methods used by the robot based on image hue and intensity. Unlike RGB color values, hue values at corresponding saturation values have been found to be insensitive to shadows and changing lighting conditions. Since all ION competition obstacles such as fencing are either black or white, they are heavily saturated making it possible to create a robust obstacle identification system that relies on hue values alone and yields few false positives during real-time operation.

The CWRU Cutter's "Polar Freespace Observer" monitors mow-able terrain in a polar coordinate space around it and reactively avoids obstacles in its path. On the robot, real world obstacle locations are abstracted and converted into polar range images for obstacle avoidance and edging. By transforming the incoming vision data to a range image in polar coordinates it is possible to use the vision data with the polar freespace observer directly. Abstracting incoming vision data to resemble polar range images is advantageous, because it allows for easy combination of information from multiple sensors. Real world obstacle locations are abstracted and converted into polar range images for obstacle avoidance and edging.

In the ION mower competition, cutting regions are defined by a series of white lines. Like the real-world where a user should not cut his neighbor's lawn, robots in the competition cannot cut outside the region boundaries. CWRU Cutter looks for and monitors white lines in the camera frames to keep the mower in-bounds during the competition. Whereas hue data is well suited for distinguishing between white lines and grass in shaded conditions, intensity data produces fewer-false positive pixels than hue under bright conditions. CWRU Cutter dynamically switches the color planes it uses to observe white lines during operation, uses the RANSAC method to fit an accurate line in real world coordinates, and calculates its displacement from the observed line in real-world coordinates so that the region boundary is not crossed.

To test our algorithms, CWRU Cutter was driven past competition obstacles and white lines via remote control in a competition-like environment. The results indicate that 89% of frames containing fence, 78% of frames containing flowerbeds, and 84% of frames containing white lines were correctly identified by the robot.

Future versions will combine hue and intensity with texture identification to create a more robust system capable of operating in an outdoor environment with continuously changing lighting conditions.