Visual Navigation in Autonomous Underwater Vehicles

Jacqueline Nelson, Marshall Tappen
University of Central Florida, Computer Vision REU

The Mission

The world of underwater robotics presents many challenges not considered in above-surface systems. Without tools such as GPS, nor costly options such as SONAR, the logical mode of navigation in an aqueous environment is vision. In this project, two cameras were implemented to accomplish six tasks for AUVSI and ONR's 12th International Autonomous Underwater Vehicle Competition.

Citronaut

- Citronaut is an Autonomous Underwater Vehicle (AUV) developed and designed by students in the Robotics Club at UCF.
- Although the bright orange hull has remained the same over the past few years, virtually all of the electronic components, the thrusters, and most of the wired connections have been upgraded and revamped this year.

- The AUV has two cameras — a forward camera and a floor camera.
- Vision processes in the AUV rely heavily on OpenCV libraries.
- The computer on the AUV runs Ubuntu, and is programmed primarily in C++.
- Citronaut complies with the Joint Architecture for Unmanned Systems (JAUS) standard.

- Citronaut will be competing against 30 other teams in this year's competition.

The Tasks

After passing through the start gate, the following must be completed autonomously:

- **Path:** A series of 6" x 48" PVC sheets along the floor of the pool, painted orange. If followed correctly, they provide the heading to the next task.
- **Flare:** A 9" red buoy moored to the floor of the pool, about 72" below the surface. The goal is to strike the buoy and "set off the flare."
- **Barbed Wire:** Two moored 72" segments of PVC pipe painted green. The are 48" apart, parallel, and approximately 96" below the surface.
- **Bombing Run:** Four 12" x 24" black bins, with 6" white border, on the pool floor. Each bin has a different red silhouette. Before the run, the AUV is given a primary and secondary target. It must drop a marker into the correct two bins for full points.
- **Machine Gun Nest:** An 18" square PVC structure painted green, 120" below the surface. The AUV must launch a projectile through the square.
- **Briefcase and Rooftop:** A 12" x 18" x 6" orange PVC "briefcase" that must be grabbed by the AUV, and taken to the water surface ("rooftop"). The briefcase must initially be found by triangulating the position of an underwater acoustic pinger.

General Methodology

1. **Blurring/smoothing**
   To compensate for image noise, Gaussian filters are applied to the input images.
2. **Color Space Change**
   Light bends differently in water than in air. As a result, colors, especially greens, are hard to extract from far away. To solve this problem, a color space change from RGB to YCrCb is used.
3. **Color Extraction**
   The YCrCb or RGB color values are checked with the desired object color, and scored accordingly. A threshold is applied to keep only the closest color values. Any other pixels are set to black.
4. **Noise Removal**
   Morphological operations erode and dilate are performed on the new image. In some cases the images are also pyramided down then up to remove as much noise as possible.
5. **Contour Fitting**
   Contours are fitted to the remaining non-black pixels in the image. The contour with the largest bounding box area is retained and set as the contour of interest.

Results

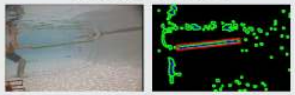
Path

Left: Input Image Right: Processed Image

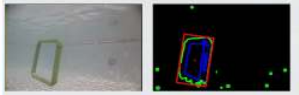
Green: Fitted Contours
Blue: Contour "holes"
Red: Bounding Box of Object

Flare

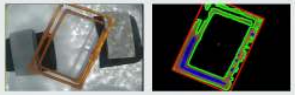
Barbed Wire



Machine Gun Nest



Briefcase

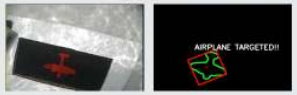


Bombing Run

Inside each of the four bins is a different red emblem. There is a factory, a battleship, an airplane, and a tank. No previous knowledge is given on the orientation or position of each emblem. Citronaut is equipped with two metal marbles that it drops into the bins as "markers".

Tank

Airplane



Battleship

Factory

To distinguish between the different objects, the bounding box shape, contour area and contour perimeter are utilized. Values are divided by the area of the bounding box to make the final classifiers invariant of orientation and distance changes. Each classifier votes for one of the objects, and the object with the most votes is chosen. If two objects tie in votes, the program moves on to the next frame.

The Competition

- **What:** AUVSI and ONR's 12th International Autonomous Underwater Vehicle Competition
- **When:** July 28th—August 2nd, 2009
- **Where:** Space and Naval Warfare Center, TRANSDEC Facility, San Diego, CA

Useful Links

- **UCF Robotics Website:**
  http://robotics.ucf.edu
- **Competition Website:**
  http://auvsi.org/competitions/water.cfm