Application of Computer Vision to Microscopic Bioapctuators

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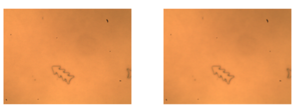
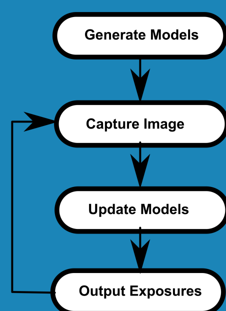
The Problem



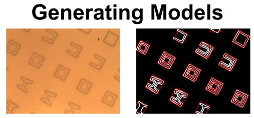
Microrobotics deals with robots with scale on the order of 1 micrometer or one millionth of a meter. Current efforts rely on external energy sources and often don't yield fully independent motion. In the GRASP Laboratory Drs. Kumar, and Steager are using photosensitive bacteria and dynamic light patterning to solve this problem. Part of this solution relies on specialized computer vision algorithms to locate the robots and project light in the appropriate places. Essentially the goal is to utilize the photo-sensitivity of the bacteria to change the ``swimming'' behavior of bacteria near the edges of a specific microrobot to direct its motion. The goal of this project is to create the software needed for these experiments.

From a computing standpoint the heart of this problem is to take an input image such as the one above and identify all tracked contours and their orientation each frame. That information can then be used to project any pattern onto individual contours.

The Algorithm

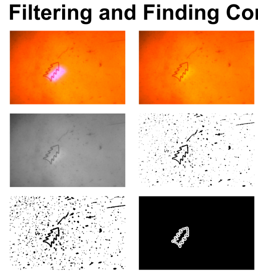


Generating Models



Generating models takes an input image and produces a set of models ready for tracking. This is accomplished by using the filtering and contour finding to identify all the contours in the image and then creating models for all of those contours.

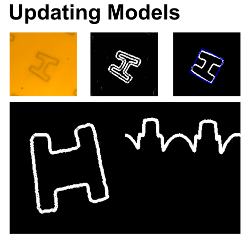
Filtering and Finding Contours



The filtering and finding of contours takes an input image and outputs a set of contours found in that image. This happens in five steps as can be seen on the left from left to right and top to bottom.

The first step removes the projected blue light from the image. The second step converts the image to a single channel greyscale image. Then an adaptive threshold is applied to the image. This sets any areas of rapid intensity change to black. The black areas are enlarged to close any small holes in the edges of the structures. Finally the edges of all the contiguous black areas are a identified and those with an area in a specified range are outputted.

Updating Models



To update all the models the algorithm loops over all tracked models and gets a small region of interest around the previous location of that object (top left). The ROI is then filtered (top middle) and the resulting contours are searched for the target model (top right).

The searching is done by looking for the contour whose area most closely matches the model's. If the areas are too different the model is considered not found and the algorithm returns the previous position and orientation of the model.

Once the model is found the center can be determined by averaging all the pixels in the contour. Using the center the algorithm generates a "rotation signal" from the contour (pictured left). This signal is a mapping from angles to distances. For each angle going out from the center the signal is mapped to the distance to the edge of the contour. If the found model is rotated relative to the original model then there will be some phase shift in the signal. Determining this shift yields the object's orientation.