



Introduction

Our multiple 3D cameras aid the intelligent workcell system to provide a safe environment for humans and robots to work together.

Problem: The current system requires calibration.

Reason: Segmentation of a spherical object.

Contribution: An efficient algorithm for a better segmentation of the sphere.



Intelligent work cell

Morphological Image Processing

Morphological operations are used to isolate objects in images. The disadvantage is that the radius has to be manually picked for every image (top four images).

An adaptive algorithm was implemented so that the radius for erosion and dilation corresponds to a fixed world metric.



Morphological Operation

Adaptive Morphological Filtering for Calibrating Multiple 3D Cameras

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Erosion and dilation with radius 3



Distant Binary Image



Erosion and dilation with radius 3



Closer Binary Image

Fixed radius did a good job removing the stick from the image further away but failed to remove the stick from the image closer





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Adaptive Morphological Filter

Distance transform specifies the distance from each pixel to the nearest non-zero pixel. The idea is to let the radius have a constant size in world metric instead of image metric.

Angle per pixel = θ , field of view = θ_{fov} , image pixel = n, world_radius = r, world distance = d_i

$$\theta = \frac{\theta_{fov}}{n}$$

Algorithm:

- 1) Turn point cloud to range image R
- 2) Create binary image *B* by via background subtraction
- 3) Do distance transform D on $B \rightarrow D$
- 4) Apply erosion to the foreground pixels

for all *i* in *B* that is background

$$d_i = \theta^* R^* D;$$

if $d_i < r \Rightarrow B = 0$; output *B*

5) Invert $B \rightarrow InvB$

6) Do distance transform Dx on $InvB \rightarrow [Dx L]$ where L_i is the linear index of the foreground

7) Apply dilation to foreground pixel in B or erosion to background pixels in *InvB*

for all *i* in *B* that is background

$$d_i = \theta^* R_i^* Dx$$
; where $j = L_i$

if $d_i < r$; InvB = 1

Results

Using a fixed radius to perform morphological filtering can be difficult. If the fixed radius is small, some noise will remain. But if the radius is large, some useful information will be lost. We tested our method on several binary images. Using an adaptive radius we are able to remove the stick and segment the target reliably in all the frames regardless of the distance to the camera.