DTU Electrical Engineering
Department of Electrical Engineering

Door Recognition and Handle Detection Using Convolutional Neural Nets

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Introduction

There exists a necessity of human intervention to open closed doors when robots move in an indoors environment. Many techniques have been explored to solve this issue (throughout the usage of either lasers scans, images or depth data) but provide an inherent loss of conceptual information. This paper presents a novel method based on a Convolutional Neural Net (CNN) followed by the fusion of two handle detection methods, to not only enhance the autonomy of robots when facing the problem of door detection, but also add adaptability to unknown and dynamically changing scenarios in real time.

Convolutional Neural Net

The *Darknet reference model*, similar to AlexNet but with only 10% of its parameters, has been trained to detect doors and cabinets. The architecture includes 9 convolutional layers followed by 3 connected layers. It allows for the detection and generation of bounding boxes at a mean rate of 14 FPS on a NVIDIA GeForce GT 730 and 150 on a Titan X.

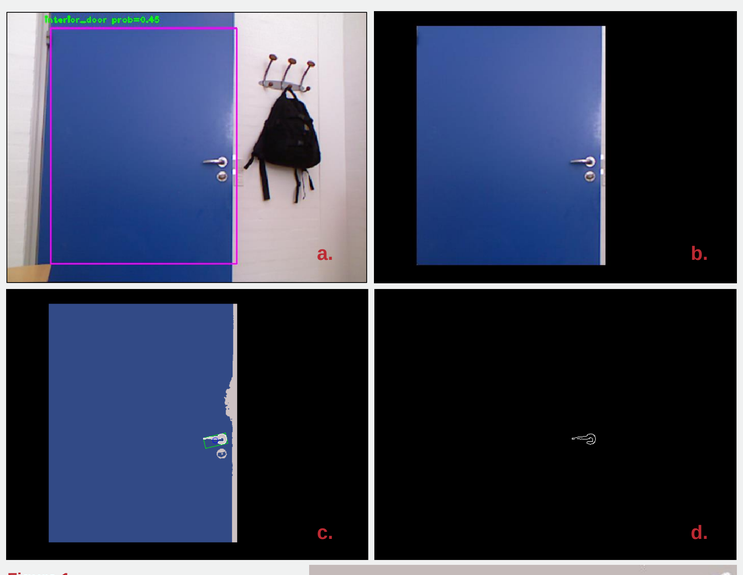
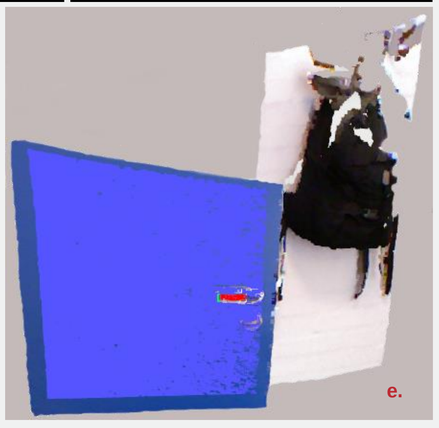


Figure 1.
Depiction of the procedure used in the visual segmentation method plus the resulting point cloud after method fusion.

a. Region of interest (ROI) selection from the output of the CNN.
b. Cropped RGB image.
c. K-means clustering of ROI with rotated rectangles (green) and centers (blue) drawn over it.
d. Binary mask applied to depth information.
e. Representation of the final door plane (clear blue) and handle (red) point clouds after the fusion of methods.



Abstract

We present a new method for robustly identifying and detecting doors and cabinets with special emphasis on extracting useful features from handles for future robotic manipulation. The novelty of this approach relies on the usage of a Convolutional Neural Net (CNN) as a form of reducing the search space.

Method 1. Visual segmentation

Once the CNN outputs a bounding box or region of interest (**a.**), the image is cropped (**b.**). A k-means clustering algorithm partitions the image into two colors (based on the assumption that door plane and handle have different colors) (**c.**). All sections clustered as door plane are removed from the image. A contour classification (size and angle) is done over the remaining data to delete everything which is not a handle (**d.**). Using a depth image, a point cloud of the handle is generated. The whole process is seen in Fig. 1 and 2.. Some imperfections might occur which will be removed by fusing the results with those of the second method.

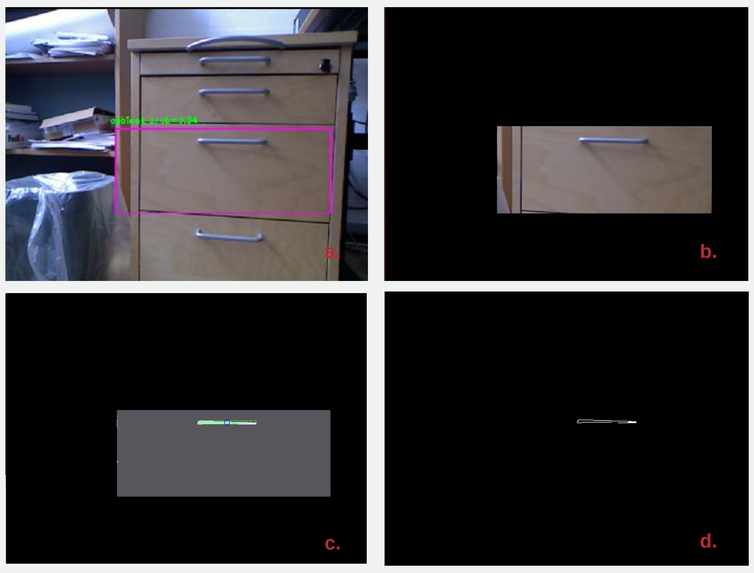


Figure 2. Another implementation of the convolutional neural net detection and visual segmentation method, this time for a cabinet.

Method 2. Plane segmentation

The full point cloud of the environment provided by the Kinect software is downsampled and cropped using the ROI from the CNN. The plane model of the door is extracted. All points in said model (*inliers*) are deleted; the rest (*outliers*) are considered as belonging to the handle. This method sometimes present false positives, such as small parts of the wall.

Fusing both methods

Similarly to a bitwise AND operation, the results of both methods are fused to remove all imperfections from each individual method. This results in a consistent, precise and robust estimation of the handle's true point cloud.

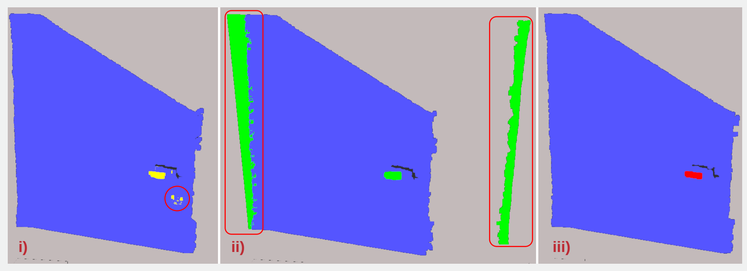
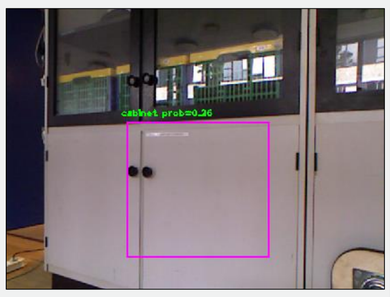


Figure 3. From left to right. **i)** Handle point cloud (yellow) obtained from the visual segmentation method (lock is included in the result). **ii)** Handle point cloud (green) derived from the direct point cloud processing method (walls are included in the result). **iii)** Final handle point cloud (red) after merging both methods (all errors from each method have been removed).

Experimental results

The algorithm was tested on several types of doors, cabinets and drawers with outstanding accuracy and real-time performance.



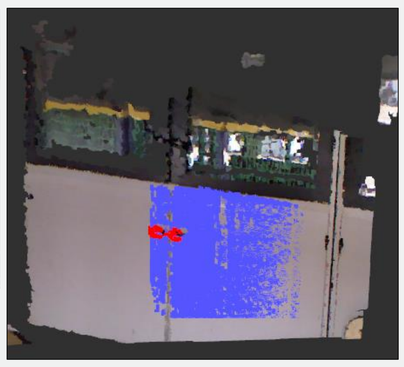


Figure 4. With basic parameter tuning the algorithm is capable of working on different types of handles.

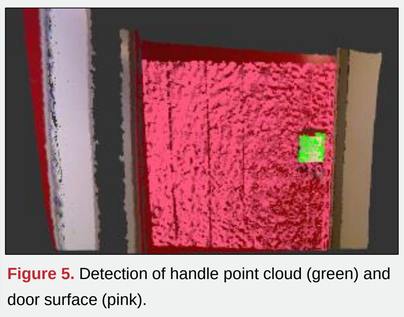
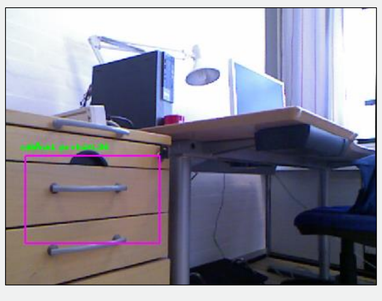


Figure 5. Detection of handle point cloud (green) and door surface (pink).



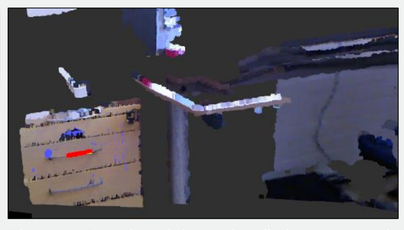


Figure 6. Detection of drawer handle in an extremely cluttered environment with intense lighting from the exterior.

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