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Research paper

Evaluation of Edge Detection Methods on Different Categories of Images

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Abstract

Object detection in an image is a challenging task. Recent developments in the field of computer vision and machine learning contributes to solving the issue in the field of object detection. Deep learning is one of the recent innovations that selects the feature of an object for evaluation. The shape is the most relevant high-level feature that helps to separate different objects. It can be visualized as a collection of edges and can be defined as a set of contiguous pixel positions where an abrupt change of intensity values occur. Hence, the selection of a better edge detection method for an object category gives higher accuracy in recognition. Our objective in this paper is to compare the various edge detection methods by evaluating the entropy as a measure, to find the best suitable method for each category of objects. Understanding the mechanism behind each of the edge detection algorithms is indispensable to improve the quality of the outcome it produces. Results show the best edge detection for a given category of an image from the Caltech 256 Image Dataset.

Keywords: *Edge Detection, Entropy, Canny, Fuzzy Logic*

1. Introduction

There are a zillion category of images that are being accumulated day by day and fetching the appropriate images that match our requirement is a tedious process. Machine learning is a methodology that helps to automatically group or label the images. The growth in the field of machine learning algorithms has been able to achieve automation to a great extent. Majority of the algorithms relies on the selection of the best features for learning and distinguishing the proper shape of an object. The low-level feature edge helps to extract the shape of the object in an image which helps to improve the efficiency of machine learning algorithms [1].

The past decade in computer vision research has focused on deep learning, and in particular convolutional neural network (CNN) techniques, allowing to learn powerful image feature representations from large collections of examples. Better shape extraction of an object helps in improving the efficiency of the various deep learning algorithms. The shape is the collection of edges that gives the geometric alignment of an object in 3D space. Edge reduces the amount of data to be processed in the object. Edge gives the detail of objects as similar to how humans perceive the object. It is easy to form descriptors that can integrate with the machine.

The development of various edge detection algorithms has paved the way for enhanced results [4, 11]. An important property of an algorithm is to detect precise, continuous and oriented edges. In this paper, we have investigated the performance of different edge detection methods for different objects and categories. We have devised an automated system that evaluates the prominent edge detection algorithms for a given category. Our system helps in the pre-selection of the best edge detection method for improving machine learning accuracy. We determine the best edge detection methodology using the entropy value and Bayesian classifier to find the result for a given category of an image.

The images for evaluation are taken from standard benchmark image dataset Caltech 256 which consists of 256 categories of images. The benchmark criteria for choosing the best result of the various results from the edge detection algorithms is by deploying the concept of entropy. The paper is organized as follows: Section I gives a general outlook on the Importance of Edge Detection in today's world; Section II gives a glimpse of the evolution of the various edge detectors already prevalent in this domain; Section III presents the proposed methodology for evaluation of the edge-based images to find the best edge detector for a given category of images; Section IV discusses evaluation and inference results related to the study; And finally Section V presents conclusions with scope for future extensions.

2. Edge Detectors

A. Robert

Robert is one amongthe oldest edge detector methodologies developed. Robert is also referred to as the gradient-based operator because they analyze the local maxima and local minima detected to produce the results [8]. The algorithm is recognized for its speed and simplicity. It works fast considering the fact the convolution matrix is only a 2x2 structure. The gradient along the x-axis and the y-axis are combined to compute the resulting image.

0	+1
-1	0

Gx

+1	0
0	-1

Gy

B. Prewitt

The efficiency of the Robert edge detection algorithm was later improved upon which led to the development of an improvised version of the first derivative operator and was termed as the Prewitt Operator [8]. This made use of a 3x3 convolutional matrix.The kernel along the x-axis can be rotated to get the convolutional matrix along the y-axis.

-1	0	+1
-1	0	+1
-1	0	+1

Gy

+1	+1	+1
0	0	0
-1	-1	-1

Gx

C. Sobel

The size of the mask is 3x3, as similar to Prewitt. The major change from Prewittthat can be observed in the Sobel is in the change of weights in the convolutional matrix. The weight of horizontal/ vertical pixel is given higher weighting than others.This gives better performance and more distinctive edges. Prewitt follows a uniform distribution of weights [8]. With the assumption that objects are likely to found in the center, more weights assigned along the middle row in both the convolutional matrix.

+1	+2	+1
0	0	0
-1	-2	-1

Gx

-1	0	+1
-2	0	+2
-1	0	+1

Gy

D. Log

All the above-discussed edge detection algorithms are all Gradient-based operators. However, Laplacian Of Gaussian is a second order derivative operator which highlights regions of rapid intensity change. The major characteristic of this operator that distinguishes it from others is that it is an isotropic differential operator which can be scaled to our needs depending on the image.

The Laplacian L(x,y) of an image with pixel intensity values I(x,y) is given by Eq 1:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2} \quad (1)$$

Three common kernels include:

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

-1	2	-1
2	-4	2
-1	2	-1

E. Canny

This is yet another gradient based operator. All the above operators face the problem of noise. It misinterprets unwanted parts as edges due to the presence of noise in the image. However canny overcomes this by performing a Gaussian-based filter before convolving [13]. Canny follows a series of steps which starts off with finding the gradient magnitude and direction for the smoothened image obtained after the convolution. The gradient contains wide ridges around the local maxima and so the next task is to thin those ridges.The final operation is to perform Hysteresis Thresholding to reduce false edge points. This series of steps followed is the reason for

better efficiency of canny over other edge detection algorithms [7].

F. Fuzzy

Among the different techniques, Canny's method has been used since its proposal by J. Canny. Canny contains different steps towards the detection of the edges. Among the stages, the hysteresis linking method is complex as it needs neighborhood data information. Retrieving this neighborhood information increases the complexity of the algorithm. To overcome this complexity, we have introduced Fuzzy logic instead of the hysteresis Linking method for edge detection [6]. Because of the less complexity compared to Canny, Fuzzy provides a fair efficiency in its results. Fuzzy Logics works on the principle of finding discontinuities in uniform regions of the image. This method takes gradient along the x-axis and y-axis and feeds as input to the Fuzzy Inference System [9]. The zero-mean Gaussian membership function is used for each input Ix (Along x-axis) and Iy (Along y-axis). The Triangular membership functions White and Black are specified for the above input. The results are shown in Fig 1.

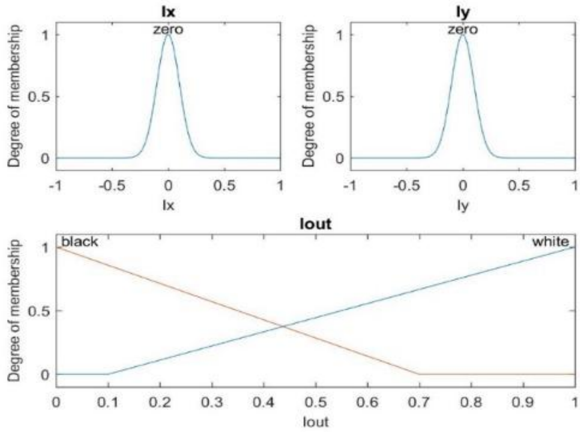

Fig 1: Fuzzy Membership Functions

3. Proposed Method

3.1 Algorithm

- Read color images one by one from a specific category in the dataset.
- Perform SOBEL, ROBERT, PREWITT, LOG, CANNY, and FUZZY edge detection algorithms.
- Compute the entropy of each of the output values.
- Store the entropy values of each image within a category inside an array.
- Write the array values into an Excel sheet.
- Using Naive Bayesian Classifier to find the best algorithm for a given category of image.

A. Entropy

The intention of using entropy as a measure of ‘interest value’ of a sub-image follows the idea that areas of interest within an image show certain amounts of disorder and since entropy measures disorder, it would serve as the best detecting measure of the interesting areas[3]. The entropy is given as:

$$H(i) = E\{-P(g) * \log[P(g)]\} \quad (2)$$

Where P(g) is the probability of occurrence of grey level g in the neighborhood I and - log[P(g)] is a measure of information associated with grey level g and called its self-information.

Higher entropy values are indicative of better edge detection methodology and low values indicate poor edge detection.

B. Naïve Bayes Classifier

The Naïve Bayes Classifier is a simple probabilistic approach that uses Bayes Theorem and theory of probability to correctly predict the class of the object. In our approach, the edge detector that gives the highest entropy value is taken as the best for that particular image. We deploy the Naïve Bayes Classifier over all the images within a category and calculate the probabilities of each edge detector and conclude that the edge detector with the highest probability is the best edge detection methodology for that given category of images. The simple idea of Bayes Theorem revolves around the following equation:

$$P(B/A) = P(A/B) \times P(B)/P(A) \quad \text{--------} \quad (3)$$

4. Experimental Setup

The experimental setup was performed using MATLAB R2016a.The flexibility offered in MATLAB helped to processthe large collection of data faster.The system requires a minimum of 4GB RAM and 10 GB Disk Space.No specific graphics card is required. The dataset used for the experiment is the Caltech 101 Dataset. The reason for choosing this dataset being our experiment is to find the best edge detection algorithm for a given category of images and this dataset provides distinctive images within various categories of different objects.

5. Evaluation

Our system has analyzed images from all categories of images and formulated the results of the best edge detection algorithm for a given category.This functions as a pre-processing before machine learning for better feature extraction. Fig 2.1 shows the output images of Robert, Prewitt, Sobel, Log, Canny and Fuzzy Edge Detectors being compared against each other. Fig 2.2 compares the entropy values of each of these methods.

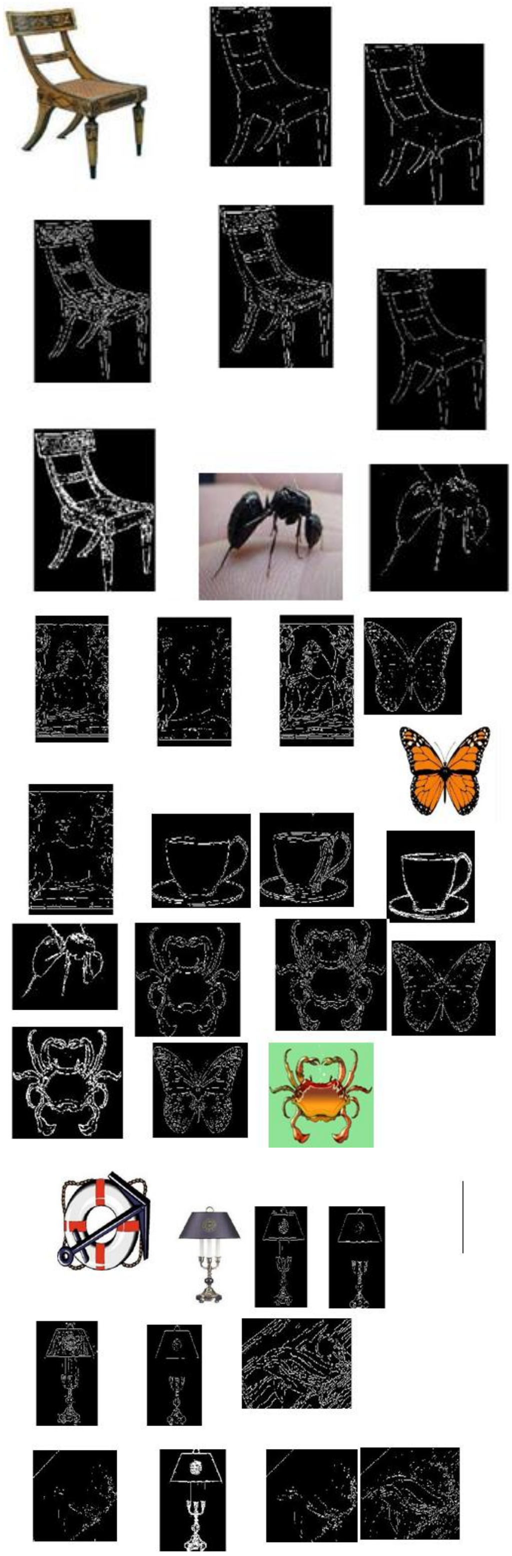

Fig 5.1: Various Edge Detection Algorithm Results for Different Categories

Category	Robert	Prewitt	Sobel	LOG	Canny	Fuzzy
Barrel	0.2076	0.2242	0.2242	0.4174	0.5626	0.6252
Cup	0.2073	0.2494	0.2498	0.2962	0.3548	0.4256
Chair	0.2095	0.1916	0.1934	0.3263	0.3938	0.5755
Budd	0.22	0.2850	0.28	0.400	0.504	0.662

ha	73		46	6	8	2
Ant	0.1872	0.1800	0.1800	0.2721	0.5070	0.3706
Butterfly	0.2801	0.2738	0.2827	0.3865	0.4806	0.6708
Crab	0.2692	0.2829	0.2849	0.3420	0.4191	0.5558
Anchor	0.3013	0.2902	0.2883	0.3533	0.4295	0.6957
Dolphin	0.1383	0.1721	0.1719	0.3391	0.5466	0.4450
Lamp	0.1719	0.1847	0.1844	0.2178	0.3273	0.4356

Fig 5.2: Entropy of Various Edge Detection Algorithm Results for Different Categories

- The inference is that entropy is the right measure to compare Edge Detection Algorithms. The higher the entropy, the better the edge detection algorithm as depicted in Figure 2.2.
- On analyzing all 256 categories the conclusion drawn is that Fuzzy is the best Detection Algorithm for most of the categories as illustrated in Figure 2.1 and Fig 2.2. Some categories like lamp show equally good result in both fuzzy and canny. However for categories such as Dolphin, Canny works better than fuzzy as depicted in Fig 3.1.
- Another conclusion that isdrawn is that the results given by Prewitt and Robert are almost the same. We infer this from the closeness of the entropy values as depicted in Figure 2.2.
- Another observation as illustrated in Fig 2.2 is thatthough the evaluation result for the best edge detection algorithm for the category 'Barrel'is Fuzzy Logic, for some images of this category, Fuzzy Logic returns terribly bad results. The use of Bayesian classifier to infer the best edge detection methodology sometimes gives rise to a few exceptional cases. The entropy values for the given image are supportive of the poor quality of the Fuzzy Logic Algorithm in such cases as shown in Fig 4.1 and 4.2.

Category	Probability of Fuzzy	Probability of Canny
Dolphin(65)	0.3076(20)	0.6923(45)

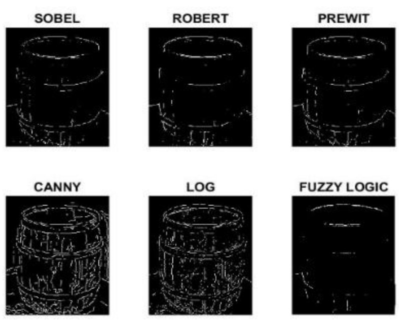

Fig 5.3: Anomaly in Category Barrel

- In the category anchor, for the below-given image shown in Fig 5.1, Robert turned out better than fuzzy and canny. This is the evidence that sometimes the simple first-order derivative with a simple 2x2 convolutional matrix can itself may give the best result. Entropy values can be inferred from Figure 5.2

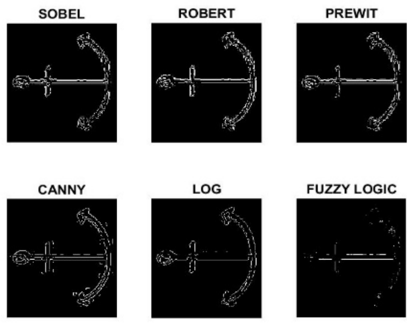

Fig 5.4: Anomaly Image from Category Anchor

Entropy	OBEL	OBERT	EWITT	LOG	ANNY	FUZZY
.402652	.20883	.223821	.208392	.143695	.183745	0.11947

Fig 5.5: Entropy of an Image from Category Anchor

6. Conclusion

We have presented an approach to find the best edge detection algorithm for a given category of an image. We conclude that edge detection algorithms vary over the different category of images. Some categories may have more than one edge detection algorithms that yield good results. Edge Detection helps to figure out the shape of the interested region in the image. Proper shape analysis further improves the efficiency of deep learning and machine learning algorithms.

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