APIVIP

Project 2
Report
Image Segmentation Algorithms

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OVERVIEW

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments or the set of pixels. The goal of segmentation is to simplify the representation of an image into something that is more meaningful and easier to analyze. It is commonly used to locate objects and boundaries in images. In more precise terms, image segmentation is defined as the process of separating the image from its background. The four major types of approaches for image segmentation are Threshold Method, Edge Detection Method, Region-based Method, and Connectivity-preserving Relaxation Method.

It has several applications like Content-based image retrieval, Machine vision, Medical imaging to Locate tumors or measure tissue volumes, Object detection, face detection, video object localization, etc.

EXPERIMENTS

Our experiments are mainly based on the research of the best algorithm, or a combination of them, to apply to images to get better results in terms of segmentation and object recognition.

All the given images were analyzed using all the previously described algorithms and object detection methods, in order to find their performances in segmentation and object recognition. Our analysis was primarily centered on the recognition of specific objects inside the images: the cup and the suitcase in "ThermalImage1.png", the needles and the "bag" in "ThermalImage2.png", the Blackbird in "Bird1.png", the two Herons in "Bird2.png", the Penguin in "Bird3.png" and the almost straight red line in "Squall.png" time-series images.

Several image enhancement algorithms were used to investigate their performances and effect on segmentation. In particular, we used: **Gaussian Filtering (GF), Histogram Equalization (HE), and Gamma Correction (GC)**, singularly and in different combinations. Canny edge detector was used not only like a segmentation algorithm but also as an initialization algorithm for Snake/Active contour (and so as an enhancement algorithm). The reason is that although it leads to a good definition of specific objects' edges/boundaries, these are not always closed or well defined. This result can be reached using a closed contour, which adheres to the correctly detected boundaries, and closes all the gaps present among them.

Moreover, we have used 4 different algorithms in our project for segmentation: **Active Contours, Canny edge detection, k-means clustering, and Fuzzy k-means clustering**. Additionally, connected component analysis is applied to obtain better segmentation results.

Active Contours: In computer vision, contour models describe the boundaries of shapes in an image. Snakes, in particular, are designed to solve problems where the approximate shape of the boundary is known. Since it is a deformable model, snakes can adapt to differences in stereo matching. Their advantage is that they can be used to track dynamic objects and they autonomously search for a minimum state. While a drawback is that their accuracy largely depends on convergence policy. In this Project we initialize the algorithm creating an initial circular snake, surrounding the object of interest. The best adherence of this snake to the object is related to the choice of the best parameters which define the properties of the "research procedure".

Parameters. (*alpha*: the continuity term penalizes changes in distances between points in the contour, *beta*: the smoothness term penalizes oscillations in the contour, *gamma*: the controlled step size for a negative gradient of the point to find local minima).

Canny edge detection: Detection of edges for an image can help for image segmentation. Canny edge detection is a technique to extract useful structural information from different objects and significantly reduce the amount of data to be processed. The advantage of edge detection-based segmentation is that it requires fewer computations. The disadvantage is that it only works well in images with good contrast between object and background.

Parameters. (*Threshold1*: The maximum threshold for the hysteresis procedure, *Threshold2*: The minimum threshold for the hysteresis procedure).

K-Means clustering: K-means clustering is an unsupervised algorithm. Its aim is to partition "n" observations into "K" clusters. Each sample belongs to the "cluster" with the nearest mean. The advantage of this algorithm is that with a large number of variables, K-means may be computationally faster than hierarchical clustering. But an important question is how to select the optimal number of clusters? One way is the Elbow method. The idea is to minimize the total intra-cluster variance. So, we find WCSS (within-cluster sum of squares). It measures the compactness of the clustering. We select the point where we see a sharp change in the graph and after that point, the graph is more continuous.

Fuzzy K-means clustering: Fuzzy k-means clustering is similar to K-means clustering. The difference is that it assigns fuzzy memberships to each sample. There is a factor "m" which determines the level of fuzziness. When m=1, it becomes K-means clustering. In this method, one point can belong to different clusters with different memberships. It performs better than "K-means clustering". The number of clusters here is also chosen using the WCSS method.

Table 1 contains all the parameters analyzed for every enhancement and segmentation algorithm.

Table 1. Range of parameters investigated for every algorithm used in this Project

Algorithm	***Gaussian Filter***	***Gamma correction***	***Canny Edge Detector***		***Active contour***		
Parameter	Sigma	Gamma	Lower Threshold	Higher Threshold	Alpha	Beta	Gamma
Values	1 - 5	0.1 - 20	0 – 1500*	0 – 1500*	0.01 – 0.2	0 - 40	0.001 – 0.2

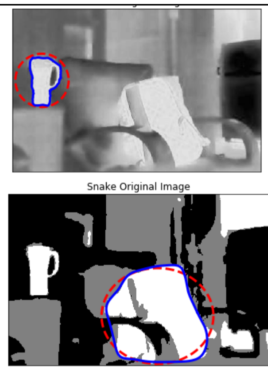
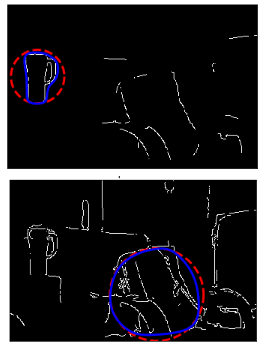
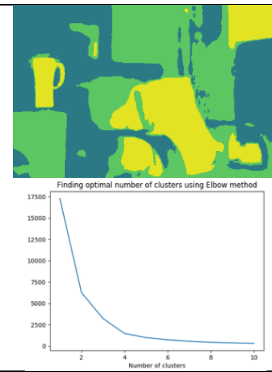
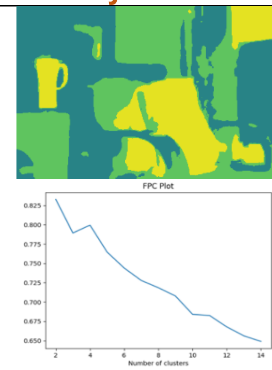
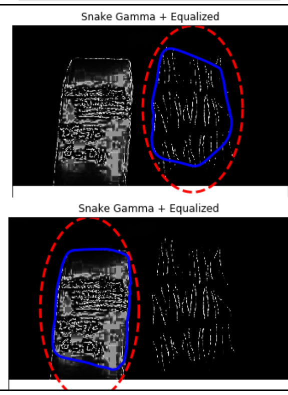
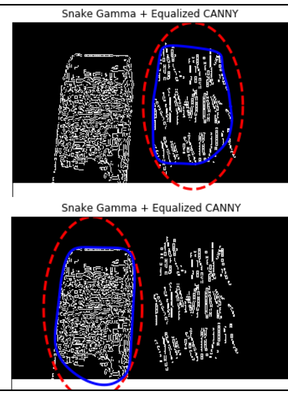
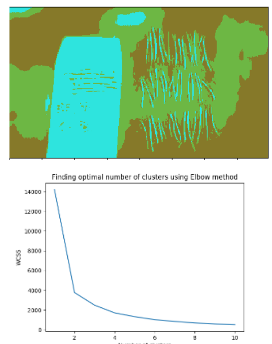
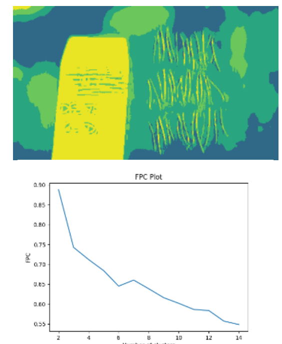
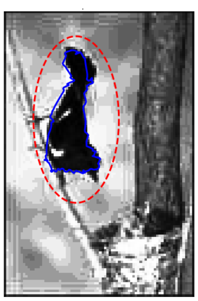
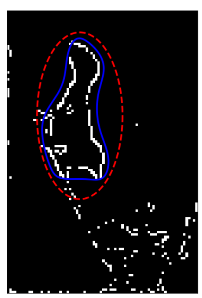
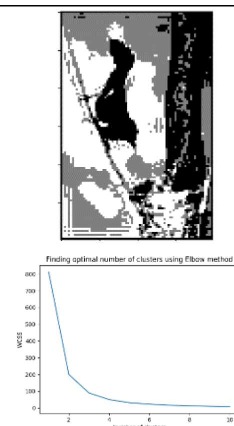
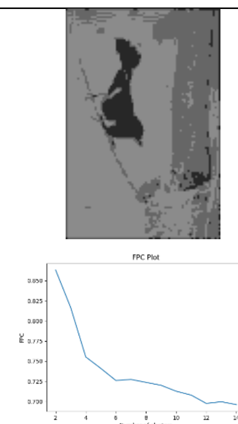
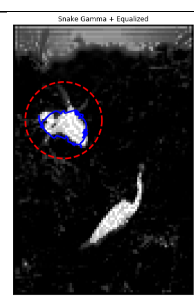
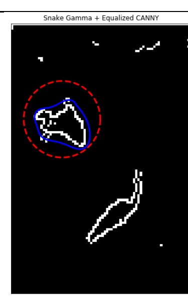
* *the ratio between Lower and Higher Threshold was not maintained close to 1:2 or 1:3 as suggested by Gonzales, R.C. et. al. "Digital Image Processing"*

RESULTS AND OBSERVATIONS

The following are some considerations we did after analyzing all the results obtained by intensive research of the best combination of algorithms and parameters to get better results in segmentation and object recognition. Table 3 contains the optimal parameters for the Canny Edge detector and Active contour (snake) for segmentation of each image.

- Enhancement algorithms seem to increase significantly the capabilities of segmentation/object detection algorithms. In particular, very good results were obtained combining Gamma correction to Histogram Equalization in almost all the images sets (as reported in Table 2). These results were achieved because of the properties of the two algorithms. Most of the objects in the images present a high difference in color intensity against the surrounding background. The application of GC contributes to an increase in the difference between the background and the object. This difference is later enhanced by the application of histogram equalization, creating a marked flat edge surrounding the object, which leads to good results in both Canny edge detector and Snake/Active contours algorithms.
- Canny edge detector gave all the important edges and performed well. But, when the contrast between background and foreground is less, it gives bad results. It was successfully used as an initializer algorithm for the snake/Active Contour method. The reason for this choice is because in some images edges are very strong, but surrounded by a noisy background. Other algorithms, as Gamma correction and Gaussian Filter, partially reduce this noise, but did not allow snakes to reach the objects' edges. Canny edge detector (with wisely chosen thresholds), associated with these "blurring algorithms" allows a strong reduction in image noise, and reinforcement of main edges, which can be easily reached by Snakes/Active Contours.
The movement of pre-defined snakes to the desired object cannot be done using Canny Algorithm's output images, because there are not always forces needed to move the snakes to the previously detected edges. In these cases a Gaussian Filter approach is required to get better results.
- The Snake method provides smooth and closed contours, but we have to know the desired contour shape beforehand. It can be useful if we want to identify only some objects in the images, as the cup or the suitcase in "ThermalImage1", but make impossible the individual detection of small and close objects, like the pine needles in "ThermalImage2".
- The results were fuzzy K-means was very good. With each image in K-means and fuzzy K–means, a picture of WCSS for every image set is shown in Table 2. The number of optimal clusters is selected using this graph.
- Fuzzy K-means gave the best performance because it assigns fuzzy membership to each sample. The optimal number of clusters can be easily selected from the WCSS graph.
- Not all objects seem to be detectable using Image Enhancement/Segmentation algorithms we know and we found. An example is the "Bird3" image, where the back of the penguin cannot be distinguished by the background, which pixels have the same intensity values.

Table 2. Some results obtained for different images sets using as values for the parameters, the one suggested in Table 2. More images are reported and will be explained in the presentation, or can be asked directly to the authors.

Input Image	Active contours	Snake with Canny	K-means	Fuzzy K-means
				
				
				
				

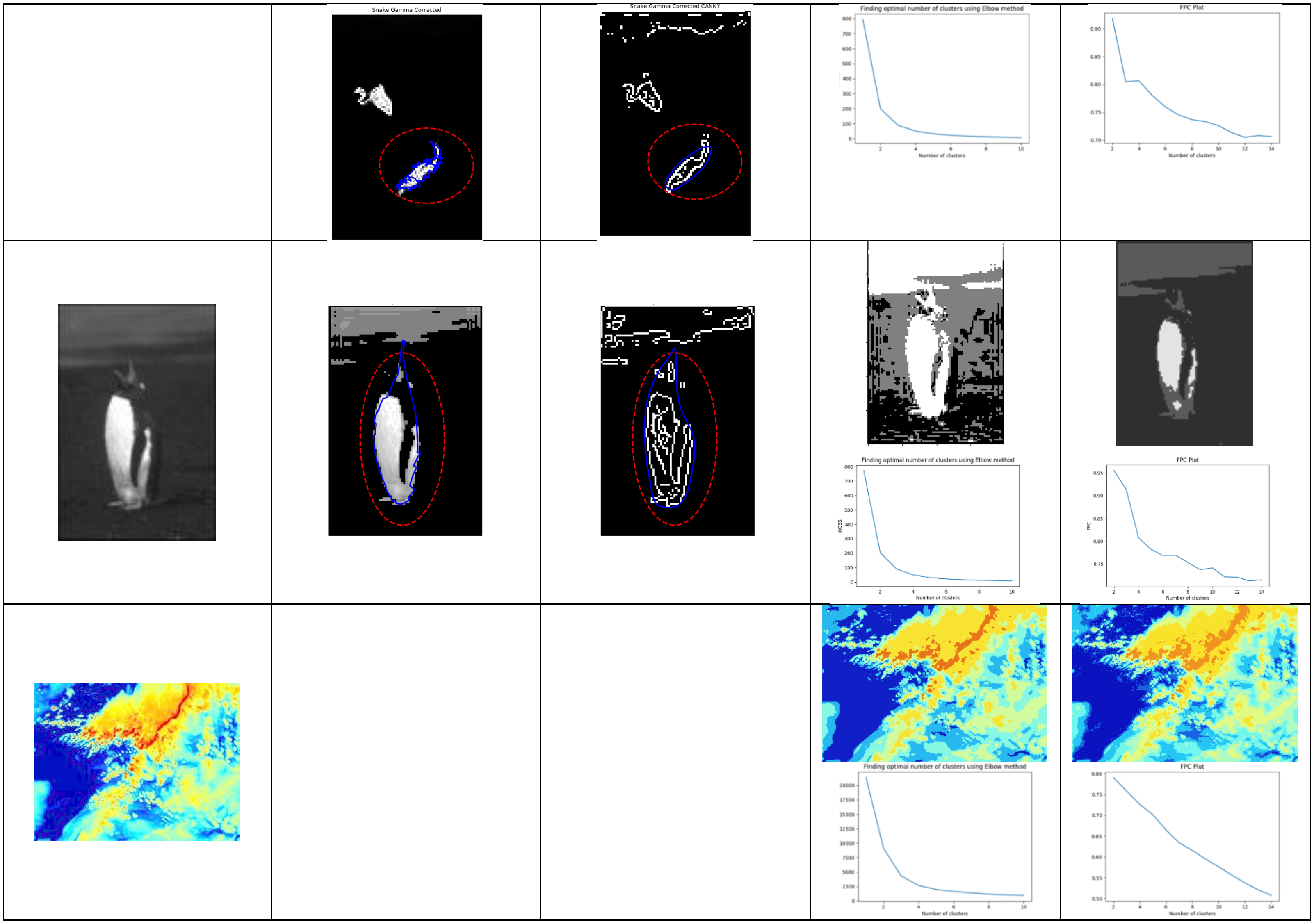


Table 3. Suggested values for every investigated image sets, used to obtain good results in the segmentation procedure. For each parameter, the first column is related to the original images, without clustering, the second column is for images clustered using K-Means algorithm, and the third column is for images clustered using Fuzzy K-Means algorithm.

	Gaussian Filter			***Gamma correction***			***Canny Edge Detector***						***Active contour***								
Image	**Sigma**			**Gamma**			**Lower Threshold**			**Higher Threshold**			**Alpha**			**Beta**			**Gamma**		
Bird1	3	1	1	0.1	0.01	0.01	50	150	100	50	500	500	0.02	0.15	0.1	40	5	1	0.02	0.2	0.2
Bird2 – Bird North	3	1	1	10	10	10	300	1000	1000	400	1500	1500	0.08	0.05	0.02	40	10	5	0.02	0.02	0.02
Bird2 – Bird South	3	1	1	12	10	10	300	1000	1000	400	1500	1500	0.08	0.15	0.15	40	5	5	0.02	0.02	0.02
Bird3	3	1	1	10	0.1	10	40	0	0	100	0	0	0.08	0.05	0.05	40	10	10	0.02	0.02	0.02
ThermInf1-Cup	2	1	1	20	20	20	20	0	0	40	0	0	0.01	0.01	0.01	25	1	1	0.001	0.001	0.02
ThermInf1-Suitcase	2	1	1	20	20	20	100	0	0	200	0	0	0.02	0.05	0.03	25	0	40	0.001	0.02	0.02
ThermInf2-Bag	2	1	1	20	20	20	40	0	0	100	0	0	0.01	0.1	0.08	25	0	10	0.001	0.02	0.02
ThermInf2-Needles	3	1	1	20	20	20	40	0	0	100	0	0	0.08	0.1	0.07	40	0	0	0.02	0.02	0.02

Nothing = Original (No algorithms), Blue = HE, Yellow = GC, Green = GC + HE, Red = Using Canny as initializer

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