



Unsupervised Underwater Images Segmentation Based on Mean Shift Algorithm

Shakuntala Devi^{1*}, Sumanto², Ghofar Taufiq³, Jefina Tri Kumalasari⁴, Giatika Chrisnawati⁵

^{1,2,3,4,5}Fakultas Teknik dan Informatika, Universitas Bina Sarana Informatika, Indonesia

shakun0726@gmail.com^{1*}, sumanto.sto@bsi.ac.id², ghofar.gtf@bsi.ac.id³, jefina.jtk@bsi.ac.id⁴, giatika.gtc@bsi.ac.id⁵

Abstract

Digital image processing is an important field in pattern recognition and computer vision, where the process of separating an object with the background acts as one of the crucial roles in executing image processing. This research will talk about mean shift algorithm implementation in processing a set of undersea images to see its effectiveness in separating the background with the object automatically based on pixel distribution and color intensity. How the mean shift algorithm works is by doing a reading process to find the center of a pixel cluster in an image before this algorithm starts to cluster or group pixels with similar characteristics. In this research, a set of image input will be used as a test under mean shift algorithm to give output of an optimal pixel segmentation or grouping, leading to a proof that the mean shift algorithm has the capability to separate a main object from the background, especially in images with intense and high contrast. Even so, in images with less intense and lower contrast, the segmentation is not as accurate. The image input will have to undergo some more pre-processing before the mean shift segmentation is implemented. This research outcome is that the mean shift algorithm is effective for segmenting marine animal images based on colors without having to initialize how many clusters as the conclusion where this method is applicable in many computer vision programs such as object detection or image pattern recognition.

Keywords: *Computer vision; image processing; mean shift; segmentation*

1. Introduction

Digital technology rapidly advancing drives a growing demand in various fields for systems that capable of automatic analyzing and understanding image to simplify works. In the world of marine life, documenting the appearance of animals or other creatures encountered underwater is a very common activity that has been gaining popularity especially in diving community [1]. However, many photographs of marine life often lack in clarity as the water absorbs light from above. It causes underwater images having lesser contrast [2].

Underwater image analysis has becoming part of essentially important research area due to its wide applications in marine biology, environment monitoring, and environmental conservation. Accurate identification and segmentation of marine organisms from underwater imagery is essential for tasks such as species classification, population estimation, and habitat assessment [3]. As stated previously, underwater images come with unique challenges compared to terrestrial images. It includes color distortion due to animals camouflaging and low contrast caused by light absorption and scattering under the water. These factors can make reliable object and background separation process a difficult problem.

From the persistent issues of low contrast, color distortion, and background complexity in underwater imagery, an effective segmentation method must be able to adapt to the subtle intensity variations while at the same time, preserving object boundaries. Methods that rely heavily on fixed thresholds often struggle under these conditions, as the visual differences between marine organisms and their surroundings are frequently minimal [4]. This limitation in image segmentation highlights the demand for a technique that could operate without pre-determined cluster and able to rely on the distribution of pixel features instead. In this context, the mean shift algorithm emerges as a suitable alternative, as it segments images by identifying natural groupings of pixels in feature space, allowing objects to be separated from the background even when contrast differences are weak [5].

This research study will present a basic implementation of the mean shift algorithm for segmenting underwater images, with separating marine life objects from their surrounding background as the main focus that could be further implemented in a more complex pattern recognition model. The proposed approach utilizes color and spatial features to cluster image pixels. It will then test the effectiveness of mean shift algorithm for object and background discrimination without the need for labeled training data. The experimental results demonstrated that the mean shift algorithm can deliver meaningful segmentation results on underwater imagery with several other processing in the presence of noise in the image data. This finding suggest that mean shift could remain as a viable and interpretable method

for underwater image segmentation, especially for humans to be able to see what's within the image better with the help of color segmentation.

2. Literature Review

2.1. Digital Image Processing

Digital image processing in computer vision contains manipulation and analysis of digital images using computational algorithms to extract meaningful information from the image, enhancing visual quality of the image, and preparing the image for further use like machine learning and pattern recognition model. This field is a foundation of computer vision system that enables the ability to perceive and interpret visual data in a similar manner to how human sees [6]. Digital image processing beset several core stages. The initial stage of image processing often involves a pre-processing step to improve the quality of the image and make it more suitable for further analysis [1]. This stage mainly include techniques like contrast enhancement, noise reduction, or color conversion. For instance that will be shown in this study, the marine imaging requires noise removal to reduce unnecessary amount of clusters.

2.2. Mean Shift Algorithm

The mean shift algorithm is an unsupervised clustering method that is non-parametric, was originally developed for locating the modes of a probability density function in feature space [5]. Within image segmentation, mean shift algorithm commonly applied by representing each pixel as a feature vector x that normally includes the spatial coordinates and color information [7].

Given a set of neighboring points within a bandwidth h , the new position of a point is computed as the average of these neighbors:

$$x^{(t+1)} = \frac{1}{N} \sum_{i=1}^N x_i,$$

where x_i denotes the feature vectors of neighboring pixels and N is the number of pixels within the kernel window. This update step shifts the point toward regions where similar pixels are more concentrated.

The difference between the updated position and the current position defines the mean shift vector:

$$m(x) = x^{(t+1)} - x^{(t)}.$$

This entire process will then repeat until the shift becomes adequately small, indicating concurrence. Pixels that seems to merge to the same location are assigned into the same cluster and forming a segmented region within the image [7]. For underwater imagery, this formulation is quite advantageous since it does not rely on predefined thresholds, which appear challenging under low contrast and uneven illumination image. Segmentation will emerge naturally from the distribution of the pixel features. This allow the marine organisms to separate from its complex surroundings even when visual differences are quite subtle. Previous studies have demonstrated that this density-based clustering approach preserves region continuity and adapts well to varying image conditions, making mean shift a suitable unsupervised method for challenging underwater environments.

2.3. Python

Python is a widely used programming language in image processing and computer vision research due to its supporting numerical computation and image manipulation through libraries such as OpenCV and NumPy. In application of mean shift algorithm to image segmentation, Python could perform efficient representation of pixel vectors and facilitates clustering operations with an array-based computation. The high-level structure of Python allows modifying and implement clustering algorithms with minimal upkeep, making it suitable for experimental studies [8]. Libraries such as scikit-image and OpenCV provide tools for the implementation of mean shift segmentation in Python. It supports image preprocessing functions such as noise reduction, as well as the mean shift model [8][9]. This combination of Python with scikit-image or OpenCV able to support a flexible workflow while making it a quite practical choice for implementing unsupervised segmentation methods that could be challenging as underwater marine life images.

3. Research Methods

3.1. Research Stages

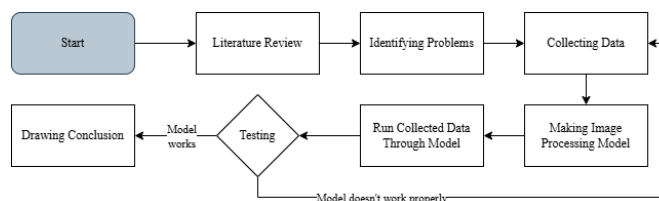


Fig. 1: Flowchart of the research stages done in this study

The following flowchart in figure 1 shows the stages that was done for this study:

1. Literature Review: Reviewing past research in order to find the topic of the study.
2. Identifying Problems: Finding a gap in previous researches that could be experimented.
3. Collecting Data: Collecting images of marine animals to be used in the model.
4. Making Image Processing Model: The beginning of designing the mean-shift image classification model.
5. Running Data Through Model: Using the collected data to test the proposed model.
6. Testing: To see if the proposed model is effective enough.
7. Drawing Conclusion: To conclude the experiment.

3.2. Data Source

This study used an open sourced database where there are around 12.000 images within the dataset used. After preprocessing the data and cleaned what are good for the test and could be ran in the device used to make the model, the final data used are only 100 images. These images include pictures of various marine animals in different background like open ocean, corals, and plain ocean bottom.

3.3. Classification Methods

This experimental study focus in mean-shift algorithm application in image processing using Google Colab as the IDE.

1. Google Colab: an online IDE used to create and running the model.
2. Mean-shift algorithm: an unsupervised classification method, the focus of this study [5].
3. Python: a high-level programming language used to create the model [8].
4. Segmentation: separating image into regions or segments based on the similarities in color, intensity, or other features [8].
5. OpenCV: an open-source library used for image processing tasks such as filtering and transformation [10].
6. Matplotlib: a library used to show the graph of the result of the experiment in Python [11].

4. Result

4.1. Data Preprocessing

Before begin the entire process, the dataset has to be curated due to the dataset having similar images and the limitation of the device used. The computer and the internet for running the model could not handle over 100 pictures at once, so it is being curated into only 100 images for the dataset. The images chosen are from various animals, ranging from vertebrates to cnidarian. These pictures also include several environments such as corals, ocean floor, and open water, to see how the mean-shift could perform in a more complicated background.

4.2. Image Preprocessing

In this study, before running the model into the mean-shift algorithm, the images must go through several preprocessing. The very first step is to uniform the size of the images. The images are reduced to just 200 pixels in height. This uniformity will make it easier to see how the algorithm will perform. After that, a gaussian blur is added into the images to reduce noise since most of the images are quite low in quality, before finally being ran into the mean-shift model.

4.3. Model Result

To make it easier and not very confusing for untrained human eyes to see, the images went through a black and white scale to see the actual value of the image, so that it is easy to notice that some colors can look different, but it has the same value as the other color, thus makes the mean-shift cluster them into one section. The mean-shift algorithm creates clusters within the image, separating colors based on their value. After that, edge outer line is applied to make it easier to see how the mean-shift clusters the image compared to the original image.

There are around 100 images tested in this experimental model, but this paper will only show two very distinct result of images with high and lower contrast. In general, this experimental study suggests that the mean shift based segmentation approach is quite capable of producing meaningful separated section in underwater images. However, the quality of the results still pretty much depending on the image's contrast and the complexity of the background. Higher contrast images tend to generate clearly defined segments, while images with lower contrast overcome greater difficulty due to limit of the visual distinction between the object and background. Despite having to overcome some challenges, the algorithm still able to highlight most dominant structures in the images without having to rely on supervised learning, indicating a potential applicability in underwater imaging with diverse conditions.



Image: 1347978273_954c423df0_o.jpg

Fig. 2: Mean-shift performance in high contrast image of a sea slug

Figure 2 shows how this model performs in a higher contrast picture. It could easily detect and trace where exactly the sea slug is. It easily makes small cluster that highlight the sea slug since sea slug has very distinctive colors compared to the rest of the background which seems to be a floor of coral and small rocks.



Fig. 3: Mean-shift performance in low contrast image of a whale shark

Figure 3 shows how this model performs in a lower contrast picture of a whale shark. The mean-shift group the entirety of the whale shark to its surrounding water. This shows that the water and the animal actually have similar value, hence why it is being sectioned into the same group.

5. Conclusion

Based on the implementation and evaluation conducted in this study towards the mean shift algorithm for image processing, the mean shift algorithm performed its effectiveness as a non-parametric, unsupervised segmentation method for underwater marine imagery. It works by clustering the pixels using color features, so it is able to separate marine organisms from background elements such as sand and coral, with sensibly smooth segmented regions. These characteristics are important for further analysis stages such as pattern recognition model, and indicate that mean shift able to serve as a feasible unsupervised machine learning approach for underwater image segmentation.

However, the mean shift algorithm is still dependent on some parameters, particularly the spatial and color bandwidths, that could directly influence segmentation quality. But it is still not as strict as other algorithm. Incompatible values of the parameter may lead the result to under-segmentation or over-segmentation. Images with very low contrast hover challenges due to minimal color differences between the objects and its background. Further study on this research may be focused on how to adapt the bandwidths and testing out several different number for the parameter, or integrating this model with a more complex model with other image processing techniques and more features to improve the image segmentation performance in complicated images with extremely low contrast or quality.

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