Cage Detection in Surveillance Videos of Offshore Fish Production Plants

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Abstract. *Cage detection is an important step in assessment of offshore fish production plant status. In this paper we propose an algorithm for cage detection in plant surveillance videos obtained using an unmanned aerial vehicle. Since a cage is approximately circular, we approach its detection as a shape recognition problem. However, a cage is susceptible to deformations due to e.g. sea currents and perspective projection during the video acquisition. Consequently, traditional circular shape detection algorithms based on Hough transform fail on this problem. We propose an algorithm based on using the slope of the tangent to the cage boundary and show that it successfully detects the cage in test videos.*

1 Introduction

In this paper we consider the problem of object shape detection, in particular circular objects detection. Knowing information about shape of some object can be very useful in different areas of computer vision, such as image classification, image retrieval, recognition of different objects, video surveillance etc. Therefore, the problem of detection of different shaped objects has become very important field of research in industrial vision applications [1], [2].

There is a vast amount of papers related to automatic visual feature extraction. A huge growth of technology in the past few decades, accompanied by growing of demands for its use in industrial applications, were motivation to researches to investigate in this area.

First papers in this field were written in 1970s. They were mostly based on low level feature extraction. One of the most commonly used low level feature extraction methods is edge detection, since it is an initial step in many object recognition systems. Edge is defined as a boundary between object and its background, and as such it is very important for object detection. Different edge detection algorithms are described and compared in [3], [4]. Other methods for low level feature extraction are corner detection and curvature extraction and some basic algorithms for obtaining of these features have been described in [4].

Second approach is extraction of high level features. By high level feature we mean detection of a shape of an object, its size, and calculation of other parameters that are important for understanding of such object (for example, diameter for circles, position, orientation, etc.). Since different geometric shapes are present in human made environments, for a number of tasks it is very important to have automatic identification and extraction of such shapes. Moreover, feature extraction process could be viewed as similar to the way people perceive the world. Even the babies are thought to recognize basic geometric shapes such as squares, triangles and circles. Knowledge about these basic shapes can be very useful later for understanding of complex forms, which can be observed as a composition of different simple structures.

Problem of detection of circular and ellipsoidal objects has been in focus of research in shape recognition community for a long time. First methods were mostly based on using of deterministic techniques such as Hough transform [5], which had very high storage and computational requirements, especially for high-dimensional applications. In order to decrease technical requirements for this method, new variations of Hough transform, such as randomized, probabilistic and fuzzy Hough transform, were introduced [6], [7]. As an alternative to this probabilistic methods, different stochastic methods, such as random sample consensus, simulated annealing, genetic algorithm and its variations, were presented. In [8] adaptive bacterial foraging optimization algorithm for circle detection is presented. It is shown that its performance is superior to Hough transform and generic algorithm methods.

In this paper very simple algorithm for detection of cage in surveillance videos of offshore fish production plants is proposed. The cage shape is roughly circular but due to elastic deformations and perspective projection in the video its shape deviates from the circle. Therefore, traditional methods for circle detection give poor results. Our approach is based on using the slope of the tangent to the cage boundary. We show that it succeeds in cage detection in cases where the methods based on Hough transform fail.

2 Material and Methods

The industry these days spreads all over the world, sometimes in places where it is uncomfortable and unhealthy for people to work for a long time, such as polar regions, sea, warm desert regions, nuclear plants etc. This is the reason why it is good to have autonomous systems for surveillance of production plants. These systems control production and operating processes automatically, test system and calculate different parameters, and, if necessary, rise some alarms to inform the operators about its state.

In Fig. 1 one of many offshore salmon production plants in Norway, Rataran is shown. Norway, as a world's leading producer of Atlantic salmon [9], is

Fig. 1. Offshore salmon production plant Rataran (Norway)

Fig. 2. One frame extracted from the video used for testing of algorithm

facing many challenges in process of fish production that can have huge influence on production loss. Among many of them, such as poor handling of the fishes during different operations as fish transport and crowding, cage defection has the great influence on production loss.

Cage defects may affect production loss in many ways. If the outside net of the cage is broken, the fish from the cage can get away. However, through that hole other species of fishes from the sea may enter the cage and use food, or even worse, eat the salmon from the plant. All this may be stressful for fish, and could trigger an increase in mortality.

There have also been a lot of research on how the cage should be designed in order to resist as many different forces that have influence on its shape (sea currents, fish grouping on one side of the cage, etc.), and also doesn't have huge influence on fish movement and behavior. It is concluded that the best shape of the cage should be circular [10], which can be visible in Fig. 1 where the white curve represents one cage. Other purposes of the cage are to keep other species of fishes and predators away from the food and salmon in the cage, as well as to stop different diseases which could be brought to the cage by sea current, such as lice, etc. This is the reason why automatic inspection and surveillance of the cage shape can be used for calculation of some parameters that may influence production process.

The idea of this paper is to test different algorithms for detection of the shape of cage. Since the cage is roughly circular, the problem of cage detection becomes the problem of circle detection.

First we tested two different versions of Hough transform, as one of the most popular techniques for shape matching and extraction.

Next, we introduce a very simple shape matching algorithm, which can be also used for shape detection, or even for detection of convexity and concavity points in an object.

We tested our algorithm on images we extracted from videos we get from SINTEF Fisheries and Aquaculture in Trondheim. Videos are gathered using a drone, which was flying over the cages, filming the fish activity and cage characteristics. One frame from video is shown in Fig. 2.

3 Tested algorithms and results

First step in the process of circular object detection was segmentation of a region of interest. Region of interest is defined as a part of image that consist of an object of interest and additional features. In Fig. 2. we can see that cage (object of interest) could be very easily separated from the background (water) using only a simple threshold, since the cage is much brighter than the water. In order to calculate its value, we chose Otsu method [11] for threshold calculation. As a side effect of segmentation with this threshold in extracted region are also included a boat connected to cage, other white lines on image, other cages and even reflection of the sun in the sea. Using mathematical morphology and making assumption that whole cage should be visible on image, we easily remove other cages, lines and reflection. As a result of segmentation we extracted the mask which consists of object of interest and additional features (boat and lines in this case) that are connected to object or located very close to it. Since the object of interest is nearly circular this features could be classified as distortions of an object that should be removed. In order to detect only cage in the mask we tested different approaches for circle detection.

3.1 Hough transform

As we mentioned before, Hough transform is one of the most popular techniques for location of the shapes in an image. In particular, it is very often used to extract lines, circles and ellipses. The implementation of Hough transform defines a mapping from the image point space into Hough (accumulator) space, based on mathematical function that describes the target shape. As an output parameter of transform, we get the coordinates of center

Fig. 3. Cage detected using phase coding method

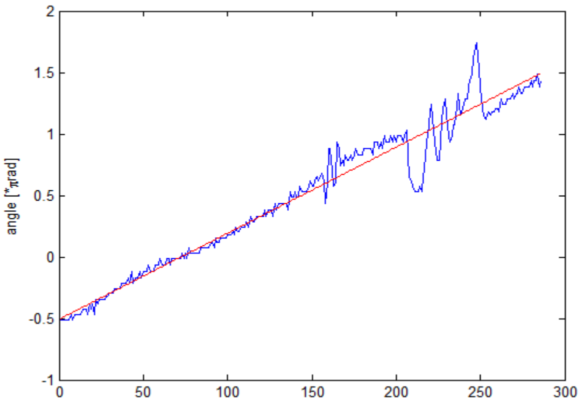

Fig. 5. Calculated angles (blue) compared with reference (red)

and radius of a circle detected in image. For this purpose we tested two different approaches of Hough transform: Phase coding method and Two-stage circular Hough transform. The main difference between these two methods is in the manner by which the circle radius is computed.

A. Phase coding method

This method uses information about edge orientation in order to reduce dimensionality of the parameter space from three to two dimensions. It also introduce use of complex values in accumulator array, where each value contain information about centers of circle (magnitude information) and radius information encoded in phase of the array values. The results displayed in [12] shows that this technique reduces mean and variance of the background level contained in accumulator, and also decrease width of the peak.

Results obtained using this method are depicted on Fig. 3. As we can see, none of the circles extracted using this method, does not represent the shape of the cage well. Reason for that is that cage is filmed in 3D space with the camera that is not fixed, in relation to cage. Also camera does not stands above of the cage, and it moves constantly, and changes in the angle of filming frequent which makes influence on extracted shape of the cage (if you look at the circle with angle different than 90º you will see a ellipse). All this affect this algorithm to achieve tolerably results.

Fig. 4. Cage detected using two stage method

B. Two - stage method

Also known as the 2-1 Hough transform [13], finds parameters of circle in two steps. First step starts from the assumption that center of a circle must lie on the normal on each edge point of the pixel. Point in which the most of the normals intersect is actually a center of a circle. In the second step, histograms of distances between potential centers and edge pixels are calculated. One histogram is computed for each potential center. As a radius was selected distance with biggest number in histogram.

Results obtained for this method are shown in Fig. 4. We can see that this method is also very dependent on the angle of the filming and it also does not achieve good results, in terms of cage detection.

3.2 The proposed method

This method is based on calculation of an angle that the tangent to the object closes with x axis. The following procedure is conducted. After segmentation of the mask we extract coordinates of its boundary pixels and put them into an edge vector. In order to increase number of different values of an angle, and increase speed of an algorithm, we did subsampling of edge vector with fixed step. Now, for each segment, defined with two neighbor pixels in this vector, we calculate an angle of the tangent using (1), where x_n and y_n define the coordinates of the n - th pixel in the subsampled edge vector. Now we have calculated the angles of tangent for each segment, and assigned them to point located in the middle between two end points of that segment. Computed angles are depicted in Fig. 5. (blue line).

$$angle_n = \arctan \frac{y_{n+1} - y_n}{x_{n+1} - x_n} \quad (1)$$

Next step is the comparison of computed angle vector with reference shown in Fig. 5. (red line). Reference is defined with equation that describes dependence of the length of curve arc from the angle (this dependency for circle is linear and it is defined with $l = r * \theta$, where r is a radius and θ is an angle). Huge deviations of the angle from the reference defines the points where are located protrusions and recesses on the circle. Those points for which this deviations are bigger from some threshold are automatically omitted. Now, we have a vector of points in which tangents constructed on object can be

Fig. 6. Circular object detected using angle information only.

Fig. 7. Cage detected using joint angle and radius information

tangents on desired object or could be parallel to ones that will be constructed on object we want to detect (in Fig. 6. we can see that tangents calculated for left side of the boat will be approximately parallel to the ones calculated for a cage in that region). Boundary of the cage is drawn connecting the extracted points with linear segments.

In order to eliminate the points located on the side of the boat, we calculate distances between the calculated center of the cage and edge points. Center is calculated in the same way as in two stage method. Since the distances of points detected on the boat are higher than ones on the cage, we finally eliminate those points. The obtained result is shown in Fig. 7. We can see that red line very well represents the boundary of the cage.

4 Conclusion

In this paper we propose a very simple method for detection of nearly circular objects and assessment of their circularity. Algorithm is tested on images extracted from the video used for inspection of an industrial process. Achieved results are compared with ones obtained using Hough transform for circle detection, and shows that this method is much better for use in area where it is required to detect single object. With this algorithm will probably be possible to detect other geometrical shapes just changing reference vector in dependence of which shape we want to detect.

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