Image Segmentation and Verification Based on Machine Learning for Vision Inspection of Chicken Slaughtering

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Abstract. According to the Islamic Law, one of the procedures in halal slaughtering of chicken is the step of severing the trachea, esophagus and both the carotid arteries and jugular veins to accelerate the chicken’s bleeding and death. Syariah Compliance Automated Chicken Processing System (SYCUT) uses the Vision Inspection Technology to detect and classify whether a chicken is halal or not. The lack of quality and halal assurance in chicken processing industry made it a need to produce such technology. The system implements image processing techniques and artificial intelligence approach, particularly the Viola and Jones object detection framework for esophagus detection. The results of the experiment from two different sites are 81.8% and 55% respectively. The detection module shows a result of 95.6% and 93.5% also from two different sites which are accuracy as good as a human personnel.

1. Introduction

According to the Islamic Law, one of the procedures in halal slaughtering of chicken is the step of severing the trachea (halqum), esophagus (mari’) and both the carotid arteries and jugular veins (wadajain) to accelerate the chicken’s bleeding and death [1]. In Malaysia, the halal certifying body, Jabatan Kemajuan Islam Malaysia (JAKIM) requires that several criteria be met [2][3]: both the slaughterer and Muslim halal inspector must be practising Muslims who are mentally sound and past the age of puberty; the slaughtering knife or blade must be sharp and free from impurities; the trachea, oesophagus, carotid arteries and jugular veins must be severed, and death must be ensured before further processing occurs.

The current halal authentication process is done manually by trained halal checkers, seemed laborious and some of the chickens are not inspected due to the absence of the halal checkers at any particular time during the process. Regular monitoring on the compliance to halal slaughtering procedures, hygiene and food safety issues as well as irresponsible use of fake halal certificates require massive manpower and high costs. JAKIM enforces and perform regular checks to ensure that the practices of the slaughtering process in the slaughterhouse are syariah compliance, however there is a possibility of irresponsible use of methods that are not according to the halal guidelines outside the inspection period.
A Syariah-Compliance Automated Chicken Processing System (SYCUT) has been developed to monitor the slaughtering process of the chicken to ensure that the chickens are slaughtered according to syariah [4-5]. The system consists of an electronic identification for detection of the chicken and a vision system to capture the images of the chicken being slaughtered. The system also consists of a software which uses image processing and artificial intelligence algorithms to detect and classify the halal and non-halal chickens.

This paper describes the methods of image processing and machine learning techniques for the halal and non-halal chicken classification used by SYCUT. We presented the methods used for vision inspection system of the slaughtering process, specifically focussing on the detection of the esophagus which is the indication that the chicken is slaughtered properly which is according to the syariah. Various stages of image processing and image detection are performed in order to improve the accuracy of the system. The occlusion, illuminations and noises due to splatering of blood are some of the challenges of the systems which affect the accuracy.

2. Methodology
In the SYCUT system, a slaughtered chicken will pass through different stages of the slaughtering process including the vision inspection system which will detect the aesophagus thus classifying the status of the chicken whether it is halal or non-halal. The SYCUT vision inspection technology, is designed to provide real-time chicken’s esophagus detection and verification for still and video images. It operates on images and videos data given their file path, camera USB, or even IP cameras. The system also provides an easy-to-use application programing interface (API).

There are two main parts of vision inspection system which are image acquisition and esophagus detection. In order to increase the overall image quality, an image pre-processing technique is used, in a way of reducing the noise and standardize the image contrast. Then, image segmentation is done to separate the background from the foreground. This is important to reduce false positive esophagus samples. Finally, the detection stage will locate esophagus in the foreground image. The summarized components can be seen as in Figure 1.

![Figure 1: Major components used in SYCUT Vision Inspection System [4][5]](image-url)
2.1. Image Acquisition and Pre-Processing
The vision inspection system can accept both still image and video image as input. It will perform sampling in the case of video images. The output of image acquisition is a still image of the chicken. The images acquired are pre-processed by using low pass filter (LPF) which passes low frequency pixel variation while attenuating high frequency variation. This is done to suppress the noise from the raw acquired images and standardizing the images contrast due to using different imaging equipment. This noise is often added to the images due to analog to digital conversion especially in environments with poor illumination (such as chicken factory). The effect of applying the LPF filter is shown in Figure 2.

![Figure 2](image)

**Figure 2:** Original image (left) and image after LPF filter (right)

The segmentation process consists of colour space conversion plus morphological technique [6]. In this process, firstly the images of the slaughtered chicken and background are to be separated. In order to do this, the RGB colour space image is converted to YCbCr colour space. The colour space in YCbCr colour space is encoded in terms of luma (Y) and two blue-difference and red-difference chrominance components (Cb and Cr). Figure 3 shows the process of decomposition filter.

![Figure 3](image)

**Figure 3:** Decomposition of filter image (a) to (b) Y, (c) Cb, (d) Cr [7]

Then, thresholding is applied to segment the slaughtered chicken from the background. Determining a fixed threshold value is not possible due to changes of imaging system, lighting ambiance and camera settings Therefore, an Otsu thresholding technique [7-8] is used to dynamically determine the threshold value based on each image’s statistics.

Next, some unwanted holes in the foreground and background are fixed by using morphological technique to erode the holes from background and dilate the holes in foreground. After we get a mask which classifies the foreground and background by a binary image, we multiply the mask to each R, G, and B channel element-wise. This then results in the final segmented image of separated foreground and background as shown in Figure 4.
2.2. Detection
The image fed into detection stage is a low noise and high contrast image where the position of the chicken is known. The goal of this stage is to find the position of the chicken’s esophagus. The idea from Viola and Jones Object Detection Framework [9] is used. This framework is chosen due to its fast detection rate for real-time application. The three ideas introduced by [9] in their object detection framework are the integral image to compute Haar features efficiently [10], boosting learning (Adaboost) which is used to develop strong classifiers as a linear combination of weak classifiers and the attentional cascade structure for fast negative rejection [11]. The following sub-sections describe framework of [9] briefly and its implementation in SYCUT as reported in [11].

2.2.1 Features and Integral Image
Based on [9], a set of features that are reminiscent of Haar Basis functions as shown in Figure 5 are used. The problem with these rectangle features is its size which is quite large. In order to compute these features very rapidly in many scales, integral image representation of images are introduced. In general, the following equation can be used to compute integral image at location \( x, y \):

\[
ii(x, y) = \sum_{s_x, s_y} i(x', y')
\]  

(1)

Where:
- \( ii(x, y) \) - integral image
- \( i(x, y) \) - original image

By using the following recurrences, the integral image can be computed in one pass over the original image as shown by VJ:

\[
s(x, y) = s(x, y - 1) + i(x, y)
\]  

(2)

\[
ni(x, y) = ni(x - 1, y) + s(x, y)
\]  

(3)

where \( s(x, y) \) is the cumulative row sum, \( s(x, -1) = 0 \) and \( ni(-1, y) = 0 \).

These features are selected by using adaptive boosting algorithm (AdaBoost). These features are obtained through a small modification on existing AdaBoost procedure by constraining the weak learner. This way, each weak learner can depend on only single features. The final classifier is the...
linear combination of these weak learners which forms the strong classifier. A method of degeneration decision tree (cascade) is used to limit the number of features computed per sub window. Decision nodes for the tree are built by using several stages as shown in Figure 6. The sub-window is rejected if any stage in the tree rejects it.

![Figure 5: Examples of rectangle features. A and B are two-rectangle features while C is a three-rectangle feature and D is a four-rectangle feature. Adapted from [9].](image)

![Figure 6: Attentional cascade. Adapted from [9]](image)

Each stage of classifier is trained to detect nearly every objects of interest while rejecting a small number of non-object samples [9]. Specifically, according to our case, each stage is designed to reject majority of the non-esophagus samples while falsely eliminating a few esophagus samples.

Lastly, verification is done using Support Vector Machine (SVM) [14-15]. Each image of candidate esophagus is given to SVM classifier and are labelled as “True” or “False”. The final detected esophagus is seen as in Figure 6 (b).

![Figure 7: Finding esophagus in real time with approximately 50ms elapsed time [5](image)

3. Experimental Result and Discussion

This section explains the experimental result and analysis. The database of images are those randomly sampled from two Malaysian abattoirs which are Az-Zain located in Selangor and 3P located in Johor. For the purpose of the experiments, a total of 265 sampled images are taken from Az-Zain and 1800 images are taken from 3P sites [12]. There are three primary goals to the experiments done. The first goal which is obtaining the overall accuracy of current system on both sites gives us a general idea of
how good the system works. The second goal being the evaluation of the system in algorithmic perspective shows how efficient and robust the system performs on different sites and different lighting situations. The third goal which is identifying the limitations caused by external environmental factors allow us to better understand the problems faced in factory environments and how we can overcome them.

3.1. Overall Performance
Assuming that most chickens are slaughtered the halal way, there should be a detected esophagus on each chicken in an image. Based on this criteria, an experiment is done to measure the overall performance of the systems in both sites. The results tell us how efficient the current system is.

A 0-1 loss function is used where if the system does not detect the esophagus, an error of 1 is added to overall error [13]. The overall performance can be seen from Table 1 below. If the overall performance is 81.8%, then it means that out of 100 chickens, the system is able to detect almost 82 of them being halal despite any other environmental factor.

It is concluded that the inefficiency of the overall system can be caused by the esophagus detection stage or the image acquisition stage. There is a big gap between Az-Zain and 3P sites. Experiments for the individual stages help us to identify the problems further.

| Sites | Overall Performance |
|-------|---------------------|
| Az-Zain | 81.8% |
| 3P | 55.5% |

3.2. Performance of Esophagus Detection
This section aims to evaluate the system’s performance without consideration of any external factors. The set of images are manually chosen to make sure that those images contain visible esophagus which a human expert can detect. An ideal detection system should be able to detect the esophagus in this set of images and does not detect non-esophagus area as esophagus.

The three terminologies used in the result analysis are False Positive (FP), True Positive (TP) and False Negative (FN). Below is the explanation of these terminologies based on the project’s case:

- **FP**: System mistakenly detects a non-esophagus area as esopagus.
- **TP**: System correctly determines an esophagus in an image.
- **FN**: System fail to detect an esophagus.

The detection system experimental result is presented by Detection Rate (DR) and False Positive Rate (FPR).

**DR** is the ratio between numbers of times an esophagus is detected correctly by the system to the number of esophagus determined by human expert. The following equation captured the relation between TP, FN and DR [14]:

\[
DR = \frac{TP}{TP+FN}
\]

**FPR** is the ratio between false positive alarm and total number of sub-windows [15]:

\[
FPR = \frac{FP}{FP+TN}
\]
An ideal detection system should have DR of 100% and zero FPR. The result of the experiment is recorded in the Table 2 below. The detection stage is able to perform well under reasonable variation of illumination and pose.

Table 2. Esophagus detection accuracy [12]

| Sites   | Az-Zain | 3P    |
|---------|---------|-------|
| Detection Rate | 95.6% | 93.5% |
| False Positive Rate | 1 in 200,000 | 1 in 250,000 |

3.3. Performance of Image Acquisition

Next, the image acquisition stage which is one of the main stages of the vision inspection system was tested for its performance. An ideal image acquisition system should have 0% invisibility rate. The test shown that the esophagus invisibility rate which mainly caused by pose variation and occlusion affects the detection performance. The results in the Table 3 below shows that 40.7% of the images taken in 3P site has no visible esophagus to be detected by a human agent.

Table 3. Invisible rate [12]

| Sites   | Az-Zain | 3P    |
|---------|---------|-------|
| Invisible Rate | 14.4% | 40.7% |

In this case of invisibility, the reasons to invisible esophagus in those images and their percentage are Table 4 below.

Table 4. Reason of invisible esophagus [12]

| Sites   | Az-Zain | 3P    |
|---------|---------|-------|
| Pose Variation | 79.4% | 62.9% |
| Occlusion | 16.2% | 37.1% |

The experimental results show that the detection performance is promising but the image acquisition performance proved to correspond to most of the failures of the system. There were some experimental changes done to tackle the problems and decrease error. The proposed solutions are in regards to algorithmic and physical structure perspective.

One of the solutions is by adding another light source to the lighting system. The amount of light hitting the chicken is controlled to about 60-70 foot candles. The new light source is placed at the opposite direction of the previous lighting system to balance shadows. The invisibility rate was decreased by 13.6% by using this lighting system while the overall system accuracy increased by 11.9%.

Next, the proposed solution for overall system’s performance is to use video processing. This is proposed in accordance to the idea that the system is able to decide better with 60 different images rather than just a few images of a certain chicken. The problems like pose variation or chicken orientation is likely to have more chance of esophagus detection in case where the chicken head keeps turning around on the conveyer. Other than that, there is also a need for tracking the individual chickens and assigning an ID to each chicken.
Additionally, the next proposed solution is to use multiple cameras to solve the pose of chicken’s neck problem. Adding another camera with different angle of view can capture the chicken’s neck in another angle, with hopes that the esophagus can be seen. On the other hand, adding the number of cameras doubles the processing time and increase the system’s complexity. Experiment done by adding another camera on the right side or left side yield an increase of 2% or 20% improvement in the overall system performance respectively.

Improving the image acquisition performance is a challenging problem and thus these and other possible solutions should be analysed and experimented further to help increase overall accuracy of the system.

4. Conclusion
This paper presented the technical description and performance analysis of the vision inspection system of SYCUT which mainly consists of two parts which are image acquisition and esophagus detection. The output of image acquisition is a still image from the slaughtered chicken. The chains of stages to perform the esophagus detection are by means of LBF for the pre-processing, RGB colour space and Otsu thresholding and morphological technique in the segmentation process. Furthermore, Viola and Jones framework is used which has a fast computation for a real-time application in the detection process, utilizing Haar features and boosting learning for weak classifier and attentional cascade structure for fast negative rejection. Lastly, verification is done using Support Vector Machine (SVM).

The experimental results yielded a promising performance of 95.6% and 93.5% detection rate by the detection stage but an unsatisfactory performance by the image acquisition stage which saw the 16.2% and 40.7% invisibility rate. The report mentioned in this paper proposed solution to improve the overall performance of the system which was 81.8% and 55.5% from the experiment results. The improvements and possible solutions are the change in lighting control, the use of video processing method instead of images and implementing multiple cameras on the site.

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