Object Detection without Color Feature: Case Study Autonomous Robot

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***Abstract*—Object detection is a major area of concern and such method has been extensively used in numerous applications whereas the success of using color information has been continuously reported with less attention given to several issues, such as the lengthy process to calibrate color, color fading, and others. Nonetheless, the need of such application that does not necessarily rely on color information has seen a hike due to the mentioned issues. In fact, some of the desirable solutions are those that take less computation time, as well as those that provide higher accuracy and scalability for a large number of objects in a scene. One application that requires such solution is in a game playing by autonomous robot. This paper suggests a novel patch carried by autonomous robots with relevant detection algorithm using contour detection and geometric moment without using the color feature.**

***Index Terms*— contour detection, image processing, object detection, without color feature**

I. INTRODUCTION

Object detection without color feature receives less attention by previous researchers due to a limited research area that needs this kind of approach. However, limitations over the use of color features gradually increasing and reported by various applications such as signboard detection [1], autonomous robot [2], pedestrian tracking[3], building detection [4]and others. Hence, recent researchers have displayed an increased interest in avoiding color information for detection of objects mainly because color is sensitive towards changes in the environment.

In the early 1980s, theories concerning object detection have suggested that objects for detection generally require shape information, but not necessarily color information. Besides, [5] has provided a hypothesis that without additional information about color, objects can still be detected through computation of its structural description. Meanwhile, another study revealed that if the shape of an object is distinctive, then the role of color can be dismissed [6]. Moreover, [5], [6] depict that color diagnostic is described as efficient based on the degree to which a specific object is associated with color. For instance, a pineapple is associated with yellow, while snow is related to white. For both objects, color information is strongly recommended, however, for other objects like building and vehicle, color association becomes meaningless and thus, do not necessitate color information. Furthermore, objects are classified into two main categories [6]; natural and artifact, whereby artifact is man-made, whereas natural is not. As such, color is highly associated with natural objects, but not with artifact. This non-dependency aspect makes detection for artifact faster without the need for color information.

In fact, the three common methods used in road sign detection are color-based, shape-based, and hybrid methods [7]. The color-based method has been reported to be rapid, but the computation time is greatly increased due to multi object traffic scenes. Besides, the red-green-blue (RGB) image captured on camera needs to be converted into color space like hue-saturation-intensity/hue-saturation-value (HIS/HSV) with the assumption that it is invariant to changes in illumination.

On the other hand, some recent studies pertaining to game playing autonomous robot also displayed increased interest to develop a system that disregards color segmentation. When the global system uses color segmentation to detect robots, the aspect of color must be calibrated in advance to improve the robustness of the system. Hence, when the resulting calibration is not robust enough, recalibration is required, thus hampering the overall performance. Another glaring issue is the color patch placed on top of the robot's head, which is not scalable for many players. Hence, the use of color pattern fails to address issues related to scalability. Moreover, the previous works by [8] described that color segmentation in robot detection has been replaced with

Manuscript received January 5, 2018; revised January 30th, 2019.

doi: 10.18178/ijmerr.8.4.646-650

continuous dynamic programming (DP) matching or General Hough transform to determine the location, the identity, and the orientation of the robot. The prior study, however, was limited to six pattern designs for six robots, which also failed in addressing scalability issues. Collectively, these ongoing works have suggested a non-color object detection system for an autonomous robot with the potential to solve the glaring scalability issue.

As such, in order to meet all these requirements, the proposed algorithm in this paper has applied several approaches based on the following methods:

1. *RGB to the Grayscale image*: The grayscale image is easier to operate than the RGB image. Besides, it has been frequently used for enhancement and edge detection [9]. Usually, this step is executed when color information is not needed [10].
2. *Threshold the Gray image*: The transformation of gray image to binary image marks the pixels that belong to background and foreground images [11].
3. *Contour detection*: Obtained from edges as object contours, these edges are connected to obtain a closed contour. This requires a linking process that seeks to exploit the curvilinear continuity[12].
4. *Contour extraction* Retrieves the connected component from the binary image and labels them [12].
5. *Feature Extraction*: Extracts the desired features that lead to the relevant image to obtain the desired information[13].

The rest of this paper proceeds as follows: Section 2 provides an overview of several related studies concerning object detection without color information, as well as the use of contour and moment for some applications. In section 3, describes the implementation results of object detection. Lastly, section 5 concludes the research finding.

II. Related Works

In developing an algorithm without color information, only a handful researches are available that clearly mention essential keywords, for instance, *colorless*, *non-color based*, *without color information* or *without color segmentation*. However, a huge amount of literature [14]–[16] available on edge, line or shape detection had been looked into without incorporating the notion of color information. This strongly points out that color information is insignificant for object detection based on edge, line or shape. The following sections elaborate the related works that have avoided colors in their applications, as well as the current use of contour and moment.

A. Non-color Based Detection

Some related research papers have disregarded the idea of color information and took a leap by proposing other varied approaches. For example, two modules in the algorithm introduced by [7] consist of detection and classification modules. The detection module applied the Multi-layer perceptron neural network to detect road signs, whereas the classification module employed a similar concept to define the types of road signs. As a result, the two modules displayed positive findings in handling particular situations like outdoor light condition and faded paint on sign after an extended exposure to sun and rain.

Meanwhile, the work presented by [17] introduces a driver support system for Road Sign Recognition System (RS2) with a colorless algorithm that applies the Hierarchical Spatial Feature Matching (HSFM) to detect road signs. The work used grey-level features instead of color ones with two variants employed in the system; a single classifier and decision tree. The proposed algorithm is meant as an alternative during bad illumination conditions.

On the other hand, another research by [18] specified that in the field of an autonomous robot, the visual cues would be removed soon, hence highlighting the importance of new vision algorithms to manage the situation [19]–[22]. These visual cues refer to the color used in the robotic game, such as the color patch placed on top of the robot's head as a marker and the ball. The method was suggested to detect the ball without specifying any color, as well as by adopting Haar wavelet and classifier. The successful result showed 91.64% detection rate with a false positive rate of 0.015%, leading to a total rate of 97.86%.

Similarly, researches on autonomous robot conducted by [8], [2], [23] also excluded colors from their algorithm. As such, [8] introduced DP to avoid color segmentation, but an employed pattern matching method to identify the position and the orientation of the robot simultaneously. The DP similarity value can provide the optimal route using backtracking to estimate the orientation of the robot. Hence, this paper depicts the substitution of color segmentation with DP method, which had been robust to variation in light conditions.

Meanwhile, [2] highlighted that the critical weakness in robotic soccer in the global vision system was due to continued reliance on color, which had been predefined. The author then introduced a pattern as a marker using a circular shape with wedges on top of the robot for detection. The algorithm detected this marker to define both identity and orientation. However, the work could only detect six robots that failed in addressing the scalability issue raised by [20]. This weakness leads to the opportunity to design a better pattern as a marker for many robots.

Other than that, [20] introduced detection of object orientation and identity without any additional marker, but only by using the shape of the robot. The shape of the robot, combined with Hough transform, was able to detect both identity and orientation. The author claimed that the color on robot pattern did not scale to large teams of the robot, as estimated by more than eleven players. Hence, the author only used a single marker on the robot to address this issue.

Another approach suggested by [23] aims to solve a problem in robotic soccer by detecting a colorless ball. The author suggested Contracting Curve Density (CCD) algorithm that fit the parametric curve into image data.

This algorithm was identical with active contour. In fact, two steps were revealed; the local statistics of RGB value and the model parameters based on the RGB statistics. The author also clearly commented that the work used shape-based information instead of color.

As for this paper, the proposed algorithm was built based on the works carried out by [5], [6], and [20], but with a varied pattern design from [2] that serves as the improved work of [20]. Besides, this paper employed the work found in [24] as a reference to compare the features and the performance.

B. *Contour Extraction and Geometric Moment*

Previous researchers have emphasized the challenges in contour detection, as well as the need to combine with another technique to tackle any raising issue. For instance, [25] combined contour detection with a descriptor to support mobile robot in recognizing objects in a specified environment. Another example is suggested by [26], who combined contour detection with Pseudo Zernike Moment (PZM) to overcome the challenges of contour detection, such as noise, shifting, scaling, rotation occlusions of objects, etc. As for [27], the active contour approach was used to detect and to track multiple objects, inclusive of periodic and non-periodic motions, using color evolution in the process. Hence, this approach required a combination of active contour and Markov Random Field theory to address the evolution of color contour.

Collectively, these studies have outlined a critical role of contour in object detection and the necessity of combining with other techniques to address several problems. Hence, this study proposes a novel approach in combining contour with a geometric moment for object detection without color information because the moment has been widely used in feature extraction.

III. Experiments and Discussion

In the experiments, the customized pattern in autonomous robot was selected as far as this study is concerned. Some researchers have named the customized pattern as *robot patch*, *robot marker* or *robot hat* because it is placed on top of the robot's head. Moreover, the design of the pattern is definitely fundamental due to its roles as an object detection mark. Moreover, the selection of robot patch as a case study is significant due to the use of autonomous robots in the near future, which has the tendency to raise issues related to non-color detection and face scalability in patch design. When the number of object increases, more patterns are required while the space provided is limited.

Previously, each patch design determines a distinct object identity, which means that if five different objects are present in a scene, then it needs five different patterns. If the number of objects increases to 11 in the future, they would require 11 different patch designs. Thus, it is desirable to discover a new flexible and scalable approach [8], [20] in order to tackle a large scale number of objects. This is especially crucial for a non-color based system for it is rather challenging to use 11 different shapes within such confined space. Hence, the patch design in this study adopts an identical pattern design for all objects, as illustrated in Fig. 1.

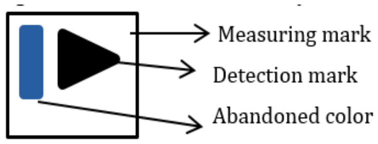

Figure 1. Pattern design

Additionally, this type of design offers flexibility and scalability since the identity of each pattern is assigned by the algorithm, but not by the pattern. Moreover, although this idea is novel, it has been mentioned by the following papers in 2015; [5] and [20], to address several issues concerning scalability in an autonomous robot. The pattern design portrayed in Fig. 1 has two important marks, i.e. measuring mark and detection mark. A small section is used for color as it is a requirement in the game that plays an autonomous robot. Measuring mark assists the algorithm in finding patch through contour detection process, while the detection mark guides the algorithm in searching the location and the orientation of the object. Besides, the identity of the object is assigned by the algorithm using moment.

```
Algorithm
detection = 0
read (source_image)
rgbtogray (source_image)
threshold (source_image)
for all element (i) do
     find_contour (source_image)
     if (contour_line =4) // rectangle detection
          extract_contour (source_image)
// finding the region of interest
          if (contour_line = 3) // triangle detection
     detection = detection +1
     end if
     end if
end for
```

Figure 2. Non-color detection algorithm

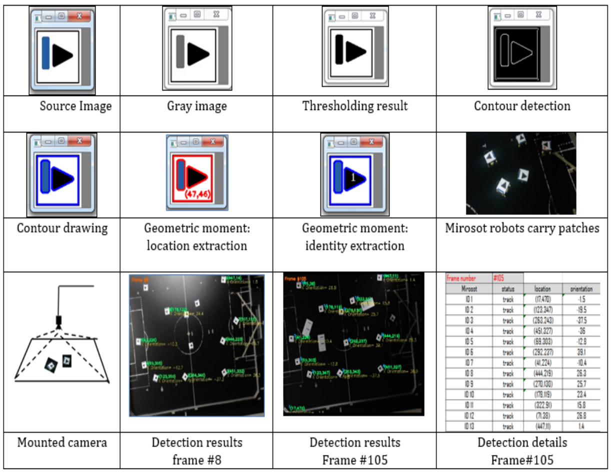

Figure 3. Detection steps in the experiment

The overall algorithm strategy incorporates four primary steps; starting from preprocessing, contour detection, feature extraction, and tracking as presented in

Fig. 2. The result of this step is illustrated in Fig. 3, where the source image is captured by the algorithm, changes to the gray level image, perform thresholding prior to contour detection. Next, geometric moment to extract location and identity is completed after contour drawing. The experiment uses a static camera mounted on top of the game field and detection results are displayed in every frame with detailed explanation.

The test results over 100 frames are presented in Fig. 4. The analysis of the obtained results suggests that illumination did affect the measurements of this system. The lowest illumination appeared from frames 41 to 60 and continuously appears from frames 61 to 80. This indicates some obvious degradation values of *P*, *R*, *S*, and *F1*.

Nonetheless, when illumination was improved, the value of the parameters improved as well, as indicated from frames 81 to 100. Furthermore, the illumination measure in the experiment had been varied - from the lowest 50 lux to 120 lux. On top of that, the comparison between precision and recall values showed that the overall precision value had been higher than that of recall. This suggests that the capability exerted by the algorithm in avoiding false positives is indeed justified. Besides, precision indicates that all objects detected were true positive without any false detection. However, this value failed in reflecting the number of skipped true positive objects.

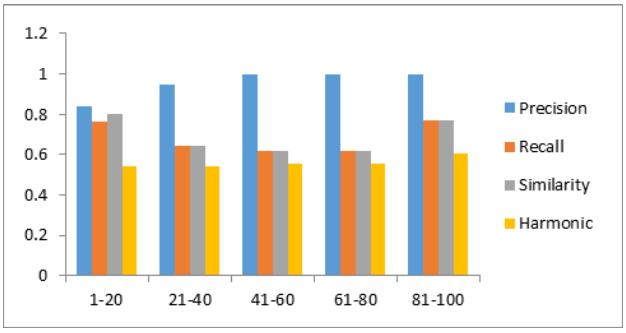

Figure 4. Accuracy of contour detection algorithm

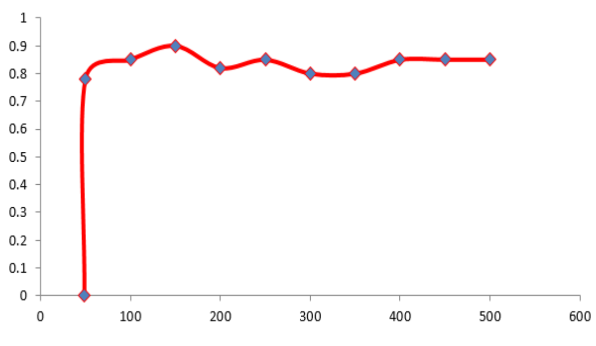

Figure 5. Detection in Illumination range of 50-600 lux

Moreover, due to low illumination, for example, only 9 objects were detected out of the 13 true positive objects in some frames. Furthermore, the recall value indicated degradation from 0.760 points at frames 1-20 down to 0.615 points at frames 41-80, along with changes in illumination. This measurement suggests that the algorithm did detect false positive objects. Figure 10 shows an example of this scenario. Meanwhile, the similarity of objects had been the highest at frames 1-20, whereas harmonic mean was the highest at frames 81-100, in which illumination was observed to be high. This result suggests that illumination did highly affect the performance of the proposed algorithm. Fig. 5 portrays detection rate against illumination range of 50-600 lux which resulted in successful detection in all time.

IV. CONCLUSION

This paper proposes an algorithm that has been proven to meet the requirement of object detection without color feature in an autonomous robot. The proposed algorithm specifically relies on two main methods that emphasize on shape recognition and feature extraction that follows. The first method is edge- and line-oriented approach to performing contour extraction, which results in object detection in no time.

Next, the second method is a geometric moment that captures and computes the global features of the objects. Both listed methods are well known in image processing, however, a combination of both is a novel approach in this study and have been proven to accurately detect static and moving object under illumination variety.

The experimental results further confirm that the proposed methods can indeed be used to detect objects in a real-time environment without depending on the color feature.

ACKNOWLEDGEMENT

The authors would like to thank Universiti Kebangsaan Malaysia (UKM) for partially funding this research work through FRGS/1/2014/ICT07/UKM/02/1

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