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Scale Invariant Feature Transform Descriptor Robustness Analysis to Brightness Changes of Robowaiter Vision Sensor System

T N Nizar[1], S Supatmi[2], E P Putro[3]

Departemen Teknik dan Ilmu Komputer, Universitas Komputer Indonesia, Indonesia

E-mail: ekoprabowoputro@gmail.com

Abstract. The purpose of this research is to identify problem detection features in computer vision that are affected by changes in brightness. The presented descriptor is Scale Invariant Feature Transform (SIFT). The method used in this study is an algorithm in computer vision to detect and describe local feature in image which robustly identify object and invariant to uniform scaling, orientation, brightness changes, and partially invariant to affine distortion. We implement this algorithm to Robowaiters object detection system that must detect and recognize objects around its task like food, beverage, refrigerator, and any kitchen objects. For this analysis case, we use beverage box image for sample image. The algorithm detects and recognize the image in normal brightness, and then the image brightness value increased and decreased. The result is that the algorithm successfully detects and recognizes the object presented and distinguishes it with a success rate of 93.5% increase in image brightness and 95.5% decrease in image brightness. it can be concluded that the SIFT algorithm is robust enough to change the lighting for our case.

1. Introduction

Computer vision is important and active area of research in field robotics[1]. The objective, robots capable to sense object as human sees object using their eye[2]. How the robot sees things is probably the most complex part of the robotic process, but the need for it is very important and very useful for many robotic applications such as vehicles capable of autonomous exploration for search and rescue operations[3], environmental monitoring[4], and planetary exploration[5]. Other application for industrial robots and home robots such as robowaiter[6] for helping disabilities people. The Connecticut Council on Developmental Disabilities (CCDD) sponsored an open research in the robotics field aimed to creating creative solutions in designing a robot that can help people with disabilities. The robot design must have sensors that can be used to distinguish food and beverage box. One of the sensors can be used for this robot are cameras that have been designed and programmed as an eye for robots.

There are many computer vision algorithm for feature detection and images matching[7], each algorithm has its own strengths and weaknesses, one of the robust algorithms is Scale Invariable Feature Transform (SIFT). SIFT is great to identify objects with clutter and under partial occlusion, because the SIFT is invariant to uniform scaling, orientation, illumination changes, and partially invariant to affine distortion[8].

The purpose of this research to implement the vision system to the waiter robot that can identify food and beverage object robustly using SIFT algorithm. The environmental condition vulnerable to

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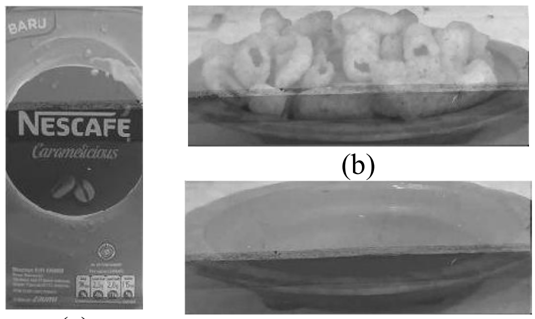
illumination changes. this paper will analyze the robustness of the algorithm to illumination changes. The algorithm will identify and recognize the same images with different brightness using simulation[9].

2. Methods

2.1. Robowaiter vision sensor system

We have study about prototype of robowaiter, this is a type of robot designed for helping people with disabilities. the robot task is to take and serve food and beverage from a prototype of refrigerator to the specific table. To detect the objects around it, the computer vision sensor system is implemented using camera and SIFT algorithm. In this research, the robots must detect and recognize plate with food or without food and beverage box. The sample image is described in Figure 1. Sample object to recognize, (a) beverage box, (b) plate with food, (c) plate without food.



(a) (b) (c)

Figure 1. Sample object to recognize, (a) beverage box, (b) plate with food, (c) plate without food.

2.2. Scale Invariant Feature Transform (SIFT)

SIFT is a method used to detect and describe the characteristics of the image. This method was published by David Lowe in 1999. Broadly speaking, this algorithm provides a method for detecting feature points on a 2-D image that is considered to have an invariant character (strong and unaffected) to geometric transformations (scaling, rotation, translation), noise, and changes in lighting levels. These points that have this special character are very useful for detecting an object recorded in various positions[10]. Figure 2 describe how SIFT is able to detect feature points on an object then stores the features data and uses it to detect the same object with different shooting positions.

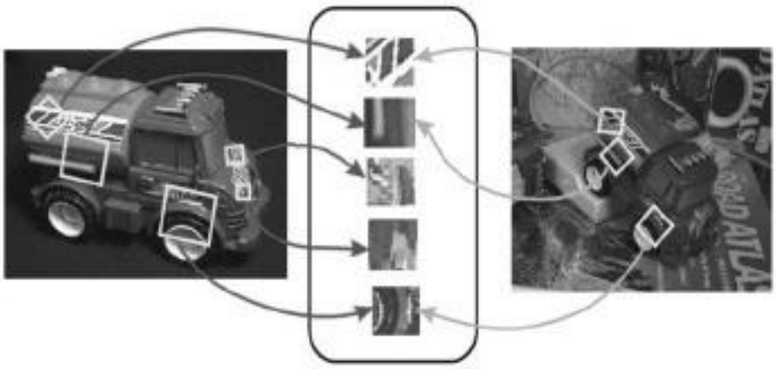


Figure 2. SIFT detection illustration.

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Figure 3 is the steps taken for object detection using the SIFT method:

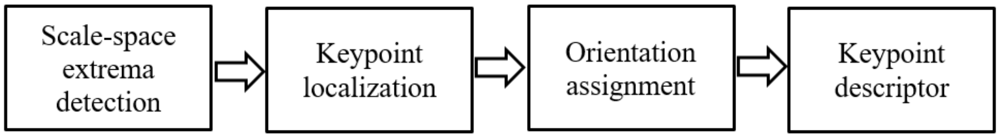
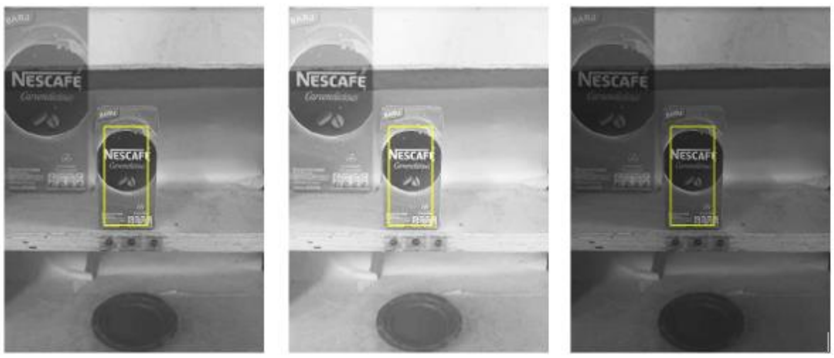


Figure 3. SIFT detection process

2.3. Brightness changes testing technique

In the previous research by Nizar et al, it is described on how to test the robustness of Histogram of Oriented (HoG) in brightness changes by increasing and decreasing value of every pixels on the image. The example for this technique is Figure 4. Example of brightness changes, (a) original image, (b) image with 50% brightness increase, (c) image with 50% brightness decrease. The mathematical formula described as[11]:

$$G(y,x) = f(y,x) \pm (n\% \times 255) \quad (1)$$



(a) (b) (c)

Figure 4. Example of brightness changes, (a) original image, (b) image with 50% brightness increase, (c) image with 50% brightness decrease.

The same technique used to this research for test the robustness of our implemented robot vision system with SIFT algorithm from brightness changes.

3. Results and Discussion

3.1. SIFT algorithm Detection Result

At first, we train the system using training images on food. The algorithm calculates key points of each image. This key point described as training key points. The obtained result of this training images listed in Table 1.

Table 1. Training key points

Object	Detected key points
Beverage box	87
Plate without food	11
Plate with food	98

One of the important things of detected key point by SIFT algorithm is the corner of image. In the plate without food image, the detected key points only 13 key points because the image is less of corner. In another case, plate with food image detected 132 key points because there are a lot of corner. Further we take other images with different condition from training images and detect the images key points using SIFT and the result compared with training key points as listed on Table 2.

Table 2. Compared key points of test images and training images

Object	Training key points	Detected key points	Accuracy (%)
beverage box	87	81	93.1
Plate without food	11	9	81.8
Plate with food	98	90	91,8
		Average	**88,9**

As of the data on Table 2, we can observe that object detection has an accuracy of 88,9%, the error due to the difference in condition between image training and image test such as brightness, position, or rotation condition.

3.2. *SIFT robustness to brightness changes*

In this chapter, we will discuss about the SIFT algorithm robustness to brightness changes. the brightness of the test images increased and decreased by 10 %, we calculate the key points of every image and brightness change and compared with training key points. The result as described on Figure 5.

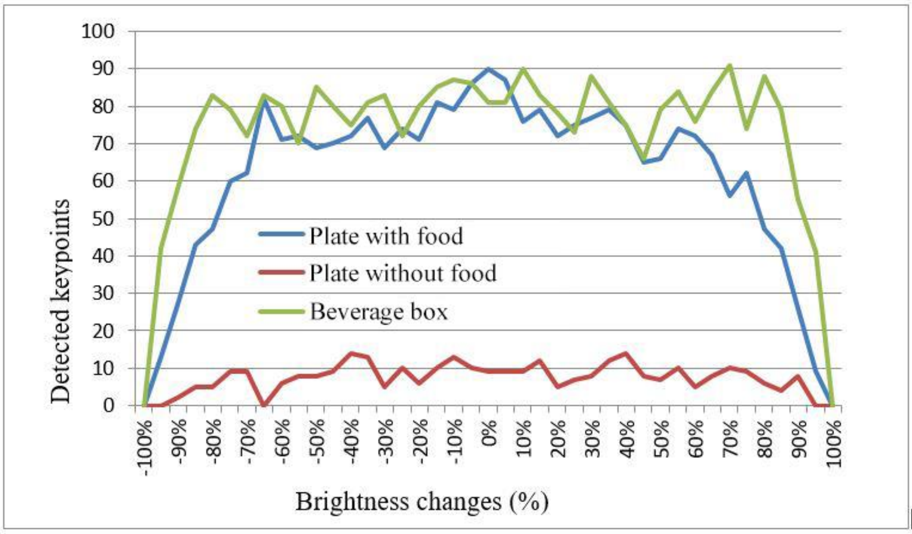


Figure 5. Performance of detected key points of images affected by brightness change.

The results of the detected key points tends to be stable with the increasing or decreasing of brightness up to 80%. The decline in the success rate of detection occurs drastically from 80% to 100%, this is due to the value of the object tend to become smaller and disappear.

3.3. *Robot vision sensor system detection.*

Finally, we implement the algorithm to our robots and we test it with total 400 trial, the success rate of detection is 95,5% of brightness increase and 95,5 % of brightness decrease as described on

3.4. Table **3**.

Table 3. Robot vision system testing result

Brightness change (%)	Brightness increase			Brightness decrease		
	Number of tests	Number of success	Success percentage	Number of tests	Number of success	Success percentage
20%	40	39	97.5%	40	40	100%
40%	40	40	100%	40	40	100%
60%	40	40	100%	40	40	100%
90%	40	38	95%	40	39	97.5%
100%	40	30	75%	40	32	80%
	Success rate		**93.5%**	**Success rate**		**95.5%**

Based on
Table 3, majority the error occurs between 80 to 100% of brightness change error value, this case due the level of brightness causes the image loss of the its features and the system fail to recognize the image.

4. Conclusion

Based on our research and obtained data, The SIFT algorithm is robust to brightness changes, because the algorithm still stable to detect key point up to 80% brightness changes both for decreasing and increasing brightness. The algorithm is convenient to be implemented on our robowaiter robot because the robot successfully detects and recognize the beverage box, plate with food, and plate without food with the success rate of 95,5% in brightness increase and 95,5 % in brightness decrease. Based on the data, the SIFT algorithm is sensitive to illumination changes for our case.

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