Experimental Investigation on Imaging System to Determine the Factors Affecting the Image Quality

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ABSTRACT

Achieving image quality is an essential task in vision systems. The image acquisition process was considered as critical process in vision system because this system depends on many factors such as lighting condition, camera resolution, object type (2D or 3D), working distance, object area, camera angle position and lens magnification. The single factor experiment conducted at different levels by changing illumination, camera resolution, object area and working distance. The output of the imaging system was images and the image contrast was one of the quality dimensions of image and it was measured by matlab tool. The aim of the output analysis was to find whether the factors affected the image contrast or not using Design of Experiments (DOE) concepts (single factor). The conclusion was made based on hypothesis and statistical data with experimental results. From the analysis of output images and experimental results, the factors (illumination, camera resolution, and working distance) significantly affect the image contrast. The predictions of factors could be applied to design the imaging system successfully.

KEY WORDS: Vision Systems, Image quality, DOE techniques.

1. INTRODUCTION

Machine vision is a quality inspection system which replaces the human inspection. The inspection quality quite high compared to the human inspection because, the inspection done by computerized automation. The major components involved in this system were the sample which was going to be inspected; imaging system includes camera, lighting and the image analysis software. The software used for comparing the standard image with sample image and it helped to make decision whether the sample is accepted or rejected.

Achieving the quality of image was difficult task in imaging system because of this system depends on many factors such as lighting condition, camera resolution, object type (2D or 3D), working distance, object area, camera angle position and lens magnification. One of the important information investigated in image was image contrast and it was considered for analyzing the image quality.

The design of experiment techniques used to find the factors involving in the imaging system and the experimental results will help to find the factors affecting the imaging system. This paper organized into following sections. Section 2 is an overview of the literature review. Section 3 discusses the problem description. Section 4 discusses the objective of this study. The experimental work explained is session 5 and the selection of factors and levels is described in section 6. Section 7 discusses the proposed method. Output analyses are discussed in section 8. Conclusion is discussed in Section 9.

Literature Review: Jiancheng Jia (2009), developed a machine vision system for industrial assembly inspection which explains a successful industrial application of machine vision technology for medical syringe assembly. And this paper describes the placement of camera (angle position) and capturing distance is an important task to increase the performance of the image acquisition process in vision system. Tang Bo (2009), designed a machine vision system for surface inspection of steel strip which explains the traditional surface quality inspection of steel strip carried out by human inspectors, which is far from satisfactory because of its low productivity, low reliability and poor economy. In this paper, the structure of the surface automated inspection system and the imaging factors (illumination, camera resolution) is described. Bundit Jarimopas & Nitipong Jaisin (2008), developed an efficient machine vision experimental sorting system for sweet tamarind pods based on image processing techniques. In this imaging system the important factors described are illumination and the placement of camera (angle position). Golnabi (2007), proposed a design of industrial machine vision system which includes Universal design, Methodology, Industrial Applications (AVI, Part identification), Key points in design, and Future developments. In imaging system design illumination, camera resolution and object type (2D or 3D) are the factors considered. R.C. Staunton (2005), presented a detected edge position evaluation using measured acquisition system factors. In this paper, the image acquisition factors Lens magnification, Camera angle position, lighting condition are described. Monica Carfagni (2005), presented a machine vision course for undergraduate students. That course includes the design of imaging system and the factors are considered in vision system. The imaging system factors are lens magnification, Camera angle position, Object area and lighting condition. Ducournau (2004), presented a machine vision system designed to count the number of emergent radical tips on seed lots, under controlled lighting, temperature and hygrometric conditions. An image acquisition system developed and the factors (illumination, camera resolution and working distance) are involved in imaging system are explained. Brain (2002), presented a Common Principles of Image Acquisition Systems and Biological Vision. The principles include the system design and the factors are considered (camera resolution, illumination and camera angle position) in vision systems. Elias

Malamas (2003), did a survey on industrial vision systems, applications and tools. Under the light of recent advances in image sensors, software and hardware technology, important issues and directions for designing and developing industrial vision systems are identified and discussed. In imaging system design illumination, camera resolution and object type (2D or 3D) are the factors considered. Ravishankar Rao (1996), presented future directions in industrial machine vision a case study of semiconductor manufacturing applications. In this paper, the image acquisition factors lens magnification, Camera angle position, lighting condition are described. Hyung-Ju Park (2011), developed a Subjective Image Quality Assessment based on Objective Image Quality Measurement Factors. The quality factor Uniformity, Contrast, Color accuracy, Loss of details, Noise and Sharpness are described. Ismail Avcıbas (2002), presented a Statistical evaluation of image quality measures. The image quality measurements, Sharpness, Loss of details, Noise, Color accuracy, Dynamic range, Contrast, Uniformity, and Lens distortion, are explained.

From the above Literature Survey the factors involved in imaging system is Working Distance, Object area, Camera resolution, Illumination, and these parameter considered for further investigation purpose.

Problem description: Achieving image quality is an essential task in vision systems. The image acquisition process was considered as critical process in vision system because this system depends on many factors such as lighting condition, camera resolution, object type (2D or 3D), working distance, object area, camera angle position and lens magnification. The image quality was mainly based on these factors. Finding the desired factors and optimal settings of factors enhance the performance of imaging system and improves the image quality. The unknown factors which affects the image quality significantly. The experimental setup helped us to find the factors affecting the image quality.

Objectives of this study:

- Predict the factors for imaging system.
- Develop the experimental setup and conduct the single factor experiments. Collect the data and analyze the output images using Matlab tool.

  Validate the experimental result by statistical methods.

2. EXPERIMENTAL SETUP

The experimental setup consists of lighting system, camera mounting stand, and PC connection cable. At different levels, the image of the object was captured using camera and the images were stored in the PC.

Figure.1. Experimental setup

Figure.2. Lighting system

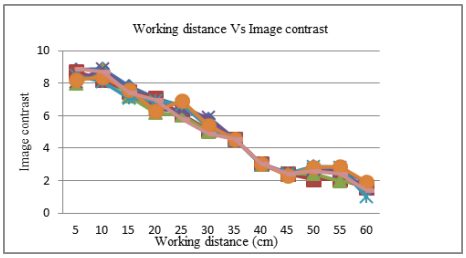
The figures.1, 2, show the experimental setup of imaging system and lighting system respectively.

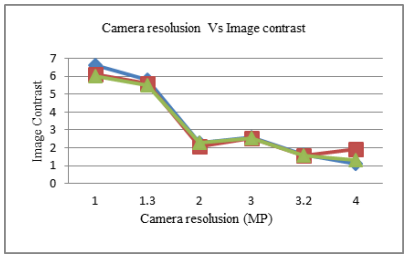
Selection of factors and levels: The following table 1 shows the factors chosen for conducting the experiments. The single factor experiments were conducted by changing factors at different levels (Low, High and medium).

Table.1. Selection of factors at different level

S.No.	Factors	Unit	Level	Variable
1	Working distance(a)	Cm	Low, High, Medium	Yes
2	Camera resolution(b)	Mp	Low, High, Medium	Yes
3	Object area (c)	m^2	Low, High, Medium	Yes
4	Illumination (d)	Lm	Low, High, Medium	Yes

The following chats show image contrast values at different working distance, camera resolution, object area and illumination. The working distance is varied from 5cm to 60cm to find the contrast values occurring with minimum deviation.





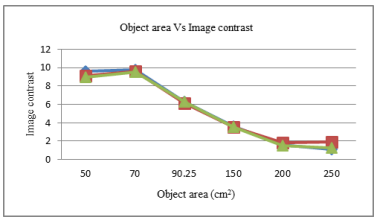


Figure.3. Contrast values at different levels

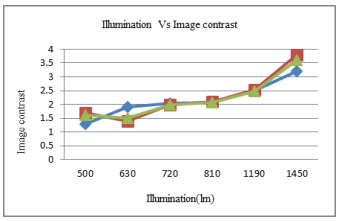


Figure.4. Contrast values at different factors

The following table.2, shows selection of levels at different working distance, camera resolution, object area and illumination. These levels chosen by getting minimum deviation contrast values at different factors.

Table.2. Selection of factors and level

S.No	Factors	Levels		
		Low	Medium	High
1	Working distance	35cm	40cm	45cm
2	Illumination	720lm	810lm	1190lm
3	Camera resolution	1.3MP	3MP	3.2MP
4	Object area	70cm^2	90.25cm^2	150cm^2

Methodology: The output of the imaging system is images. The images are analyzed using MATLAB and measured the contrast value. Contrast is one of the quality dimensions of images. The aim of the output analysis is to find whether the factors affect the image contrast or not using Design of Experiments concepts (single factor) the conclusion was made based on hypothesis and statistical data. The optimal setting can be achieved by finding the minimum deviation of output among the different parameter levels.

Output analysis: Single Factor Experiments

Factor: Working Distance:

Other factors: Illumination: 720 lm, Camera resolution: 3 Mp, Object area: 90.25 cm^2

Hypothesis:

H_0: The working distances do not affect the image contrast.

H_1: The working distances affect the image contrast.

Table.3. Experimental data, ANOVA table for working distance experiments

S.No.	Working distances	Image contrast			
		1	2	3	$y_{i.}$
1	35cm	4.69	4.34	4.92	13.95
2	40cm	3.06	2.69	2.5	8.25
3	45cm	2.42	1.48	1.58	5.48
					y..= 27.68

Source of Variation (SOV)	Sum of Squares (SS)	Degrees of Freedom (DOF)	Mean Square (MS)	F_0
Working distance	12.43	a-1 = 2	= SS/ DOF = 6.215	42.86
Error	0.87	N-a= 6	0.145	-
Total	13.3	N-1=8	-	-

Where a= number of levels=3, n= number of replicates = 3, N= Total number of trial =an=9

From statistical table F α (2, 6) = 5.14, α = 5%, The F_0 >F α so reject H_0 and accept H_1. The working distance significantly affects the image contrast.

Factor: Object area

Other factors: Illumination: 720 lm, Camera resolution: 3 Mpα, Working distance: 35cm

Hypothesis:

H_0: The object areas do not affect the image contrast.

H_1: The object areas affect the image contrast.

Table.4. Experimental data, ANOVA table for object area experiments

S.No.	Object area	Image contrast			
		1	2	3	$y_{i.}$
1	70 cm^2	9.5	9.89	1.12	20.51
2	90.25 cm^2	1.19	1.19	1.02	3.4
3	150 cm^2	1.15	1.15	1.15	3.44
					y..= 27.35

Source of Variation (SOV)	Sum of Squares (SS)	Degrees of Freedom (DOF)	Mean Square (MS)	F_0
Object Areas	64.91	a-1 = 2	= SS/ DOF = 32.46	3.98
Error	49.11	N-a= 6	8.14	-
Total	114.02	N-1=8	-	-

Where a= number of levels=3, n= number of replicates = 3, N= Total number of trial =an=9

From statistical table $F^{\alpha}(2, 6) = 5.14$, $\alpha = 5\%$ The $F_0 < F^{\alpha}$, so accept H_0 and reject H_1. The object areas significantly do not affect the image contrast.

Factor: Camera resolutions

Other factors: Illumination: 720 lm, Object areas: 90.25 cm^2, Working distance: 35cm

Hypothesis:

H0: The camera resolutions do not affect the image contrast.

H1: The camera resolutions affect the image contrast.

Table.5. Experimental data, ANOVA table for camera resolutions experiments

S.No	Camera resolution (MP)	Image contrast			
		1	2	3	$y_{i.}$
1	1.3	5.8	5.43	6.8	18.03
2	3	1.06	1.15	1.09	3.3
3	3.2	1.21	1.53	1.62	4.36
					y..= 25.69

Source of Variation (SOV)	Sum of Squares (SS)	Degrees of Freedom (DOF)	Mean Square (MS)	F_0
Camera resolution	45	a-1 = 2	= SS/ DOF = 22.5	125
Error	1.1	N-a= 6	0.18	-
Total	46.1	N-1=8	-	-

Where a= number of levels=3, n= number of replicates = 3, N= Total number of trial =an=9

From statistical table $F^{\alpha}(2, 6) = 5.14$, $\alpha = 5\%$ The F0 >F^{α} so reject H0 and accept H1. The camera resolution significantly affects the image contrast.

Factor: Illumination

Other factors: Object areas: 90.25 cm^2, Camera resolution: 3 Mp, Working distance: 35cm

Hypothesis:

H0: The illuminations do not affect the image contrast.

H1: The illuminations affect the image contrast.

From statistical table $F^{\alpha}(2, 6) = 5.14$, $\alpha = 5\%$

The F0 >F^{α} so reject H0 and accept H1. The illumination significantly affects the image contrast.

The minimum variation of output image contrast at: Working distance: 35cm, Camera resolution: 3MP, Illumination: 720lm and Object area: 90.25cm2.

Where a= number of levels=3, n= number of replicates = 3, N= Total number of trial =an=9

Table.6. Experimental data, ANOVA table for Illumination experiments

S.No	Illumination (lm)	Image contrast			
		1	2	3	$y_{i.}$
1	720	2.03	2	2	6.03
2	810	2.04	1.93	2.03	6
3	1190	2.56	2.5	2.48	7.54
					y..= 19.57

Source of Variation (SOV)	Sum of Squares (SS)	Degrees of Freedom (DOF)	Mean Square (MS)	F_0
Illumination	0.52	a-1 = 2	= SS/ DOF= 0.26	14.18
Error	0.11	N-a= 6	0.02	-
Total	0.63	N-1=8	-	-

9. CONCULSION

From the analysis of output images and experimental results, the following factors involved in imaging system are found to affect the image contrast. Working distance, Camera resolution and Illumination.

Table.7. The factors affecting image quality

S.No.	Factors	The parameter affected the image contrast?
1	Working distance (a)	Yes
2	Camera resolution(b)	Yes
3	Object area (c)	No
4	Illumination (d)	Yes

The predictions of factors can be applied to design the imaging system successfully and the optimal settings of these factors can be used to achieve the image quality, increase the performance of the imaging system.

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