EXPERIMENTAL INVESTIGATION ON IMAGING SYSTEM TO DETERMINE THE FACTORS AFFECTING THE IMAGE QUALITY USING 3 FACTOR FACTORIAL EXPERIMENTS

R Balamurugan [(1)]
Assistant Professor, Department of Mechanical Engineering
M Kumarasamy College of Engineering, Karur
Tamilnadu, India
balamuruganr.mech@mkce.ac.in

H Abdul Zubar [(2)]
Associate Professor, Department of Mechanical Engineering
Knowledge Institute of Technology, Salem
Tamilnadu, India
abdulzubar@gmail.com

***Abstract*— Achieving image quality is an essential task in vision systems. The image acquisition process is 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 experiments and 2 factor factorial experiments conducted at different levels by changing illumination, camera resolution, object area and working distance. The output of the imaging system is images and the image contrast is one of the quality dimensions of image [14] and it is measured by Matlab tool. The aim of the output analysis is to find whether the factors affected the image contrast or not using Design of Experiments (DOE) concepts (2 factor factorial experiments) and also the interaction between these factors were examined. The conclusion is 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 can be applied to design the imaging system successfully.**

Keywords—Vision Systems, Image quality, DOE techniques.

I. 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 are the sample which is 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 helps to make decision whether the sample is accepted or rejected.

Achieving the quality of image is 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 is image contrast and it is 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.

II. LITERATURE REVIEW

Jiancheng Jia (2009) [2] 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 et al (2009) [3] 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) [8] 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). H.Golnabi et al (2007) [1] 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) [7] 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 et al (2005) [10] 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. S. Ducournau et al (2004) [6] 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. A Brain et al (2002) [4] 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 N. Malamas et al (2003) [17] 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. A.Ravishankar Rao(1996)[16]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 et al (2011)[13] 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 et al (2002)[14] 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.

III. PROBLEM DESCRIPTION

Achieving image quality is an essential task in vision systems. The image acquisition process is 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 is 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 help us to

IV. OBJECTIVES OF THIS STUDY

1. Predict the factors for imaging system.

2. Develop the experimental setup and conduct the single factor experiments. Collect the data and analyze the output images using Matlab tool.

3. Validate the experimental result by statistical methods.

V. EXPERIMENTAL SETUP

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

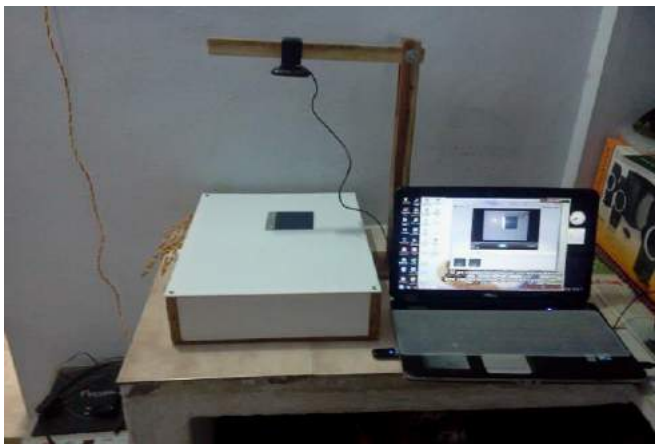

Figure.1 experimental setup

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

Figure.2 Lighting system

The appropriate lighting condition made before talking the images. The different object size, lighting condition, illumination and camera used for talking the images at different level. Once the taken the image saved in personal computer for future analysis purpose. The analysis of the images done by MATLAB software tool to find the image quality. Here the image quality analyzed by measuring the contrast value. The experiments conducted using single factor with blocking concepts that is considering the environmental constrains.

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

VI. SELECTION OF FACTORS AND LEVELS

S.NO.	Working distance (cm)	Image contrast							
		1	2	3	4	5	6	7	8
1	5	8.8	8.7	8	8.1	8.5	8.2	8.4	8.9
2	10	8.9	8.2	8.8	8.9	8.1	8.4	8.5	8.7
3	15	7.8	7.5	7.2	7.5	7.1	7.6	7.9	7.4
4	20	7.1	7.1	6.2	6.4	6.9	6.3	6.8	7
5	25	6.6	6.1	6	6.3	6.7	6.9	6.2	5.8
6	30	5.8	5.1	5	5.9	5.3	5.4	5.5	4.9
7	35	4.58	4.56	4.56	4.56	4.57	4.56	4.58	4.56
8	40	3.06	3.04	3	3.02	3.01	3.04	3.05	3.03
9	45	2.42	2.42	2.43	2.46	2.42	2.32	2.4	2.42
10	50	2.9	2.1	2.4	2.7	2.9	2.8	2.5	2.6
11	55	2.7	2.1	2	2.6	2.8	2.9	2.5	2.4
12	60	1.9	1.6	1.8	1.5	1	1.9	1.5	1.4

The following above shows the factors chosen for conducting the experiments. The single factor experiments are conducted by changing factors at different levels (Low, High & medium).

Table1. Selection of factors and level

The following table shows the image contrast values at different working distance. The working distance is varied from 5cm to 60cm to find the contrast values occurring with minimum deviation.

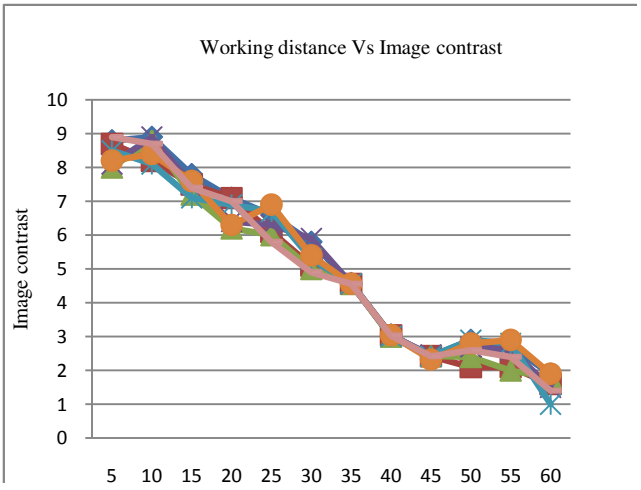

Table 2. Working Distance Vs Image contrast

From the above chart the minimum output variation of image contrast occurs for working Distance of 35cm, 40cm & 45cm.

From the below chart the minimum output variation of image contrast occurs at Camera resolutions of 1.3MP, 3MP and 3.2 MP.

S.NO	Camera resolution (MP)	Image contrast					
		1	2	3	4	5	6
1	1	6.6	6.1	6	6.2	6.5	6.8
2	1.3	5.8	5.6	5.5	5.6	5.7	5.8
3	2	2.3	2.1	2.3	2.5	2.4	2.2
4	3	2.6	2.55	2.5	2.65	2.5	2.7
5	3.2	1.6	1.55	1.58	1.5	1.52	1.2
6	4	1.1	1.9	1.3	1.8	1.5	1.3

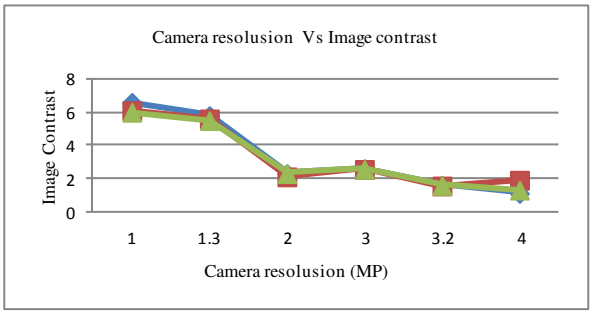

Table 3. Camera resolutions Vs Image contrast

The following table shows the image contrast values at different object areas. The object areas are varied from 50cm^2 to 250cm^2 to find the contrast values occurring with minimum deviation.

S.NO	Object area (cm^2)	Image contrast					
		1	2	3	4	5	6
1	50	9.6	9.1	9	9.2	9.5	9.8
2	70	9.8	9.6	9.5	9.6	9.7	9.8
3	90.25	6.3	6.1	6.3	6.1	6.4	6.2
4	150	3.6	3.55	3.5	3.65	3.5	3.7
5	200	1.6	1.8	1.5	1.9	1.55	1.2
6	250	1.1	1.9	1.3	1.8	1.5	1.3

From the above chart the minimum output variation of image contrast occurs at Object areas of 70 cm^2, 90.25 cm^2, and 150 cm^2.

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	$70cm^2$	$90.25cm^2$	$150cm^2$

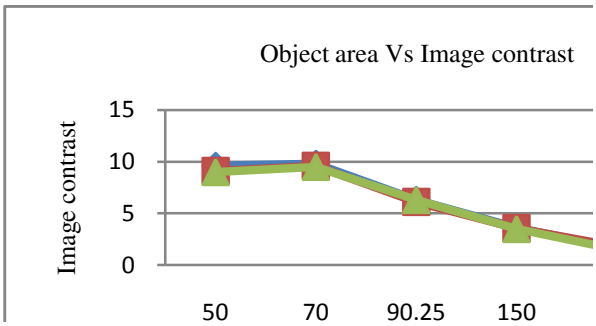

Table4. object area Vs Image contrast

The following table shows the image contrast values at different illumination. The illuminations are varied from 500lm to 1450lm to find the contrast values occurring with minimum deviation.

S.NO	Illuminatio n(lm)	Image contrast					
		1	2	3	4	5	6
1	500	1.3	1.7	1.6	1.3	1.9	1.4
2	630	1.9	1.4	1.5	1.8	1.9	1.6
3	720	2.03	2	2	2.08	2.1	2.05
4	810	2.08	2.1	2.07	2.09	2	2.03
5	1190	2.5	2.53	2.48	2.45	2.5	2.48
6	1450	3.2	3.8	3.6	3.7	3.4	3.9

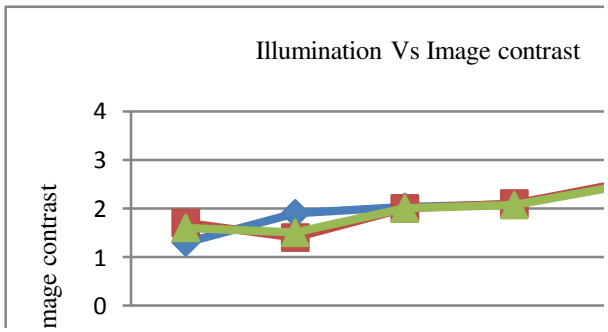

Table 5. Illumination Vs Image Contract

From the above chart the minimum output variation of image contrast occurs at Illumination levels of 720lm, 810lm, and 1190lm.

From the analysis of output images the minimum variation of image contrast at different factors levels are tabulated below.

VII. 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.

VIII. OUTPUT ANALYSIS

Factor factorial Experiments

Factor: camera resolution(A), working distance(B) & illumination(C)

Hypothesis:

H_0: There is no interaction between camera resolution, illumination and working distance.

H_1: There is an interaction between camera resolution, illumination and working distance.

Camera resolution (A)	Working distance (B)								$y_{i..}$
	35 cm				45 cm				
	Illumination (C)								
	720lm		1190lm		720lm		1190lm		
1.3 MP	5.41	5.38	6.28	6.46	6.42	6.08	3.06	3.12	42.21
	10.79		12.74		12.5		6.18		
3 MP	3.26	3.2	4.78	4.24	5.76	5.28	7.02	7.14	40.68
	6.46		9.02		11.04		14.16		
3.2 MP	2.46	2.3	3.48	3.56	9.26	9.42	8.06	7.24	45.78

	4.76	7.04	18.68	15.3	
B × C Total $y_{.jk.}$	22.01	28.8	42.22	35.64	$y_{....}$ =128.67
$y_{.j..}$	50.81		77.86		

Table 6. Experimental data for 3 factors (illumination, working distance & camera resolution) experiment.

Where a= Number of level for camera resolution=3, b= Number of levels for working distance = 2, c= Number of levels for illumination = 2, n= Number of replicates = 2, N= Total number of trials = a.b.c.n=24

A×B Total $y_{ij..}$		
A	B	
	35cm	45cm
1.3MP	25.5	18.7
3MP	15.5	25.2
3.2MP	11.8	34

Table 7. Experimental data for 2 factors (camera resolution & working distance)

A×C Total $y_{i.k.}$		
A	C	
	720lm	1190lm
1.3MP	23.29	18.92
3MP	17.5	23.18
3.2MP	23.44	23.34

Table 8. Experimental data for 2 factors (camera resolution & illumination) experiment.

Source of Variation(SOV)	Sum of Square(SOS)	Degrees of Freedom(DOF)	Mean Square(MS)	F_0
Camera resolution(A)	1.71	2	0.855	7.125
Working distance(B)	0.46	1	0.46	3.83
Illumination (C)	2.72	1	2.72	17.66
AB	7.86	2	3.73	32.75
AC	5.36	2	2.68	22.33
BC	4.26	1	4.26	35.5
ABC	3.72	2	1.86	15.5
Error	1.4	12	0.12	-
Total	27.49	23	-	-

Table.9.ANOVA for 3 factors (illumination, working distance & camera resolution) experimental data

From statistical table $F\alpha$ (2, 12) = 3.89, α = 5%

$F\alpha$ (1, 12) = 4.75, α = 5%

The $F_0 > F\alpha$ so accept H_1 and reject H_0.

There is an interaction between camera resolution, illumination and working distance. The working distances do not affect the image contrast.

The lighting illumination and camera resolution significantly affects the image contrast.

I. CONCLUSION

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.

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.

S.No.	Parameters	The interaction of parameter affected the image contrast?
1	Working distance (a)	No
2	Camera resolution(b)	Yes
3	Illumination (d)	Yes
4	Working distance (a) & Camera resolution(b)	Yes
5	Camera resolution(b) & illumination (d)	Yes
6	Illumination (d) & Working distance (a)	Yes
7	Illumination (d) , Working distance (a) & Camera resolution(b)	Yes

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