Journal of Engineering and Applied Sciences 4 (5-6): 342-347, 2009
ISSN: 1816-949X

Illumination Systems for Autonomous Robot: Implementation and Design

Awang Hendrianto Pratomo, Mohd. Shanudin Zakaria, Anton Satria Prabuwono and Khairuddin Omar
Center for Artificial Intelligence Technology, Faculty of Information Science and Technology,
University Kebangsaan Malaysia, 43600 UKM Bangi, Selangor D.E., Malaysia

Abstract: Un-uniform illumination is the main problem in autonomous robot system. It causes the robots cannot detect another robot, obstacle and other environment. Camera system also needs a uniform illumination for capturing image. Furthermore, autonomous robot system needs uniform illumination during the operation. The objective of this research is to design and implement uniform lighting system for autonomous robot. In this research, the lighting system is developed by using standard and low-cost fluorescent lamps. The result of this research is lighting system configuration that can be implemented for illumination systems in a workspace area of autonomous robot.

Key words: Illumination system, lighting design, lighting configuration, autonomous robot

INTRODUCTION

Light is an essential for camera and image processing to know an environment and to recognize an object. Without lighting the camera cannot capture an image, recognize the color, shape and around of the environment. Lighting design for the image processing includes the values for the lighting, such as position, color and intensity of the light resources. Poorly designed lighting can result in unintelligible images, under and over illuminated regions show poor contrast and did not effectively to get image in real world transformation (Shacked, 2001). To take a picture with the desired appearance, one has to search through the space of possible lighting specifications.

Un-uniform illumination caused of irregular illumination is the main problem in autonomous robot system. Irregular illumination is the main reason for incorrect estimation for the robot to detect the other robots and the obstacles. The vision system needs uniform illumination to recognize the object. In autonomous robot case the center of workspace area is more illuminated then the corner. When the object is positioned in the center of workspace area is possibly that the object can strongly recognized. Un-uniform illumination and illumination condition are more constant during the autonomous robot operated.

Lighting design, however, remains a big problem. An application where good lighting design is important is the technical illustration. Capturing the image is suitable conditions for the good correlation of the optical parameters with the roughness (Akers *et al*., 2003). Lighting conditions is an important factor, the impact on the image pattern and thus, the optical parameters. The lighting conditions, such as grazing angle, the light to sample distance, the orientation of the grooves on the surface to the light are varied and their influence on the optical surface parameters (Xu *et al*., 2004).

The objective of this research is to design and implement the illumination system in workspace area of autonomous robot. The robot will identify the object using color image that requires the same lighting intensity in all workspace areas.

Related work: A lot of works have been done in development of illumination systems. Xu *et al*. (2004) develop illumination systems to create a new detection approach based on the least squares method. This system is stable in relation to changes in lighting and shadow conditions.

Mariani (2001) presents a face location system in a complex background and robust to a wide range of lighting conditions, likely to appear in an indoor environment. Mendez-Vazquez *et al*. (2008) develop a different way of using DCT (Discrete Cosine Transform) and LBP (Local Binary Pattern) to compensate for illumination variations in face recognition.

Wu and Narasimhan (2009) develop a formulation for near-lighting shape from-shading problem with a pinhole camera (perspective projection) and presents a solution to reconstruct the Lambertian surface of bones.

Gerard *et al*. (1998) study an alter-native to the standard blue-screen technique (weather man method) by exploiting the color shifts of light sources and filtering

Corresponding Author: Anton Satria Prabuwono, Faculty of Information Science and Technology,
Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor D.E., Malaysia

each camera lens and correcting white balances for each camera. Besides, the research provides three important benefits i.e., presents another solution to the foreground background segmentation problem by using local lighting conditions to force a separation of colors in the chromaticity color subspace, discusses the use of the white balance and exploits the relationship between white balance shift and the color tint and provides a solution for correcting a wrong camera white balance acquired in the data.

Klancar *et al*. (2004) describe a non-uniform illumination is the main reason for loss (or incorrect estimation) of the player or the ball during the robot soccer game. In their research, they show that in the playground consists of several peaks and valley of type illumination. From this research he made a test from efficiency for the camera to recognize color in their playground.

In this research, we develop lighting configuration using low-cost fluorescent lamps to create uniform illumination for autonomous robot system.

MATERIALS AND METHODS

Framework of autonomous robot: The complete design of the autonomous robot system is shown in Fig. 1. The system is divided into hardware and software frameworks. The hardware framework consists of the field (workspace area), autonomous robot, CCD camera, personal computer, Bluetooth access point and lighting system. Assume that field has a part that locate robot to moving. While, ball is moving over on the field, camera will capture images of autonomous robot and the ball around the field.

The images will be transferred into computer via firewire port. Furthermore, images will be processed and analyzed by the software (autonomous robot engine). The system will send instruction of strategy of robot soccer and strategy for doing activities.

Autonomous robot: Autonomous robots are intelligent machines capable of the tasks in the world of themselves, without explicit human control (Pratomo *et al*., 2009). We use Merlin robotic system as shown in Fig. 2 (Shacked, 2001).

Vision system: The robot vision system takes a live image from an overhead camera (that is mounted 3 m above the field) and processes that image to determine the position and orientation of the objects on the field.

The camera is used to capture images from the field and relays the information to an off-field computer. The image-capture card in the computer passes the data

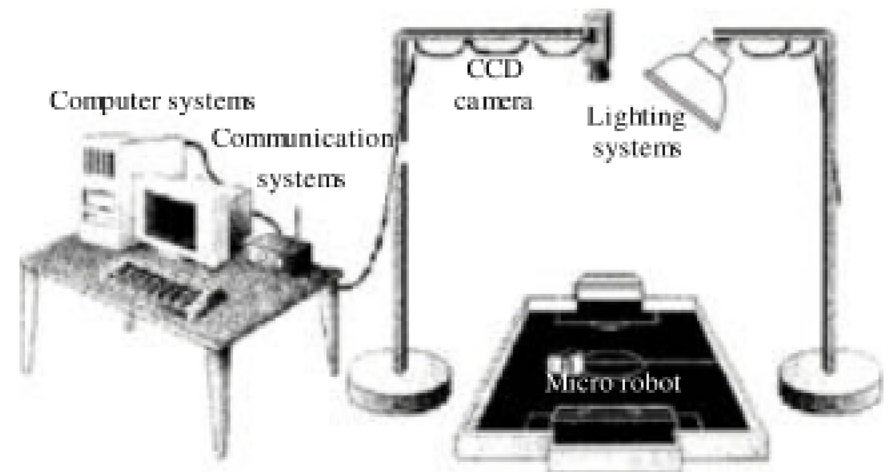

Fig. 1: Autonomous robot system overview

Fig. 2: Merlin robotics system

Fig. 3: CCD camera

recorded by the camera on the CPU to engage in the processing the image is used to, sort, identify colors and color blobs that appear from the image. The vision system is used to identify and decipher the various robots and each individual orientation. In the research, the robot vision system used Sony CCD camera as shown in Fig. 3.

Computer system: Computer system is the main part of autonomous robotics system. This system is the central of processing the strategy or the instruction of robot movement.

The strategy system allows the robots to initiate strategies relative to the position of other robots and another obstacle on the field. The strategy system receives the data from the vision system and processes it through a variety of calculations to determine which type of action should be chosen and make decision. The objective is to provide strategic functionality to the robots and create different algorithms to adapt different scenarios of the robots tasks.

Communication system: The communication system transmits the commands from the CPU to the robot. The communication and robot control system receives data from the computer system via Bluetooth communication. This sub-system processes the values given in the protocol from the strategy system to determine distance, direction and degree of orientation. This system is given data from the vision system and through the strategy system and finally onto the communication system for robots to execute actual movement. The robots execute instructions such as stop, move forward and backward and rotate. Their positions are tracked using the camera systems.

Lighting system: Lighting is an essential part of this system especially for knowing environment and making an activity. The camera needs light for getting the image to recognize the color, shape and around the environment.

Lighting calculations are performed in the design process to provide information on lighting system performance. We can use the results of the calculations to choose the design and alternatives or to refine a particular design. Lighting calculations are mathematical models of complex physical processes, in a little room. Since these models never exactly in every detail, the calculations are approximations of the real situations.

Level of average illumination: Level of illumination at one particular room in general defined as level of illumination of average at the work plane. The concerned of the work plane is horizontal area of located imaginary 0.05 m above floor at all rooms. Level of average illumination is (Rea, 2000):

$$E_{Avg} = \frac{F_{Tot}}{A} \tag{1}$$

Where:

F_{tot} = Total luminous flux from all lamps enlightening in an work plane

A = Wide of work plane

Number of armature: To calculate the number of armature, first calculate total flux luminous that needed to get the lighting level using the equation (Rea, 2000):

$$F_{Total} = E \times A \tag{2}$$

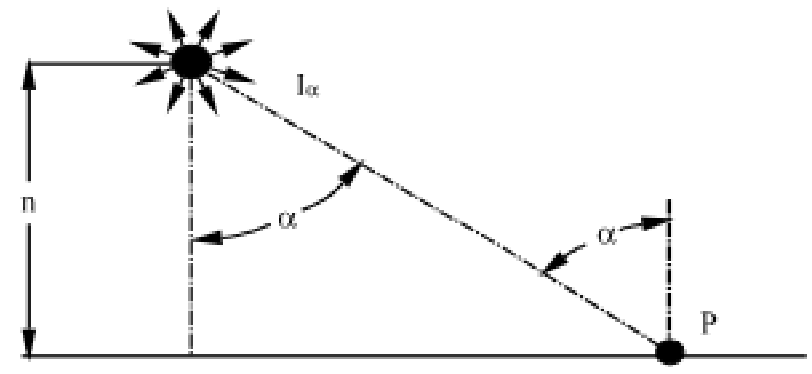

Fig. 4: P has been received the directly components from the light source

Total armature is calculated using equation as follows:

$$N_{Tot} = \frac{F_{Tot}}{F_l \times n} \tag{3}$$

Where:

F_l = Flux Luminous one lamp

N = Amount of lamp in one armature

Level of illumination: Level of illumination by direct light component in one particular point at work plane from a light source which can be considered as a point light source, is the image as shown in Fig. 4 can be counted using equation (Ganslandt and Hofmann, 1992):

$$E_P = \frac{I\alpha \times Cos^3 \alpha}{h^2} (lux) \tag{4}$$

Where:

I_α = Lighting intensity at the angle a (Candela)

h = Armature height at the work plane (m)

If there are multiple armatures, the level of illumination is calculated from the luminance level caused of the respective of each armature and expressed as follows (Lighting Handbook):

$$E_{total} = Ep1 + Ep2 + Ep3 + \ldots\ldots (lux) \tag{5}$$

Experiments: The lighting system design is implemented to get the standard illumination in a field of 2.6×1.9 m. The height of aperture lamp from work field area is 245 cm. The main focus of the research is to get the uniform lighting intensity in a workspace area. The vision system takes a real-time image from an overhead camera and processes that image to determine the position and orientation of the objects on the workspace area as shown in Fig. 5.

We applied three kinds of design using low-cost fluorescent lamp. In first design, we used two armature fluorescent lamps that consist of four fluorescent lamps. The installation is shown in Fig. 6. The second experiment, we used four fluorescent lamps with the

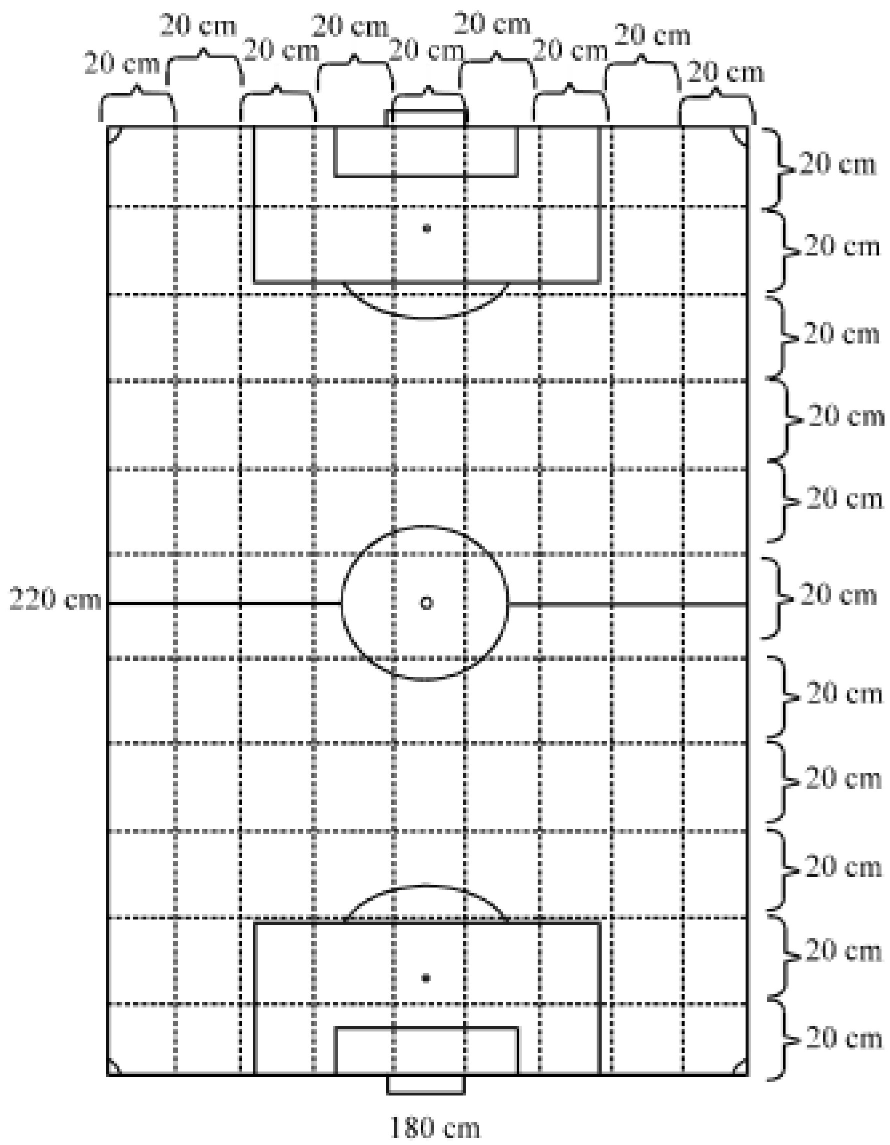

Fig. 5: Workspace area with location for illumination calculation

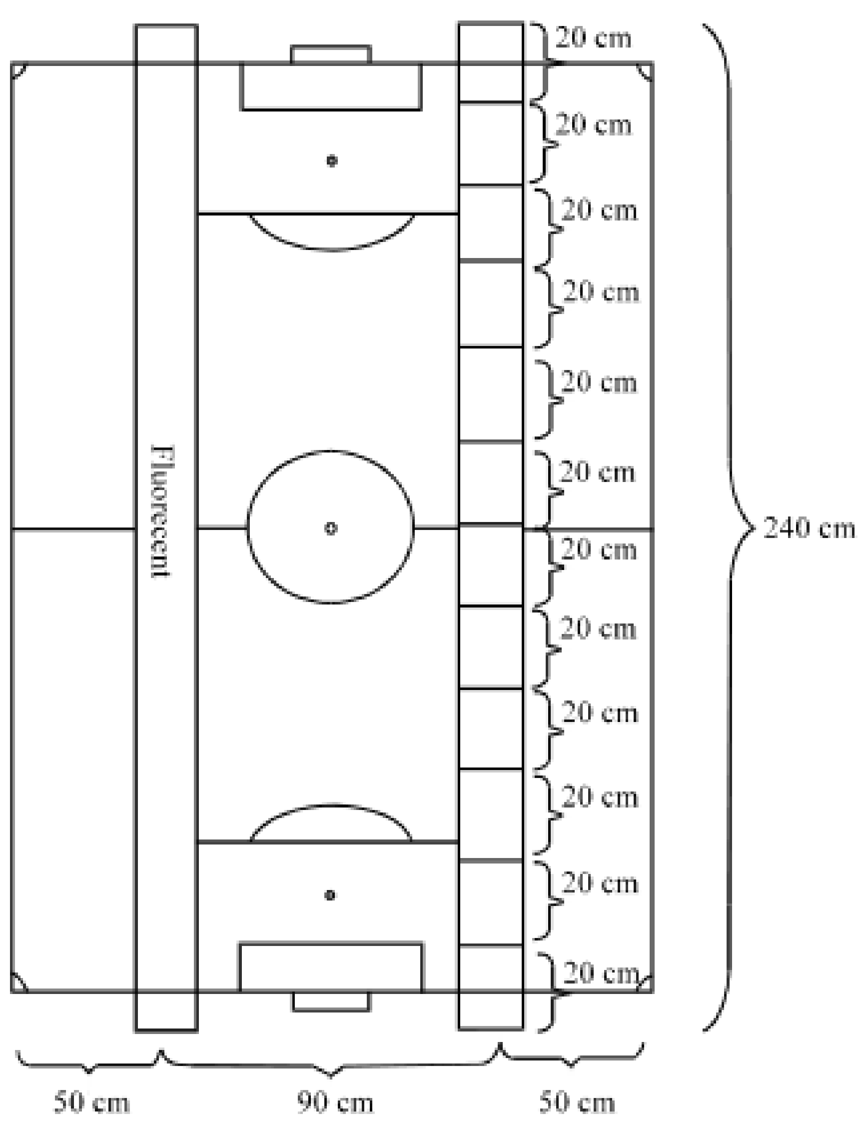

Fig. 6: Design of two armature fluorescent lamps

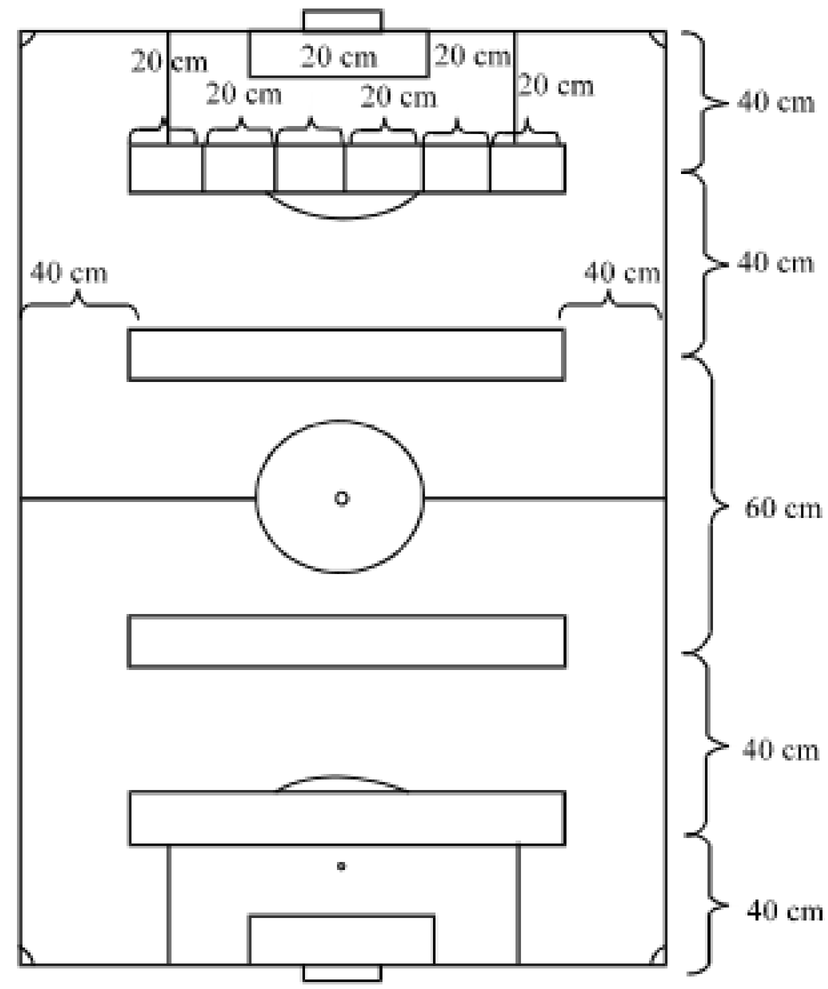

Fig. 7: Design of four fluorescent lamps

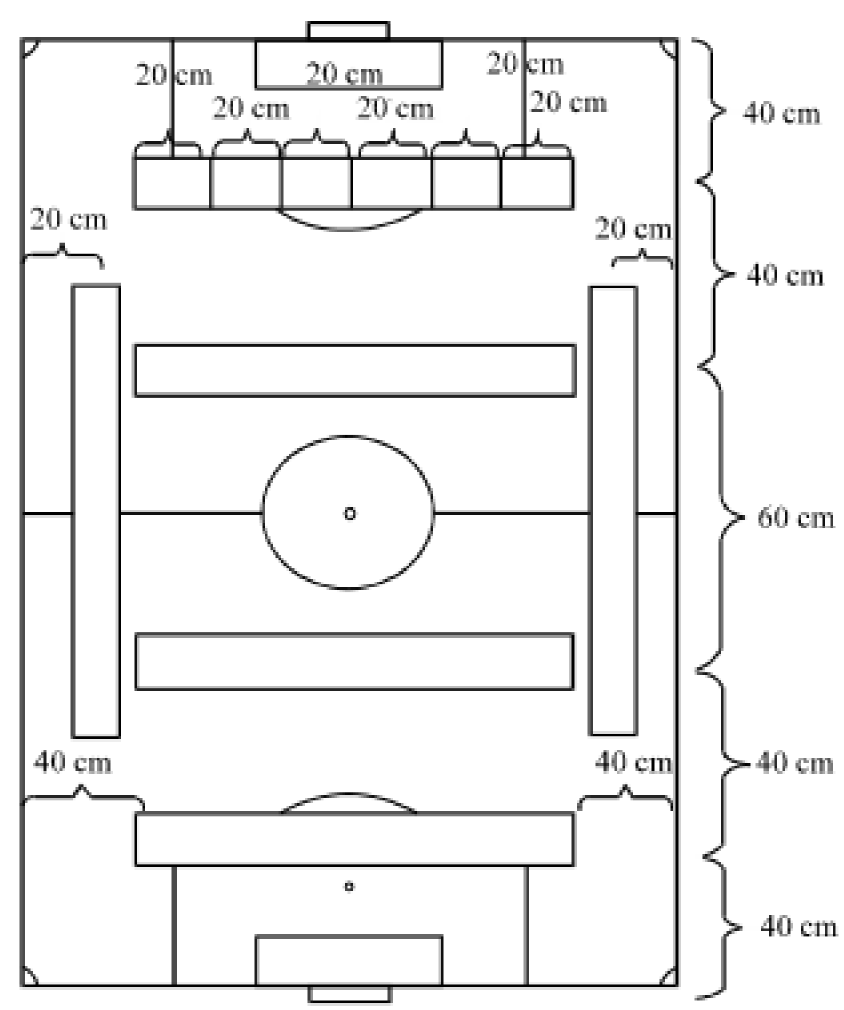

Fig. 8: Design of six fluorescent lamps

installation design as shown in Fig. 7. The third experiment, we used six fluorescent lamps with the installation design as shown in Fig. 8.

RESULTS AND DISCUSSION

Flux meter is used to measure lighting intensity at the certain points in all workspace areas. We have implemented the lighting design in the following experiment. The first experiment, we used two armatures of fluorescent lamp that consist of four fluorescent lamps as shown in Fig. 6. The calculation of flux in all workspace areas uses Eq. 4 from the data of fluorescent lamp

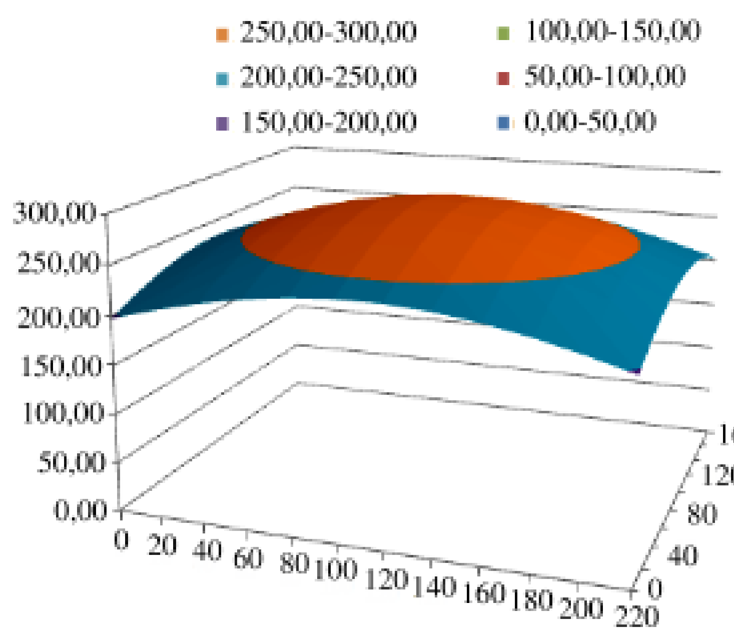

Fig. 9: Illumination distribution with two armatures of four fluorescent lamps (calculation result)

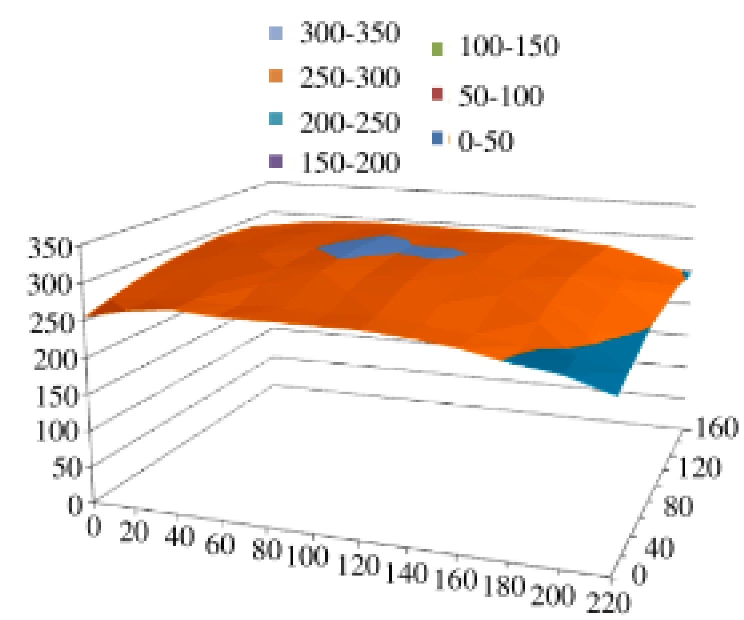

Fig. 10: Illumination distribution with two armatures of four fluorescent lamps (measurement result)

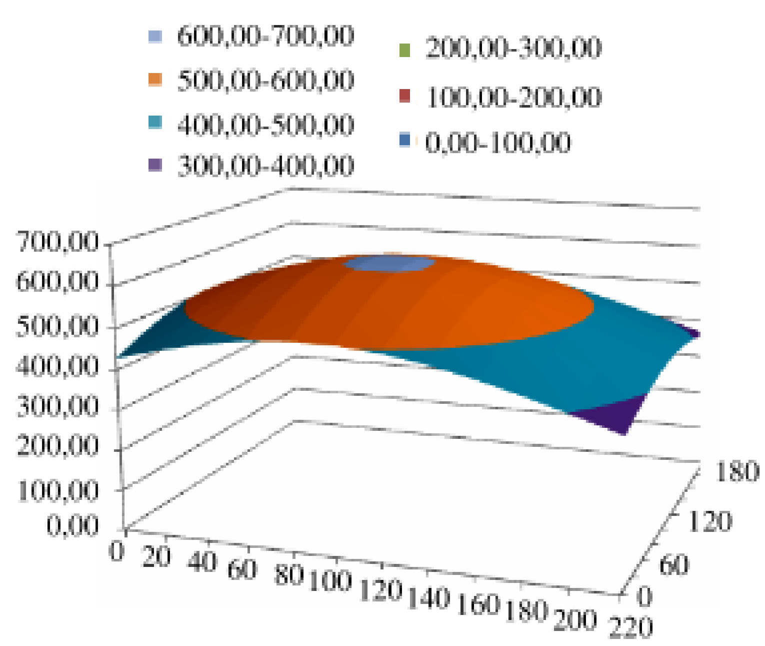

Fig. 11: Illumination distribution with four fluorescent lamps (calculation result)

intensity as shown in Fig. 9. Then to calculate total areas in all workspaces uses Eq. 5. The result of illumination distribution is shown in Fig. 10.

In the second experiment, we apply four fluorescent lamps with the design as shown in Fig. 7. The flux calculation in all workspace areas uses Eq. 4. Then to

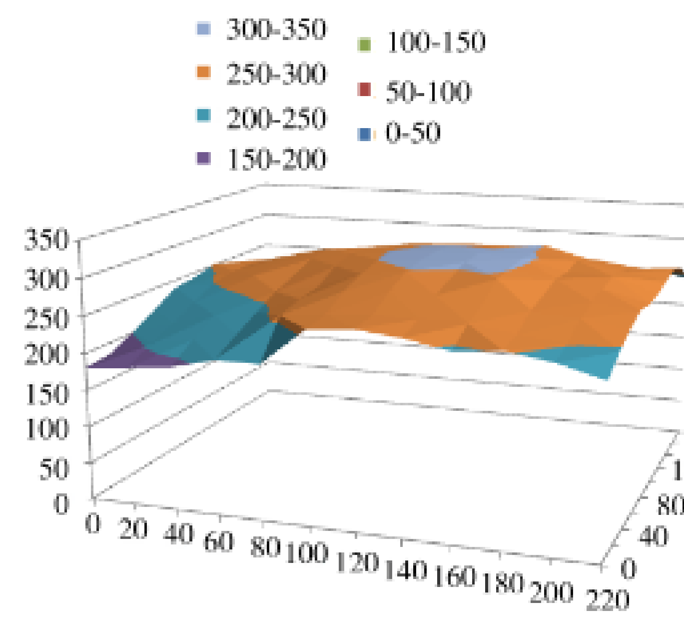

Fig. 12: Illumination distribution with four fluorescent lamps (measurement result)

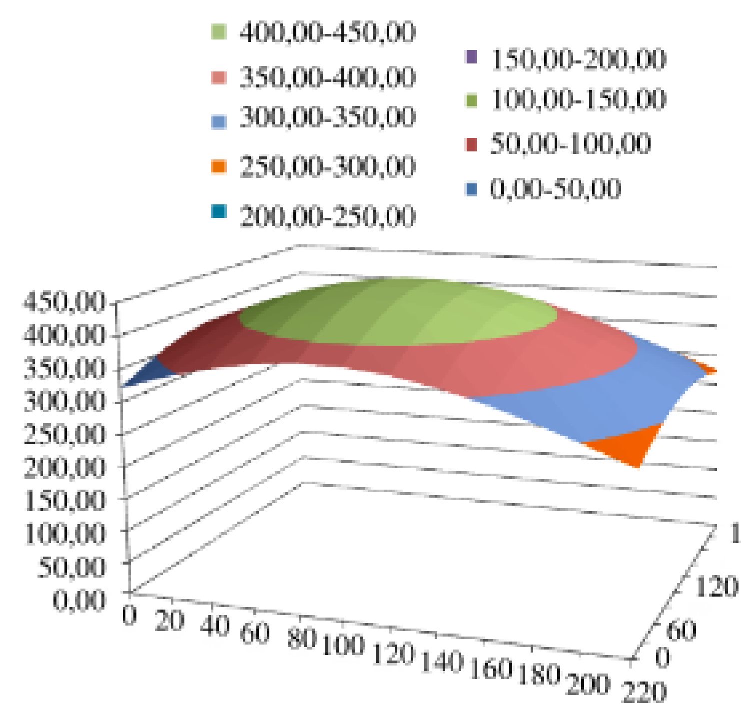

Fig. 13: Illumination distribution with six fluorescent lamps (calculation result)

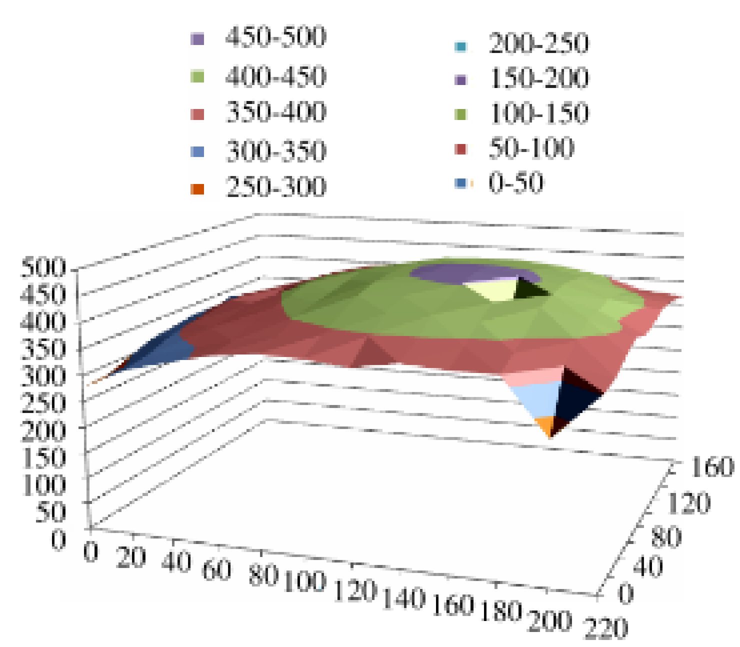

Fig. 14: Illumination distribution with six fluorescent lamps (measurement result)

calculate total areas in all workspaces uses Eq. 5. So, we get a calculation result as shown in Fig. 11 and measurement result as shown in Fig. 12.

In the third experiment, we used six fluorescent lamps with the design as shown in Fig. 8. The flux calculation in all workspace areas uses Eq. 4. Then to calculate total areas in all workspaces uses Eq. 5. The calculation result is shown in Fig. 13 and measurement result is shown in Fig. 14.

CONCLUSION

This study presents the design and configuration of fluorescent lamp in a workspace area for autonomous robot. To get an optimum calibration needs a good lighting condition. Calibration process requires the same lighting intensity evenly across the workspace area for the robot can recognize the environment.

We select fluorescent lamp due to the lighting effect that produced by the lamp. We need the lamps with white clear lighting effect, so the robots can recognize the objects without any disturbances from the illumination system. Fluorescent light requires armature that can provide light intensity evenly same on work space area. Besides, these lamps require suitable design and configuration to get the uniform illumination in all workspace areas.

From this research, we can conclude that the suitable configuration for workspace area of autonomous robot is using two armatures of fluorescent lamp that consist of four fluorescent lamps. The lamp configuration and design is shown in Fig. 6. The result shows the illumination distribution is uniform in all workspace areas.

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