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Light Sensor Selection of Wi-MoLS (Wireless Modern Light Sensor) Based on Analytic Hierarchy Process (AHP)

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***Abstract*— This paper presents a technique for selecting the light sensor candidates according to its effectivity and sensitivity criteria. The light sensor candidates, such as light dependent resistor, photodiode, and phototransistor, is taken due to its good performance in daylight sensing. Analytic Hierarchy Process (AHP) which provides a structured technique for organizing and analyzing complex decisions based on mathematics was chosen. It offers simple ways in matrix based-operations to rank the best light sensor candidates over those criteria. The results show that light dependent resistor is the most effective and sensitive light sensor by 62.16 % in score instead of phototransistor (19.72%) and photodiode (18.12%).**

Keywords-analytical hierrachy process; light sensor candidates, effectivity, sensitivity

I. Introduction

Green building is a concept that starts with the understanding that the built environment can have effects on the natural environment as well as the people who inhabit buildings every day. Recently, green building is applied by utilizing green technology for buildings and it is adopted by many governments and corporations. This concept can be applied in various types of energy, one of which is electricity. Artificial light averagely consumes electrical energy by 37% of the total electrical energy consumed [1]. For reducing the artificial light consumption, various implementations had been done, such as by applying daylight harvesting system in the room. Daylight harvesting system is an intelligent light control system based dimmers that are used to reduce the light energy in buildings when the natural light is provided from the outside of building [2]. It regulates electric power flow to the lamp which is controlled by electrical responses of daylight sensor system. The daylight harvesting system is built by two big sub-systems as known as daylight sensor system and dimmer unit system. Daylight sensor system consists of a light sensor and illuminance level control systems which are integrated on one physical circuit for detecting the level of natural lighting in an interior room.

There are numerous research which develop daylight sensor system for optimizing its work. One of them is designing wire connected-light sensor as daylight sensor system [3]. This configuration has some disadvantages, one of which is the length of the cable between the controlled lamps and light sensor. If the length of cable is getting longer, the installation of the lighting system will be more complex and require greater cost. So, it is necessary to do research about designing a wireless daylight sensor system called Wi-MoLS (Wireless Modern Light Sensor) that can handle access data and mobile for use [4][5].

The development of wireless light control technologies has been increasing every year. The Pulse Width Modulation (PWM) control technology that have been used often by many researches. The light sensor data sent in the form of PWM shall be received by the receiver module consisting of filter and demodulator. It has a good capability to control the rate of illuminance [6]. The wireless daylight sensor system which needs to be considered is performing a separated physical circuit of light sensor and illuminance level control. For best performance, the integration between its daylight sensor subsystems becomes most important requirement needed [7].

However, not all types of light sensors can be matched by wireless daylight sensor system requirement. Before starting to apply wireless daylight sensor system, a proper selection of light sensor must be considered. There are so many selection methods to determine the best entity candidates over some criteria. One of them is Analytical Hierarchy Process (AHP). The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process to decide a conclusion with both quantitative and qualitative aspects are considered [8]. The best candidate will be used as daylight sensor in daylight harvesting system.

II. Analytical Hierrachy Process

The AHP starts with decomposing the problem into a hierarchy of sub problems so that it can be easier to subjectively evaluate [9]. In this study, both effectivity and sensitivity are used to decide which sensor to be chosen. Both criterion is used to specify a preference for each sensor. The output of AHP is a list of feasibility values indicating the sensor chosen.

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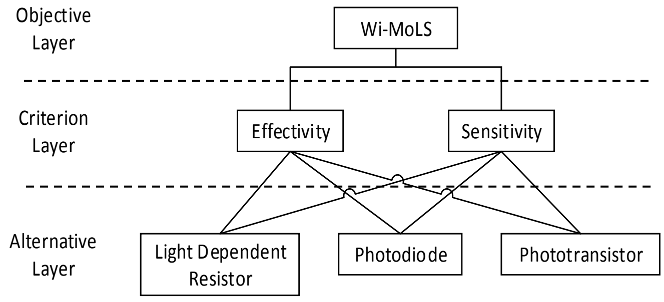

Figure 1. Light Sensor Selection of Wi-MoLS

The criteria decision is considered by the sensing characteristic of each light sensor. The light sensors will sense the 0.1-2400 nm sunlight wavelength [10]. According to their datasheets, the light dependent resistor, photodiode, and phototransistor could utilize 80% of light input when the light input is within 850-990 nm [11], 680-780 nm [12], and 800-900 nm consecutively [13]. It's clear that the light sensors can work optimally within the sunlight wavelength range. Those, these sensors could be considered as Wi-MoLS' light sensor.

III. METHODOLOGY

A. Collecting the Data

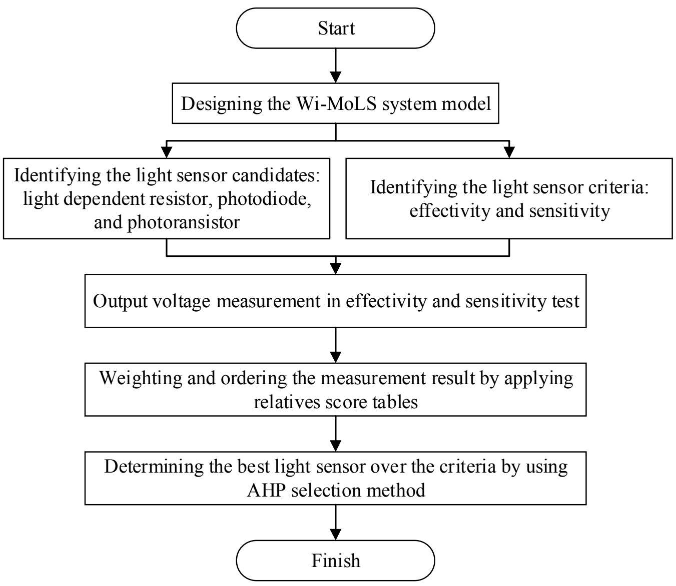

Figure 2. Flowchart of collecting the data

The output desired in this research is to take the most effective and sensitive light sensor of Wi-MoLS by using AHP selection method. Fig. 2 illustrates the flowchart of this research which is started from modeling the Wi-MoLS. It's designed by integrating of light sensor and illuminance level control component which is built by several integrated electronic components like microcontroller and transmitter module.

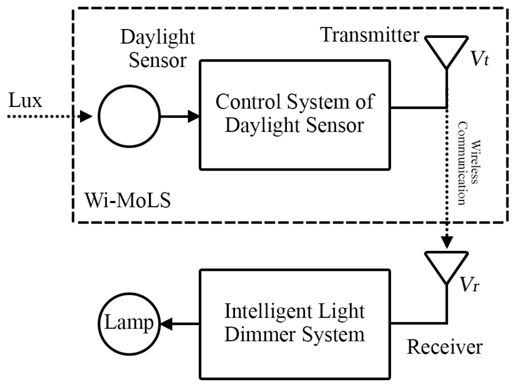

Figure 3. Wi-MoLS system model

Fig. 3 depicts that daylight sensors which is considered by using light dependent resistor, photodiode, and phototransistor are connected to daylight/illuminance level control system. It's consist of microcontroller which works as the main controller of Wi-MoLS and transmitter module which delivers lux amount data to the receiver module. The transmitter-receiver modules are represented by Bluetooth hardware due to its fair performance in short distance communication and price for use. After the data has been sent, it is converted by intelligent light dimmer system as output voltage for supplying the DC lamp need.

TABLE I. VARIABLE IDENTIFICATION

Test	Control Variable	Independent Variable	Dependent Variable
Effectivity	Rate of illuminance (300 lx) and test location	Angle of lux source (0^0, 15^0, 30^0, 45^0, 60^0, 75^0, and 90^0)	Output voltage
Sensitivity	Angle of lux source and test location	Illuminance level value (2-820 lx)	

According to the TABLE I, the output voltage supplying to the DC lamp is used as measurement result of effectivity and sensitivity test. The applied light sensors would give a unique response of effectivity and sensitivity. Effectivity means that angle change of lux source received by light sensors does not influence the Wi-MoLS' performance represented by output voltage change. Mathematically, the magnitude of output voltage rate of change (ΔV) towards changes of lux source incident angles ($\Delta\alpha$) must be minimum. In addition, the sensitivity means that the change of illuminance received by light sensors can maximally affect the output voltage. So that the magnitude of output voltage rate of change (ΔV) toward change of illuminance received (ΔE) must be maximum.

After earning the test results for each light sensor, the best order of test results is conducted which can be used as priority level representation. In creating the pairwise comparison matrix, each test result must be weighted by relative score table following TABLE II.

TABLE II. RELATIVES SCORE TABLE

Value of a_{ij}	Interpretation
1	*i* and *j* are equally important
3	*i* is slightly more important than *j*
5	*i* more important than *j*
7	*i* is strongly more important than *j*
9	*i* is absolutely more important than *j*

The pairwise comparison matrix is filled by relative score element of candidates and criteria considered. Furthermore, the vector of candidates and criteria score is computed and resulting the candidates ranking over the criteria desired.

IV. RESULTS AND DISCUSSION

A. Ouput Voltage Characteristics of Effectivity Test

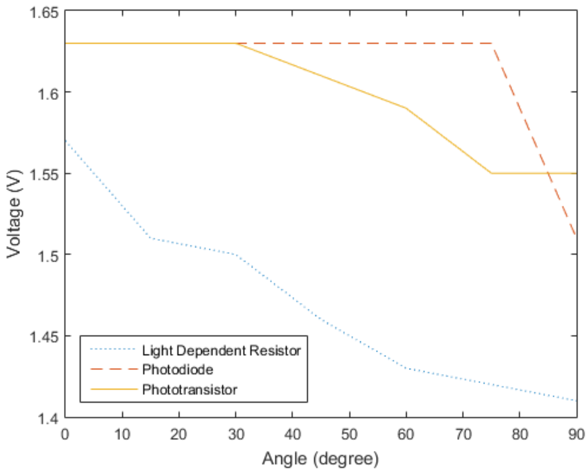

Fig. 4. Output voltage characteristics as a result of incident light angle variations

Fig. 4 shows the response of each light sensor as a result of angle variations. light dependent resistor responded differently in each direction of light angle. Photodiode gave significant changes of voltage when the angle of incidence of light more than 70°. Meanwhile, phototransistor gave significant changes of voltage when the incidence angle of light more than 35°. Optimum value of effectivity was reached when voltage changes to the incident angle of light also known as gradient of Voltage – Angle curve is minimum, which means the changes in the incident of light don't affect the voltage changes. Based on Fig. 4, photodiode's slope is -0.0009 Volt/° which makes it have the minimum magnitude value among the phototransistor (-0001 Volt/°) and light dependent resistor (-0.0017 Volt/°). Thus, photodiode is the best light sensor over effectivity criterion compared to others.

B. Output Voltage Characteristics of Sensitivity Test

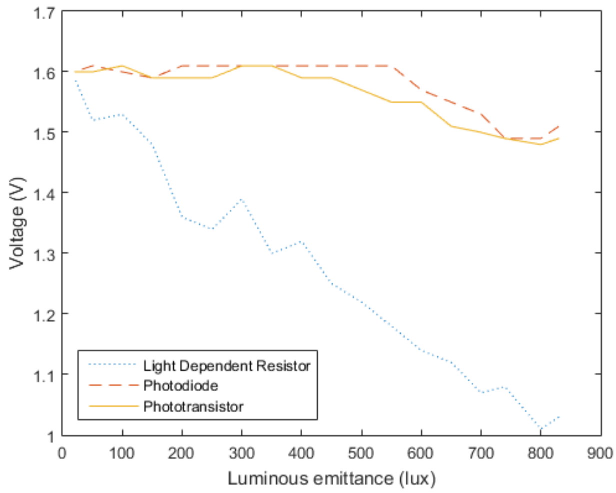

Fig. 5. Output voltage characteristics as a result of lux source variations

Fig. 5 shows the response of each light sensor as a result of lux source variations. The more lux received to sensor, the lower value of voltage is resulted (even though each sensor has each internal of voltage). Photodiode gave the biggest output voltage of Wi-MoLS among the other light sensor while LDR gave the lowest output voltage on the same lux. In range of 2 to 820 lx, light dependent resistor gave the most significant changes of voltage among the other light sensor. Optimum value of sensitivity was reached when voltage changes to the incident angle of light also known as gradient of Voltage – Luminous Emittance curve is maximum, which means the changes in the lux source variation is maximally affect the voltage changes. Then, the light dependent resistor has value of -0.9 Volt/Lx which makes it have the maximum value among the phototransistor (-0.2 Volt/Lx) and photodiode (-0.1 Volt/Lx). Thus, LDR is the best light sensor over sensitivity criterion compared to others.

C. Analytic Hierarchy Process (AHP) Analysis

According to the experiment result, the Photodiode was the best effective sensor followed by phototransistor and LDR. In other side, the LDR was the best sensitive sensor followed by phototransistor and photodiode. For determining the best light sensor over both of effectivity and sensitivity, AHP is good to be applied because it gives a structured technique for organizing and analyzing complex decisions based on mathematics. In TABLE III, IV, and V, the three sets of matrix consist of two sets of light sensor candidates and a set of criteria ordered from most to least desirable are created. Those matrix value elements are determined by matching the TABLE II value and their importance characteristic.

TABLE III. PAIRWISE COMPARISON MATRIX OF LIGHT SENSOR UNDER EFFECTIVITY FACTOR

Light Sensor	LDR	PD	PT
LDR	1	1/9	1/7
PD	9	1	1/2
PT	7	2	1

TABLE IV. PAIRWISE COMPARISON MATRIX OF LIGHT SENSOR UNDER SENSITIVITY FACTOR

Light Sensor	LDR	PD	PT
LDR	1	9	8
PD	1/9	1	2
PT	1/8	½	1

TABLE V. PAIRWISE COMPARISON MATRIX OF CRITERIA

Criteria	Effectivity	Sensitivity
Effectivity	1	1/3
Sensitivity	3	1

After making the pairwise comparison matrix of light sensors candidate and its criteria, the priority scale matrix of light sensor is settled according to TABLE VI and VII.

TABLE VI. PRIORITY SCALE MATRIX OF LIGHT SENSOR

	Effectivity	**Sensitivity**
LDR	0.05467	0.81053
PD	0.38041	0.11486
PT	0.56492	0.07461

TABLE VII. PRIORITY SCALE MATRIX OF CRITERIA

Effectivity	0.25
Sensitivity	0.75

By multiplying the priority scale matrix of light sensor and criteria, percent of score matrix can be obtained. According to TABLE VIII, light dependent resistor has the biggest percentage among photodiode and phototransistor which means light dependent resistor is chosen to be the first priority light sensor.

TABLE VIII. PERCENT OF SCORE MATRIX

	Percentage (%)
LDR	62.16
PD	18.12
PT	19.72

V. CONCLUSION

In expecting the best work of Wi-MoLS for controlling building illuminance by adjusting the incoming natural light coming to the building, the best light sensors must be selected over expected criteria. The effectivity and sensitivity test had been performed to evaluate the light sensors characteristic. AHP is used to select the best light sensor candidates. The result shows that light dependent resistor is the most effective and sensitive light sensor by 62.16 % in score instead of phototransistor (19.72%) and photodiode (18.12%).

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