PLEA 2015
BOLOGNA, ITALY
09-11 September 2015

DESIGN OF SMART SHADING DEVICE FOR BUILDINGS IN A HUMID TROPICAL CLIMATE

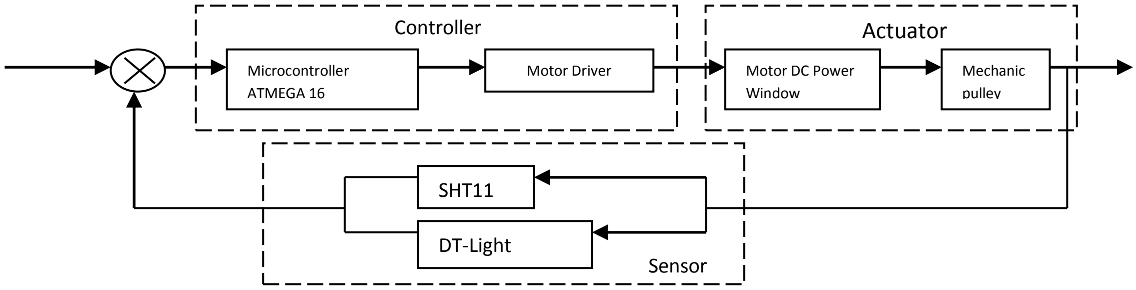


Fig 1: Block diagram of smart solar control and shading device.

WHICH ARE YOUR ARCHITECTURAL (R)SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Research summary

This study aims to develop a design concept that is responsive to climate, especially on buildings in a humid tropical climate. Hot and humid climatic condition is one crucial issue in achieving thermal comfort in buildings. Control of direct solar heat, which can cause excessive heating in the room is the central theme of the scope of this study. The use of permanent shading devices is often not able to block the sunlight where the angle changed from time to time during the year. Shading device design does not take into consideration the main parameters of angle of direct light because of failure to apply the optimal design tool. Shading devices can be adapted to the automatic changes is needed, especially to avoid excessive heating in a room. The purpose is to design the control appropriate shading devices. Smart shading device is the ability of construction to react in real time to reduce the heat directly from the sun into the room. Smart shading devices depend on the input data and information; and acting if conditions exceed the certain limits interval. The use of sensors and actuators as an inseparable part so that these devices will be smart or even smarter in interacting with the environment in accordance functionality desired building or room. Application of the tool at a tested house scale of 1:1 has been tested. The test, of course, of the tool has been done and went well. The object of this study is part of a series of research to get the smart building design completely and thoroughly, both the parts or elements of architecture and the functioning of the building for a goal of reduction of energy use.

Keywords: Smart shading devices, intelligent building, humid tropical climate

1. Introduction

Challenges faced by engineers and architects today is the problem of energy saving, particularly in both residential and public buildings. Issue energy savings triggered by the more limited and more expensive sources of energy derived from fossil fuels, but still abundant renewable energy.
In the construction sector, according to studies on energy consumption both offices and residential buildings, approximately 40% of the energy used for air conditioning in the room, even room cooling in a humid tropical climate. The energy consumption will increase when a building is designed without regard to site conditions and environment, use of inappropriate materials and cooling installations. It is understandable that the average building in a humid tropical climate facing the problem of how to maintain the condition of the building comfortable. This is a reason for the large energy requirements as a result of the occurrence of excessive heating due to very large direct sunlight into the room and unobstructed; using a controlled shading devices are highly recommended. The use of permanent shading devices is often not able to block the sunlight angle changing from time to time during the year. Conception of shading device design does not take into consideration the main parameters of the interval angle of light falling directly because of failure to apply the optimal design tool. Shading devices that can be adapted to the changes automatically is needed, especially to avoid excessive heating in the interior building.

2. Research objectives

Several series of studies conducted by Kindangen et al. (1993-2006) have been published, especially regarding the performance of parametric studies of architectural elements to improve the performance of natural ventilation. It was also reported that ventilation performance, especially for thermal comfort depending on the pattern and magnitude distribution of air flow, especially the contribution of inlet and outlet. The integration of smart devices on openings or windows for ventilation delivers performance mutually reinforce one another. The role of the windows or ventilations are generally useful in order to reduce heating in the interior room.
The study of solar heating and shading device control becomes important when the architects and designers are faced with the problem of climatic parameter fluctuations such as air temperature, humidity and daylight day by day. Several studies on permanent smart devices such as published by Ahmed et al. (2011) concluded that the use of permanent shading devices can improve the thermal performance in office space. Matusiak et al. (2006) proposed a method for the design of the exterior shading devices permanently. Marie Claude Dubois (2003) described the results of research that a method of determining the shading devices. These studies are basically done in moderate climatic conditions and will be different when applied in a humid tropical climate. While Chia-Peng (2004) reported that the shading devices in architectural design can control the level of illumination with light during the day, while Carmody et al. (2006) conducted a similar study with the object of commercial buildings.
Research of dynamic window systems and new switchable published by Karlsson (2001), especially in the control system and the potential energy savings, then by Lee et al. (2004) and Jian Yao et al. (2011) examined primarily on the economic aspects of the

building and its operation in energy saving system. European Commission (2002) in the program *Thermie* published system of shadings for European climate; thus the appropriate reference to the Southeast Asian climate is still very limited even similar studies have not been publicized until now. Research on the material, typology and orientation of shading devices have been done by Gutierez et al. (2007) which concluded that the experimental studies were done very useful to build a database of shading design. External shading devices to maximize the views and visual performance, especially in terms of lighting was done by Kim et al. (2009). Similarly, the results of Wong et al. (2003) and Corrado et al. (2004) reported an analysis of some of the important influence of external shading devices for lighting and natural ventilation. Rosencrantz Tobias (2005) in his doctoral thesis research reported that with an evaluation by measuring and simulating the performance of windows and shading devices will provide a very significant contribution to energy efficiency.
Research on smart shading devices has little to find, countless researchers Lu, Jiakang et al. (2011) reported the use of a simple light sensor to get smart light. Pablo La Roche (2006) proposed a smart passive system in order to achieve carbon neutral buildings or zero emission building. He was also in 2005 doing some research, shadowing effect of the combination of smart and ventilation for thermal comfort. One of the researchers who produced many publications in intelligent control is Selkowitz et al. (2006, 2008, 2009), especially in the automation of shading devices and smart glass for natural lighting control. Buhagiar et al. (2008) strengthening the research results Selkowitz especially for application to the Mediterranean climate. Application of smart shading devices for humid tropical climate so far has not been found.

3. Methods

In an effort to build a basic model of smart shading devices, by integrating sensors, actuators and control motorization in accordance with the devices function. Some steps are done repeatedly to get the base models and proper algorithms.
In the design, the basic concept is a guideline to plan and design something; this concept contains steps and instructions to determine the necessary supporting things in the design. Figure 1 presents a block diagram of smart solar control and shading devices.
One of the steps used in designing has divided the system into several sub-systems and then the sub-system into several sections so it will be easier to determine the components that will be used. From the block diagram illustrates the sub-systems with different functions to build a system. The sub-system is the controller, sensors and actuators. The controller consists of ATMEGA 16 micro-controller and motor driver, sensors consists of a SHT11 sensor as temperature and humidity sensor, DT-Light sensor as a light sensor, and actuators consist of DC power window motors and mechanical pulley to raise and lower the shading panel.
In each section requires a voltage source. For ATMEGA 16 AVR micro-controller system sourced voltage of 12 volts, the motor drivers with source voltage of 18 volts with a flow of 5 Ampere, DC motor drivers are used to set the direction of rotation of the motors that raises or lowers shading panel, SHT11 sensor, multi-turn potentiometer and DT-Light sensor requires a voltage source of 5 volts. The multi - turn potentiometer is used to detect the rotation of DC motors. The number of motor rotates which will affect the state or position of the shading.

4. Results and design potential

4.1. Hardware Design

A test house used in this design is a wooden house with a size of 5.5 x 6 m. This house type is a traditional Minahasa wooden house that is often sold in the public market. The house comprises a terrace, two chambers as a living room and bedroom. The living room has been chosen as a studied room. This room consists of two windows on the West and South sides. The roof is made of corrugated zinc sheets, wood window frames fitted with plain glass. The test house is located at the Faculty of Engineering Sam Ratulangi University in Manado having a particularly good position oriented to the orientation of which is considered the largest solar heating. Shading device is placed on the Western side, because on this side the lighting and heating effect of the sun is optimal.

Fig. 2. A test house.

Central controller using ATMEGA 16 micro-controller. Sensors in this design use 3 pieces of sensors which are DT-Light sensor, SHT11 and multi-turn potentiometer. DT-Light sensor is used to measure illumination intensity (Lux), SHT11 for indoor air temperature (°C) and humidity (%) and multi-turn potentiometer is used to measure the rotation of the motor that raises and lowers shading. The multi-turn potentiometer is used as the input DC power window motor that used to adjust the position and state of the shading. The output of this sensor in the form of analogue voltage to be compared to results for the adjustment of shading position.

Super High Torque motor (DC) having an internal gear is used as actuators. It has a level of high torque as the advantages of this motor than other DC motors, capable of lifting loads weighing up to 70 kg. The engine rotation speed of approximately 67 rpm. Mechanical shading is used to roll the rope using a pulley system where the pulley diameter of 7 cm. The pulley is made of acrylics that connect to a DC power window motors and potentiometer multi-turn. Rolling the shading strap causes the rise and fall shading panels according to the position and the desired state. For shading panels materials have tried several types and brands; of the results of this experiment showed that the type of window shading with pleated folding type more suitable for modelling and testing. Shading is used to block direct sunlight entering the room; shading panel size used is 50x50 cm.

4.2. Software Design

The design of the software includes the manufacturing flow chart of the smart solar control and shading devices. The program will be executed when the micro-controller get a voltage of 12 volts. It initialize Chip, PORT, I2C, ADC and the routine process of the sensor reading. A DT-Light sensor is calibrated on the unit of light intensity (lux), SHT11 sensor is calibrated in units of temperature (°C) and air humidity with %, for multi-turn potentiometer calibrated at 10-bit ADC. An actuator does a routine that will determine any conditions and circumstances of shading panel position up or down according of inputs the temperature sensors, air humidity and light; for 5 shading positions (state 0-4).

Fig. 3. Installation of smart shading device equipments.

The routine and subroutine of the main program in the design consist of initialization, regularly read sensors, actuators and run the appropriate sensor readings. Flowchart runs the corresponding actuator, sensor readings, based on the inputs used of light sensors, temperature, and air humidity, then the specified threshold value determines position or state of shading.

Table 1. Parameters of Threshold Input Sensor.

Parameters	Thresholds		
	I	II	III
Light (lux)	<200	200-350	>350
Temperature (°C)	<25	25-30	>30
Humidity (%)	<50	50-60	>60

Shading device position is divided into 5 positions

Table 2. Shading Condition.

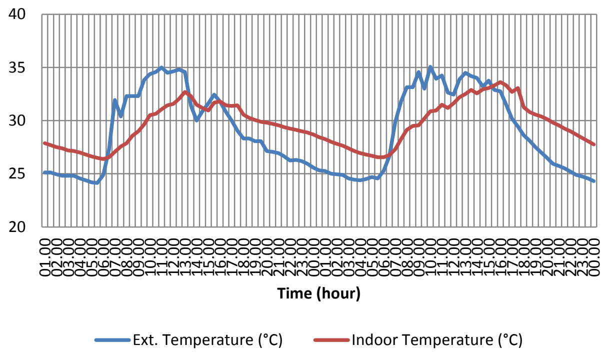
State	Position Shading
0	Closed Full
1	Bit Closed
2	Medium
3	Slightly Open
4	Open Full

The following table represents states of shading response to the parameters of light, air temperature and humidity.

Table 3. State Shading on the parameters.

Light	Temperature	Humidity	State of Shading
>350	>30	<50	0
>350	>30	50-60	0
>350	>30	>60	0
>350	25-30	<50	0
>350	25-30	50-60	1
>350	25-30	>60	1
>350	<25	<50	0
>350	<25	50-60	1
>350	<25	>60	1
200-350	>30	<50	1
200-350	>30	50-60	1
200-350	>30	>60	2
200-350	25-30	<50	1
200-350	25-30	50-60	2
200-350	25-30	>60	2
200-350	<25	<50	1
200-350	<25	50-60	2
200-350	<25	>60	3
<200	>30	<50	2
<200	>30	50-60	3
<200	>30	>60	4
<200	25-30	<50	3
<200	25-30	50-60	3
<200	25-30	>60	4
<200	<25	<50	3
<200	<25	50-60	4
<200	<25	>60	4

Air temperature measurement's results during two days consecutively in a room equipped with shading device compared to exterior air temperature were presented in Figure 4. The same figure for indoor and exterior air humidity. The measurement used digit-data logger TLH; which was put in the room and the outside. Window and doors of a room in which shading panel applied were closed a whole day; it is mean that no ventilation gets a role to control its micro climate. The shading device has shown its performances to be able to maintain indoor air temperature lower from the outdoor; effectively happen at 6 am to 4 pm, In the remaining time, the room temperature is higher than outside. Air humidity in this room is more controllable at interval 55 to 77% compared to the outside that is more fluctuated.



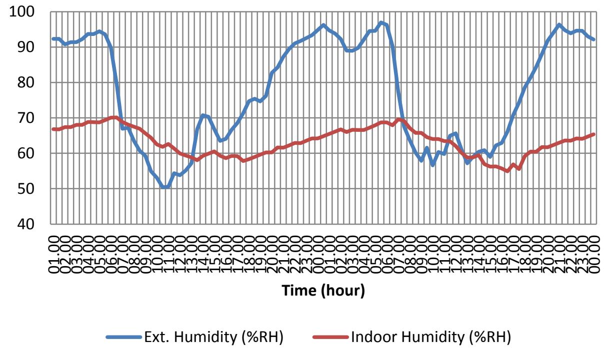
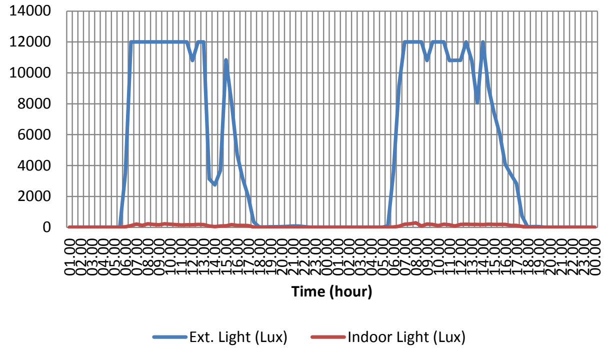


Fig. 4. Profile of exterior air temperature and humidity.

The shading device plays an important role to control level of indoor illumination. As known daylight factor depends on sky components, externally reflected components and internally reflected components; it can be fluctuated follows sky conditions. Figure 5 shows that indoor illumination has a pattern complying changes of exterior illumination. During the day, indoor illumination is between 50 to 300 lux.



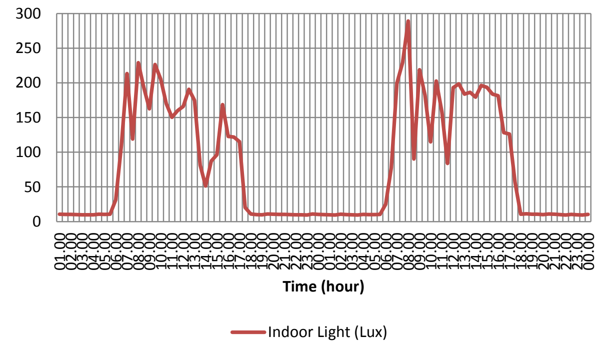


Fig. 5. Profile of exterior and indoor illuminations.

5. Conclusions

Design of smart shading device has been performed with main stages namely design of hardware and software, and overall design. Applications in scale 1 : 1 in a building model has been tested. Tests on the course of the tool has been done and went well. Selection of the type of shading device adapted to the materials and tools available, although there are several types of alternatives that can be applied. This study should be continued with emphasis on reliability tools and industrial applications; some improvement, notably more detailed algorithms and substantial needs to be done, in order to put forward as industrial products.

6. Acknowledgments

This study was financed by Sam Ratulangi University (USR)/RUPT. We express our gratitude to the Rector USR and Leader of Institute for Research and Community Service (LPPM) USR.

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