International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Solar Energy Harnessing Optimization Algorithm in a Robotic Solar Tracker with Arduino Based Monitoring System

Mirafe R. Prospero, Neil P. Balba, Ricky V. Bustamante, Gerby R. Muya,

Abstract*: *Solar power although an abundant source of renewable energy must be utilized properly. One of the main factors to optimize its benefits is the capacity of the consumers to efficiently channel its power. The motivational factor of this endeavor is creating a robotic sunlight tracker system in harnessing solar radiant to its optimum potential in the Philippine setting, where sun's insolation is low on the average due to the factors affecting climate conditions (like temperature, rainfall, storminess, winds, etc.).The study developed a prototype robotic sun tracker that is operated by a microcontroller using the sun's perpendicularity and shadowing techniques in the design of the mechanism that injected an intelligent comparator algorithm. A motor control method was used to execute the best turn to harness the optimum solar energy with an Arduino based monitoring system that measured the voltages obtained from each of the set-ups. The result was a 29% improvement in generating electricity using the robotic sun tracker system versus static panel installation.

Index Terms*: *Arduino based monitoring system, microcontroller, robotic sun tracker, shadowing technique, solar radiant

I. INTRODUCTION

The discovery of electricity leads to the many wonderful inventions that have made the lives of mankind easier. But as the earth is aging so as some of its resources like the nonrenewable sources of energy that the majority of mankind are consuming. Thus, more and more countries are starting to divert the greater percentage of their electricity to renewable energy sources [1] as convened in the Paris Agreement on Climate Change which the Philippines is also a member [2].

The **Greenpeace** organization in the Philippines reported the need to fully implement and support the **RE** (Renewable Energy) **Act of 2008** where energy efficiency measures would

help the country in deterring the rising costs of fossil fuels[3].

Solar power as an abundant source of renewable energy must be optimized and utilized properly and one of the main factors to maximize its benefits is the capacity to efficiently channel its power. The solar irradiance which is the amount of radiant energy coming from the sun [4] is not the same between countries as described in global solar atlas [5]. As for the philippines which is not even in the top 50 countries with the highest index of solar insolation distribution. The motivational factors of this undertaking are to create a robotic tracker in harnessing sun's power in its optimum potential in the philippine setting, where sun's insolation is low on the average and to determine the efficiency of utilizing a robotic sun tracker versus the static installation of solar panels.

II. RELATED WORKS

Hargreaves [6], presented the obtained data from **NASA LaRC** Power Project, the distribution of earth solar insolation at the ground level of the top 50 nations and unfortunately the Philippines is not included.

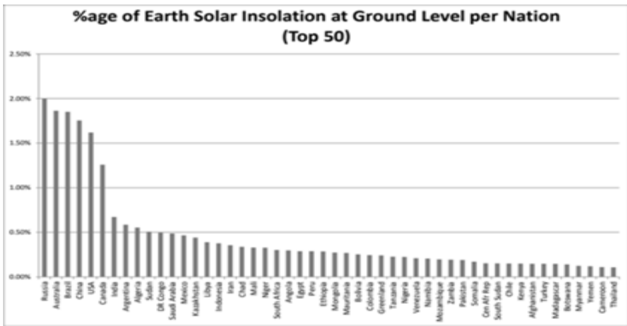

Fig.1. Top 50 Nations for Earth Solar Insolation (2015)

Fig.1shows the top 50 nations in terms of earth solar insolation, this means that these countries are capable of generating more solar power energy without the extra help from panning and tilting technology such as automatic sun tracker. The earth's rotation in a particular region will complete one rotation every 24hrs (based on a solar day) and thus moves at a rate of 15° per hour (one full rotation is 360°). Because of this, the sun appears to move proportionately at a constant speed and creates a daily *solar arc* that serves as the path of the sun's motion across the sky. At certain latitude that corresponds to its angle, the sun will travel across the sky each day [7].

Manuscript published on 30 August 2019.
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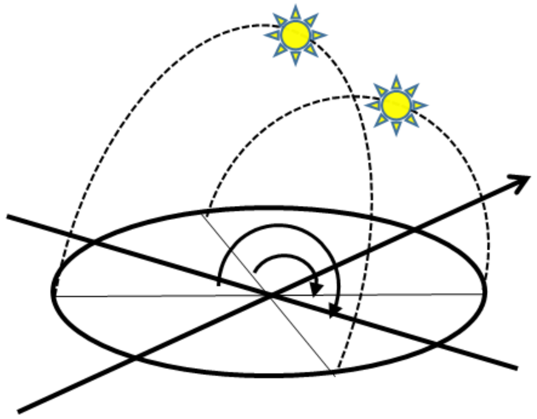

Fig.2. The different angles of the sun. Source: Adapted from [7]

Fig. 2 shows that the sun moves at a rate of 15° per hour to create the sun's arc will be the theory behind why every minute is critical in harnessing the sunlight, thus solar panel must be tilted move in accordance with this arc.

R. del Rosario, et.al.[8], proved that the solar trackers can add to the productivity of harnessing the sunlight, in terms of cost and size saving as well as the number of solar energy gains. The study was based on a real-time keeping chip, to automatically determine the optimum amount of sunlight in every 30minutes from 6AM-5P in a small farm with an incubator, lamp, and aquarium pump motor. Using tact switches to manually tilt the motor of the panels and to modify the clock thru 16x2 LCD. Thus, the paper highly recommends integrating the wireless technology using a microcontroller to maximize its duty cycle up to 6% and to become flexible and efficient in terms of management and maintenance.

Bione, et.al.[9], conducted a study to compare the performance of the pumping systems driven by fixed, tracking and tracking with concentration PVs. A theoretical simulation, as well as the experimental comparison between three cases, was performed. The effects showed that it had significantly proven that PV with tracker obtained higher value in terms of volume of water is pumped out of 7.4 m^3/day. Based on these findings, it has proven that there is a significant difference between fixed PV (photovoltaic) solar panel and the PV with a tracker, which concluded the latter to be more efficient.

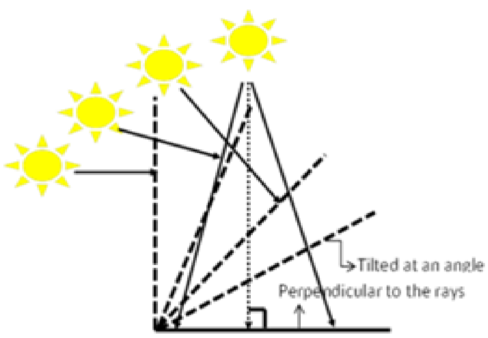

Fig. 3. The panel perpendicular efficiency to the rays of the sun. Source: Adapted from [10]

Fig.3 illustrates the efficiency of *solar irradiance* collection of the solar panels that depends on when the sun's rays are perpendicular to the panel's surface [10].

Light Dependent Resistor (LDR) or photocells serve as the input transducers in the system. These photocells are light sensors devices that automatically detect lights. An LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it. Miniatures *photocells* LDR were used in developing the prototype [11].

Fig.4. A miniature Light Dependent Resistor (LDR) sample.

Figure 4 shows a miniature photocell or LDR in a miniature epoxy sealed open frame package (4mm dia.). Resistance reduces as light falling on the device increases.

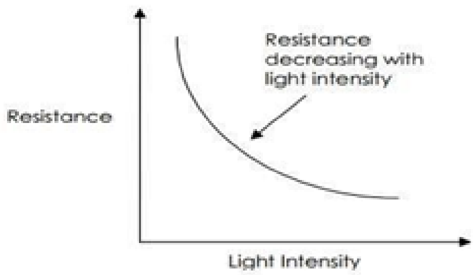

Fig.5. Typical LDR resistance vs. Light Intensity Graph

Figure 5 represents a typical LDR resistance versus light intensity graph that shows that resistance is *inversely proportional* to light intensity.

Shinya, et al.[12], presented theories on shadowing technique on their paper, "Rendering Techniques for Transparent Objects", the concept of shadowing to calculate luminance for a particular area for emphasis in terms of rays of light that will be reflected from a light source which is important for creating a realistic picture of transparent objects for computer graphics.

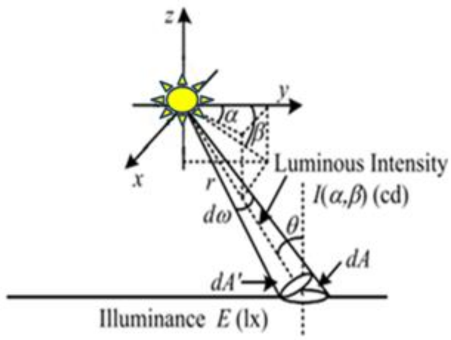

Fig.6 Illuminance formula for luminous intensity. Source: Adapted from [12]

Fig. 6 shows the formula to get the luminance of a certain set-up and to get its luminous intensity.

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DOI: 10.35940/ijitee.I7541.0881019
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The theory of shadowing to get the *luminance concentration* is used in designing the holder mechanism of the photocells or light dependent resistors (LDR) as the light sensor to control the turns of the motors (servo).

Actuators are motors that convert energy into turning force which then move or control a mechanism or a system into which they have been incorporated. An actuator can introduce motion as well as prevent it. It typically runs on electric or pressure (such as hydraulic or pneumatic). The control system can be controlled mechanically or electronically, software driven or human operated [13]. The "servo" motor is used as a type of actuator to the system to provide speed control and position accuracy due to its feedback mechanism.

The resistance (ohm) of light sensors (LDR) is converted to voltages using **Ohm's law**. This law states that the "electrical current flowing through a fixed linear resistance is directly proportional to the voltage applied across it, and also inversely proportional to the resistance", forming the relationships between the *Voltages, Current and Resistance of Ohms Law* [14] as shown below.

$$\text{Current, (I)} = \frac{\text{Voltage, (V)}}{\text{Resistance, (R)}}\text{, in Amperes, (A)} \quad (1)$$

Ohm's Law Relationship

III. THE PROPOSED FRAMEWORK

Different concepts and algorithms were used in the designing of the system's prototype.

The block diagram below represents the important phases used in the development of the robotic sun tracker using light sensors.

A. Block Diagram of the System

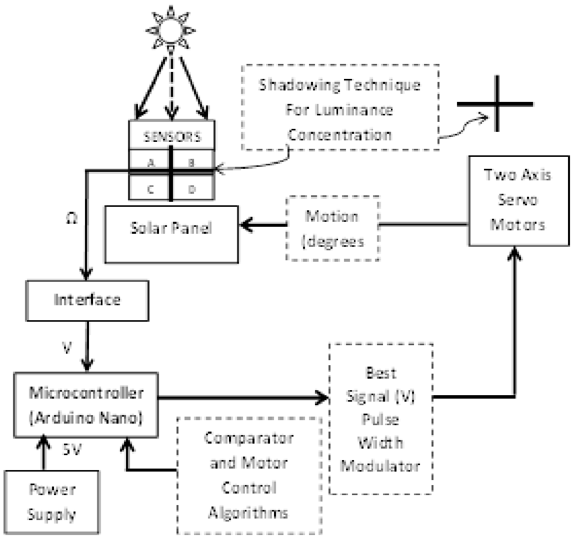

Fig. 7 Block Diagram of a Dual Axis Sun Tracker System

Fig. 7 models the system from the mechanism that holds the four light sensors (LDR) in a dual axis border and a solar cell connected to the two-axis servo motors. These two-axis servo motors execute the best angle turn based on the best signal pulse modulator (SPM) that is based on the algorithms applied in the Arduino coding that process and perform to execute the optimum angle turn facing directly the sun.

B. The Design

The design of the robotic sun tracker is divided into four major phases:

1. Solar Panel Holder (light sensors and solar cell)
2. The Interface (circuit converter)
3. The Microcontroller (Arduino nano)
4. The Actuator (Servomotor)

The Solar Panel Holder

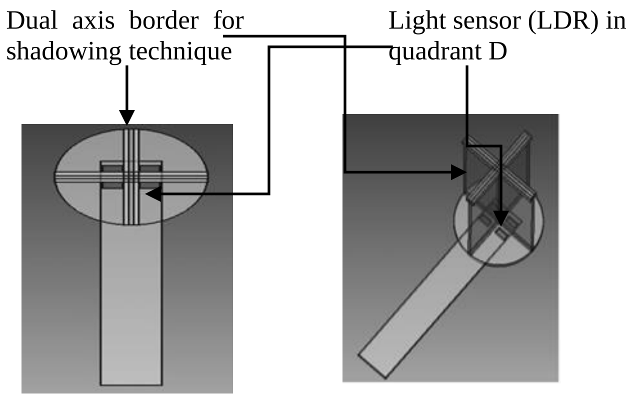

Fig.8 Holder's Top View **Fig.9**Holder's Isometric View

Figures 8 and 9 model the holder's top and isometric views respectively printed in a 3d printer that served as the material to hold or to put together the dual axis border and the light sensors. The X part top of the dual axis border was designed using the shadowing technique for illuminance concentration [15].

The Interface

Applying Ohm's law in the circuit design of the interface that converts the Resistance coming from sensors (LDR) as analog output to the voltage that served as an analog input to the microcontroller (Arduino nano).

The Microcontroller

The microcontroller using an Arduino nano is the brain of the system. The 4 analog signals from the interface were fed to the analog input pins of the Arduino Nano. The comparator algorithm was applied for the optimum results that were converted into digital signal outputs as the best vector direction for the Servo motors turns.

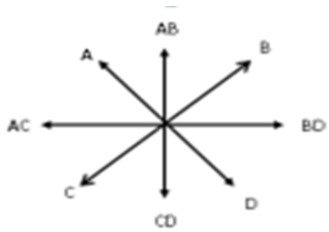

Fig.10. Vector Direction for Servo Motor Movement

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Fig. 10 shows the vector guide in addressing the 30% tolerance of pulse width modulator signal values.

Fig.11 An Arduino Nano microcontroller**.**

ig. 11 pictures a small and compact type of microcontroller that was used in processing the codes in Arduino. This was programmed using intelligent comparator and motor control algorithms to obtain optimum results.

The Actuator (Servo Motor)

Fig. 12 A Micro-Servo motor (SG-90) 180 degrees for Arduino.

Two Servo motors were used for dual axis movement that executes the best turns to track the sun. These turns are in digital signals Pulse With Modulation (PWM) fed by the microcontroller [16].

C. The Arduino Based Monitoring Module

The Arduino based monitoring system is a module that monitors and measures the number of voltages produced by the two set-ups namely the one using the robotic sun tracker and the other set-up that panel is in static mode.

The program automatically monitors and evaluates the results of both set-ups graphically. These graphs are the basis for evaluating the performance of the robotic sun tracker system.

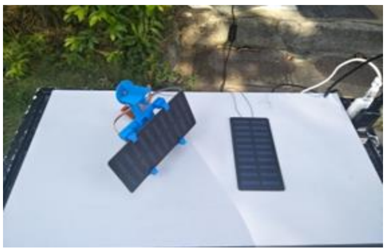

Fig.13 The actual set-up for testing and validation procedures.

Figure 13 shows the actual set-up during the testing and evaluation of the study. It shows the robotic sun tracker in parallel with the panel installed in a static position. The system was tested between 7 am to 3 pm on a day with fair weather.

IV. RESULTS

The result of the Arduino based monitoring system is presented based on its tabulated outputs.

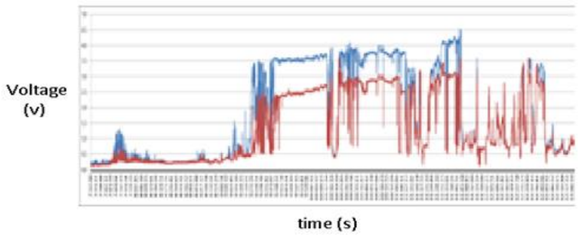

Fig.14. Graph of voltage measurement of using Robotic Sun Tracker versus panel in a static position

Fig.14 presents the result of the Adruino based monitoring system. The curve line in color blue denotes the value using the robotic sun tracker while the line curve in color red denotes the value of panel installed in a static position.

Below is the table of values in terms of the voltage generated by both set-ups.

Table I

Voltages generated by each of the set-ups.

	Robotic Solar Tracker	Static Panel
accumulated total voltages	30634.82893	23688.664

The values show an improvement of 29% which is significantly showing an increase in performance on using a robotic sun tracker.

V. CONCLUSION

The study has proven a very significant improvement of 29% on the capacity of the robotic sun tracker to harness more radiant energy than static installed solar panels.

But other factors must be taken into consideration for further undertakings, such as the sturdiness of the set-up, the quality of the panels to use, the cost to incur for using the system, space to use for the set-up and others.

This paper also emphasizes on the need for more simple yet powerful innovations to kick-off now that humanity is more aware of the crisis brought about by climate change and increasing cost of none renewable sources of energy [17].

REFERENCES

1. "Here Are 11 Ways to Shift to Renewable Energy", Climate Reality, 2019. [Online]. Available: https://www.climaterealityproject.org/blog/follow-leader-how-11-countries-are-shifting-renewable-energy. [Accessed: 03- Mar- 2019].
2. R. Cabato, "Paris Agreement effective in PH on Earth Day 2017", CNN, 2019. [Online]. Available: http://cnnphilippines.com/news/2017/04/20/paris-agreement-effective-earth-day.html. [Accessed: 30- Aug- 2018].
3. "Fossil fuel- dependence puts at risk Philippines' economic growth prospects - Greenergy", Greenergy, 2017. [Online]. Available: http://greenergydev.net/fossil-fuel-dependence-puts-at-risk-Philippines-economic-growth-prospects/. [Accessed: 26- Aug- 2018].
4. B. Dunbar, "NASA - SOLAR IRRADIANCE", Nasa.gov. [Online]. Available: https://www.nasa.gov/mission_pages/sdo/science/Solar Irradiance.html. [Accessed: 25- Aug- 2018].
5. "Global Solar Atlas", Globalsolaratlas.info, 2016. [Online]. Available:

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Journal Website: www.ijitee.org

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http://globalsolaratlas.info/knowledge-base/introduction. [Accessed: 25- Aug- 2018].
6. C. Hargreaves, "The Worldwide Distribution of Solar Resources by Nation.", Australia, 2018.
7. R. Lee Jin Yu, T. Lee Ji, Y. Hao Lim, H. Guang Lim Ghim, A. Lim ShuEn, and K. Lim Wee, Math.nus.edu.sg. [Online]. Available: http://www.math.nus.edu.sg/~mathelmr/gem-projects/hm/0304-1-66-sun_and_architecture.pdf. [Accessed: 27- Aug- 2018].
8. Rosario, R. Gustilo and E. Dadios, "Optimization of A Small Scale Dual-Axis Solar Tracking System Using Nanowatt Technology", Journal of Automation and Control Engineering, vol. 2, no. 2, pp. 134-137, 2014. Available: 10.12720/joace.2.2.134-137 [Accessed 14 August 2018].
9. Bione, O. Vilela and N. Fraidenraich, "Comparison of the performance of PV water pumping systems driven by fixed, tracking and V-trough generators", Solar Energy, vol. 76, no. 6, pp. 703-711, 2004. Available: 10.1016/j.solener.2004.01.003.
10. "How is system efficacy calculated for PV lighting systems using various light sources? | Photovoltaic Lighting | Lighting Answers | NLPIP", Lrc.rpi.edu. [Online]. Available: https://www.lrc.rpi.edu/programs/nlpip/lightingAnswers/photovoltaic/15-photovoltaic-efficacy.asp. [Accessed: 02- Sep- 2018].
11. "How an LDR (Light Dependent Resistor) Works", Kitronik. [Online]. Available: https://www.kitronik.co.uk/blog/how-an-ldr-light-dependent-resistor-works/. [Accessed: 19- Sep- 2018].
12. M. Shinya, Y. Dobashi, K. Iwasaki, M. Shiraishi, and T. Nishita, "A Simplified Plane-parallel Scattering Model for Rendering Densely Distributed Objects such as Foliage", Journal of Information Processing, vol. 21, no. 2, pp. 349-357, 2013. Available: 10.2197/ipsjjip.21.349.
13. "How Actuators Work - Basic Actuators for Motion Control", Tigertek.com. [Online]. Available: http://www.tigertek.com/servo-motor-resources/how-actuators-work-in-motion-control.html. [Accessed: 30- Mar- 2019].
14. "Ohms Law Tutorial and Power in Electrical Circuits.". [Online]. Available: https://www.electronics-tutorials.ws/dccircuits/dcp_2.html. [Accessed: 20- Sep- 2018].
15. S. Ahmadi, "Shadowing, ergodic shadowing, and uniform spaces", Filomat, vol. 31, no. 16, pp. 5117-5124, 2017. Available: 10.2298/fil1716117a [Accessed 9 October 2018].
16. "Pulse Width Modulation - MicroController Electronics", MicroController Electronics. [Online]. Available: https://microcontrollerelectronics.com/pulse-width-modulation/. [Accessed: 18- Sep- 2018].
17. "Renewable energy sources and climate change mitigation: special report of the Intergovernmental Panel on Climate Change", Choice Reviews Online, vol. 49, no. 11, pp. 49-6309-49-6309, 2012. Available: 10.5860/choice.49-6309 [Accessed 10 November 2018].

AUTHORS PROFILE

Mirafe R. Prospero finished Master of Science in Computer Science. She has been an academician for more than two decades now and currently connected as assistant professor and program chair of Computer Studies department of Lyceum of the Philippines University-Laguna. She has published several papers both for local and international publications. The latest paper publication is a Scopus indexed journal for International Conference on Control and Computer Vision (ICCCV 2018) of International Association of Computer Science and Information Technology Organization (IACSIT). She presented papers in the 17th (WCASET) World Conference on Applied Science Engineering and Technology under the umbrella of (IFERP) Institute for Engineering Research and Publication. She is also a mentor of several students' organizations and adviser/coach of winning computer contests for local, national and in the 2017 Microsoft Imagine Cup world competition that made her students top 8 among the 39 world finalists.

Dr. Neil Balba is an International IT and Engineering consultant and educator. He works as a dean, a professor and conducts lectures in different countries. He became Corporate IT Director of Group of Companies and MIS Director. He is also active in different professional organizations and became the President of the Philippine Society of Information Technology Educators Incorporated-National (PSITE). He also became the Regional President of PSITE-Region 4, National Board of Institute of Computer Engineers of the Philippines (ICPEP), a member of Institute of Electronics Engineers of the Philippines (IECEP), Board of Integrated Southern Tagalog Association of Information Technology Education (ISITE), Board of Mechatronics and Robotics Society of the Philippines (MRSP) and International Association of Engineers (IAE). He is a graduate of 3 Doctorate Degrees, 3 Masters Degrees and 5 undergraduate programs focused on Engineering, Information Technology, and Management. Currently, he is the Technical Panel for Information Technology of ISO/IEC under Philippines' Department of Trade and Industry (DTI), Technical Panel of Malaysian Scientist Technical Association (MALSETAS), and Honorary Fellowship Member of Institute for Engineering Research and Publication (IIFERP-International). He is also an International and Local Accreditor for Washington Accord (PTC), Seoul Accord (PCAB) and PACUCOA and also a member of Regional Quality Assessment Team (RQAT) of Commission of Higher Education in the Philippines. Dr. Balba presented and published several numbers of researches locally and internationally and became keynote speakers in different research conferences in different countries. He was a recipient of several awards internationally and locally including several Best Papers and Best Papers' Presenter.

Engr. Ricky V. Bustamante is an academician and a researcher. He has active participation in several professional organizations in the Philippines. Currently, he serves as the Vice President for Robotics of the Mechatronics and Robotics Society of the Philippines (MRSP); and is also the Governor of the Institute of Electronics Engineers of the Philippines (IECEP), Laguna Chapter. He graduated Bachelor of Science in Electronics and Communications Engineering, also a Professional Electronics Engineer, and finished Master of Engineering, major in Electronics and Communications Engineering. He has been an active educator and an active advocate of Outcomes-based Education with training attended from the Philippines and US. In the area of research, he has served as Editor-in-Chief of the LPU Laguna Journal of Engineering and Computer Studies (ISSN 2467-5172) and was an Associate Editor of LPU Laguna Journal of Multi-Disciplinary Research (ISSN 2467-5199). Currently, he serves in the editorial board of "The Academic Society of Convergence Science". He is also a core member of the (WCASET) World Conference on Applied Science Engineering and Technology under the umbrella of (IFERP) Institute for Engineering Research and Publication. He has several kinds of research with ICACR 2017 proceedings in 2017 International Conference on Automation, Control and Robots and has researches presented and published in IEEE Xplore Digital Library (2018).

Dr. Gerby R. Muya is an associate professor and the research director of the Lyceum of the Philippines-Laguna. She earned her Bachelor of Science in Development Communication degree at the University of the Philippines, Los Baños, Laguna; after which she studied Master of Arts in Communication specializing in Communication Research at the University of the Philippines, Diliman, Quezon City. She attained her Doctor of Philosophy in Development Communication degree at the University of the Philippines, Los Baños, Laguna; recognizing her as top 5 Outstanding Doctorate Graduate. Dr. Muya served as project leader and researcher of various government and industry-commissioned researches. She is currently the project manager of a CHED-funded Discovery Applied Research and Extension Trans/Inter-Disciplinary Opportunities (DARE TO Grant-in-Aid). Dr. Muya also worked as the project leader of a research project of the Philippine Association of Private Schools, Colleges, and Universities (PAPSCU) Excellence in Academic Research Link (PAPSCU PEARL). From 2017-2019, she was the chair of the Research Committee of Network of CALABARZON Educational Institutions, Inc. (NOCEI). Her research works involve knowledge management, media literacy, communication studies, and mental health, to name a few. She has also produced and presented research papers in local, national, and international conferences. She also has published several papers in Scopus-indexed journals. She has 20 years of experience in teaching communication major courses and English as a Second Language to college students. Dr. Muya also has more than 10 years of higher education administrative work.