Portable Spectrometer Device for Mapua-Phil-Lidar2 Using Charged Coupled Device Array

Jose B. Lazaro Jr, Alejandro H. Ballado, Jr., Jann Pauline P. Deriquito, Shawn Michael L. Lamod, Brent Andrew Q. Mendez, and Meo Vincent C. Caya
School of Electrical, Electronics and Computer Engineering, Mapúa University
Muralla Street, Intramuros Manila 1002 Philippines
Email: {jblazaro; ahballado}@mapua.edu.ph; {jppderiquito; smllamod; baqmendez}@mymail.mapua.edu.ph; mvccaya30@gmail.com

***Abstract*—The study presents a portable spectrometer device for Mapua-Phil-Lidar2 in providing reliable spectral information. This information will complement the unreliable land satellite data that sometimes become obscure and give erratic results to accuracy for resource mapping. Upon using the portable spectrometer device a supplementary data can now be used to complete the resource map and provide an accurate spectral signature of each plant under the study. The proposed portable spectrometer device used a charged coupled device array which converts reflected light into voltage for processing. The developed portable spectrometer consists of Atmega1284P-PU microcontroller, concave holographic grating, charged couple device sensor, Global Positioning System (GPS) sensor, graphical Liquid Crystal Display (LCD) module and Secure Digital (SD) memory card. This study highlights the spectral signature taken from the following plants: avocado, banana, cacao, coconut, mango, sugar cane and cottonfruit/santol which cover certain part of the agricultural resources area in the Philippines. A desktop application was also developed to serve as the main interface to transfer the acquired spectral information from the proposed device to a computer for post processing and integration on the Resource Maps.**

***Index Terms*—charged coupled device array, holographic grating, portable device, spectroscopy**

I. Introduction

Spectroscopy is a technique in which a part of the electromagnetic spectrum is split up to acquire the intensity values of the range of wavelength it covers [1]. Spectroscopy is mainly used for the identification of substances. Because different substances differ in spectral signatures, remote sensing techniques can be applied using high altitude imaging sensors, where it can acquire spectral information of the earth's surface that can be used in making an inventory of natural resources [2]. Resource Management can evaluate the sustainability of ecological systems and provide basis for industry planning [3]. Some studies [4], [5] have been done in tree classifications using spectral signatures, LiDAR data and land satellite imagery. In a study [6], they developed a portable low cost spectrometer. The system was intended to be employed mainly for educational purpose.

Mapua-Phil-Lidar2 is a project that aims to create a nationwide resource map that uses light detection and Ranging (LiDaR) and land satellite imagery to develop models for decision support that can be used in urban/rural development planning and resource management in the area of agricultural and coastal resources. Mapua-Phil-Lidar2 uses land satellite data that comes with spectral information as a supplement for incomplete LiDAR data. The problem with currently available land satellite data is that reflectance spectral readings of surfaces based on the radiation from the sun that were affected due to cloud cover and may result in an unreliable spectral signature from the land satellite imagery. With this, there was a need for a portable device that can measure spectral signatures on a target area in the land satellite imagery by performing field surveys to measure crops spectral signatures.

The proposed system was the development of a handheld spectrometer that can be used on the field and measure spectral signatures of the visible light range of various crops. The proposed system must measure spectral information of various crops considered in Mapua-Phil-LiDAR-2 plant classifications. Also, the system must determine the location where the spectral signature of a particular crop was measured using a GPS module. The location data from the GPS module was used for cross checking of the location from the land satellite imagery. The spectral signature, classification, locational data and other features in the Land Satellite data are important information for the resource mapping.

The proposed portable spectrometer device can be used in data collection in acquiring spectral signatures of various plant classifications. It should be used in an open area with a clear view of the sky. Furthermore, the device can only acquire valid spectral signatures during daytime with clear environmental conditions (i.e. without significant cloud cover and or precipitation) as reflectance readings are dependent on the incident sunlight which were presented in the study [7], [8].

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Corresponding author: Jose B. Lazaro Jr (email: jblazaro@ mapua.edu.ph).

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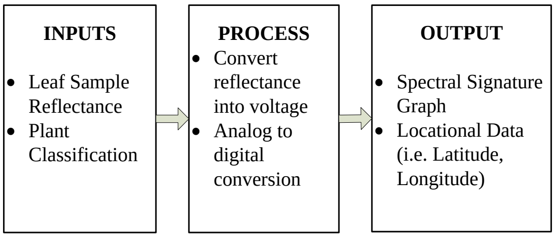

Fig. 1. Conceptual framework

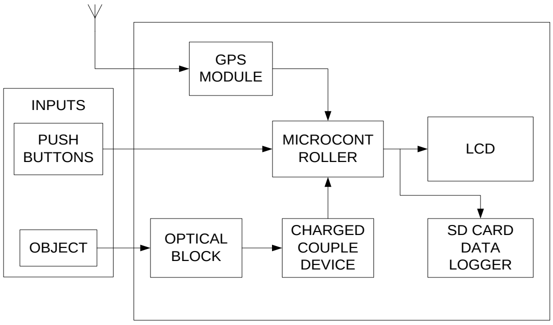

Fig. 2. System block diagram

II. Materials and Methods

In the development of the proposed portable spectrometer; the components and device requirements are needed for the acquisition procedure including the spectral signatures of each crop on the field [9]. Thorough study is needed since it involves accurate reading of each crop based on its spectral signature; including leaf sample gathering and classification. In the hardware development, the components included in the design are: ATmega1284P, concave holographic grating, Charged-Couple Device (CCD), graphical LCD display, SD card breakout board, and GPS module.

A. Hardware Development

Fig. 1 shows the conceptual framework of the proposed system, wherein the main input of the portable spectrometer was the reflectance from the plant species. The process involves converting the reflectance signals through diffraction grating as the reflected light hits the surface of the concave holographic grating. It then provides a light spectrum that is directed to the CCD array [10] giving the required wavelength as spectral signature of the subjected plant species. The CCD array converts the reflected light into voltages using an Analog to-Digital Converter (ADC), these are pixel wise digital signals provided using the ADC0820-IC. The GPS6MV2 (GPS module) determines the coordinates/location (longitude and latitude) where the sample was measured/scanned. The spectral signature of the sample can be seen in a wavelength-reflectance axis in the LCD and can be stored in the SD memory card when the save button is pushed.

Fig. 2 shows the block diagram of the proposed system. Firstly, the system needs the information about the type of crop or tree species before the start of a spectral scan. Objects are scanned through the optical block which is composed of slit, and diffraction grating. The light that entered on the entrance slit is dispersed in the diffraction grating which was also been presented in a similar study [11]. Diffracted spectral lines fitted into the image plane of the CCD sensor. The spectral components from the grating were delivered to the charged couple device array. This device operates as an analog shift register where the charge is transferred from one cell to another. Table I shows the description of the components and materials required for the development of the portable spectrometer.

TABLE I. Hardware Components

Components	Description
Atmega1284P-PU Micro-Controller	CMOS 8-bit AVR® Microcontroller, 128K Bytes Flash, 16K Bytes SRAM. DIP40 Packaging.
Charged Couple Device Sensor	TCD1304AP Toshiba Charge Coupe Device Linear Image Sensor, 3648 Element Low dark current photodiode. DIP22 Packaging.
GY-NEO6MV2 GPS Sensor	u-blox Neo-6 GPS Module, 3.3V 50 Channel, GPS L1 frequency, 4 pin header board
ST7920 Graphic LCD Module	Digole 128x64 Dots Serial/Parallel Liquid Crystal Display, 20 pin header board
Micro-SD Breakout	Maker-lab Micro-SD card breakout board, 3V level logic shifting (3V/5V compatible), Serial Peripheral Interface, 6 pin header board

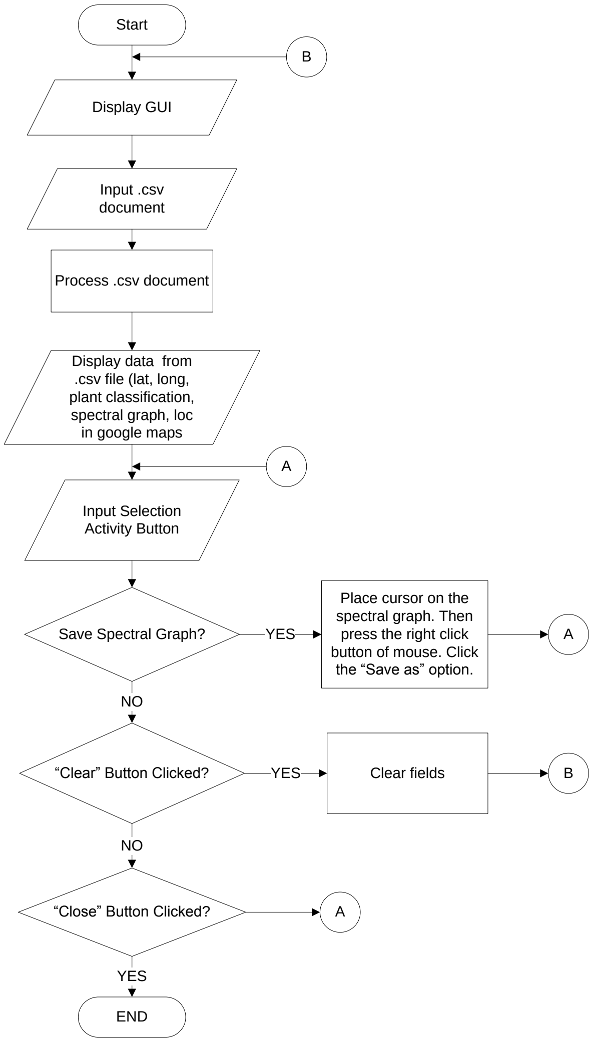

Fig. 3. Software application flowchart

B. Software Development

The software application flowchart is shown in Fig. 3. Upon clicking the software application, the program will start to load and display the created graphical user interface. The user is only allowed to upload .csv extension file on the program. To upload the file which contains the gathered data, the user needs to click the "browse" button. The file will be processed by retrieving the values such as plant classification, date, time, latitude, longitude, map location and spectral graph then, these data will be shown on the screen. If the user wants to save the spectral graph, the user should place the cursor on the graph and press the right click button of the mouse. The "Save As" option will appear that will allow the user to save the spectral graph of the plant classification. If the user clicks the clear button of the application, the text fields and data will be set cleared. Consequently, the user can use again the desktop application to process another document file from the micro-SD card. The desktop application will be terminated if the user clicks the close or "x" button.

C. Hardware Development

The main schematic diagram of the portable spectrometer is illustrated in Fig. 4. ATmega1284P-PU serves as the microcontroller which interfaces all sensors, inputs and outputs needed in satisfying the objectives of the design project. The following are all connected to the microcontroller: TCD1304AP (CCD), SD card reader, 128x64 Graphic LCD, and GPS (GPS6MV2). The portable spectrometer is powered with 5V supply.

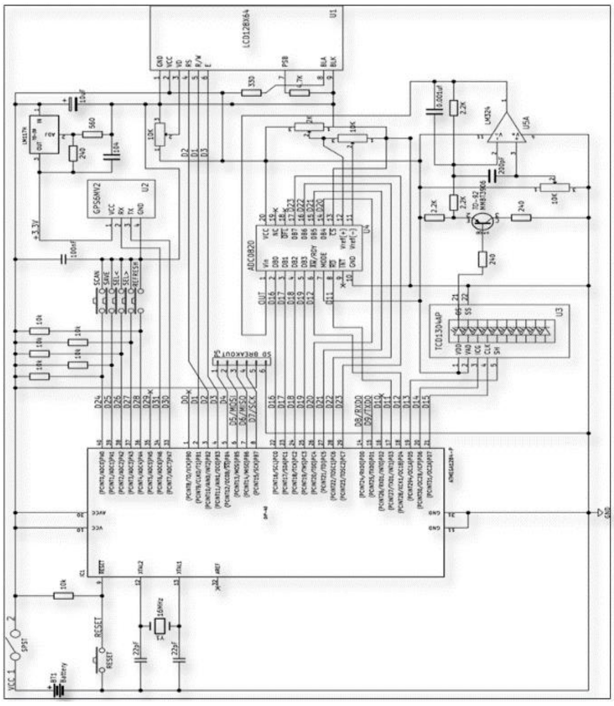

Fig. 4. Proposed portable spectrometer

The graphical LCD display is connected to pins 1 to 3 of Port B. It includes 10K Potentiometer that is used adjust the contrast of the display. SD card module would be used to save values uses the standard peripheral interface (SPI), master in slave out (MISO), master out slave in (MOSI), serial clock (SCK) and chip select (CS) are connected accordingly communicate with the micro-controller. 5 momentary (non-latch) type push buttons are connected to the microcontroller to invoke functions of the program, each makes use of a 10K pull up resistor to pull the voltage to high initially and prevents the circuit to short when the button is pressed. The GPS module is connected to 2 pins from Port A, its supply voltage comes from the LM117 voltage regulator which steps down the 5 V to 3.3 V in which the GPS module operates. The TCD1304AP or the CCD detector is connected to the pulse width modulation (PWM) pins of the microcontroller, its output is fed to an amplifier circuit which is then fed to an inverting amplifier to switch the signal from indicating brightness as low voltage to indicating brightness to high voltage. The output of the op-amp is connected to the 8-bit ADC0820 which digitizes the analog signal and sends it out to Port C of the microcontroller (connected to pin 0 to 7 of Port C).

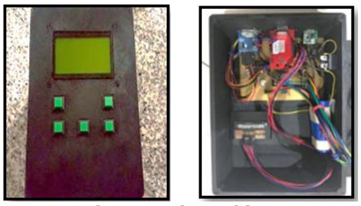

Fig. 5. Actual proposed portable spectrometer

Fig. 5 shows the actual proposed portable spectrometer for Mapua-Phil-LiDAR2. The device has graphical LCD for showing the data and five buttons for scanning, refreshing GPS values, selecting classification and saving the gathered data.

III. Results and Discussion

In this section, various tests were conducted to verify that the developed portable spectrometer using charge coupled device array works correctly. Plant leaves are the core test subjects in this design however the proponents also used colored light emitting diodes (LEDs) to test if the resulting spectrum responds to varying wavelengths of light. The proponents conducted the data gathering in Ato Belen's farm, one of the accredited learning sites of Agricultural Training Institute, located in San Pablo City, Laguna. The developed desktop application is used to review the collected data.

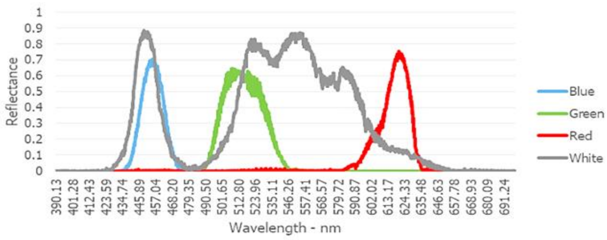

Fig. 6. Spectral signature of colored LEDs

Fig. 6 contains the testing results when colored LEDs are used in the portable spectrometer. The *x*-axis of the graph is for the wavelength of the spectral response while the reflectance value is mapped in the *y*-axis. It can be said that the spectral responses of the blue, green and red LED light is consistent with its corresponding wavelength regions. The blue light had peaked around 457 nm which is well within the wavelength 450-495 nm of blue light. The green LED light peaked around 512 nm which is within the 495 nm to 570 nm region of green light. The red LED light peaked around 624 nm which is also within the 620 nm to 750 nm region of Red light.

The proponents used Avocado, Banana, Cocoa, Coconut, Mango, Santol and Sugarcane as test samples for portable spectrometer. The source of light used is the natural light that comes from the sun. Fig. 7 illustrates the spectral signatures of healthy Avocado, Banana, Cacao, Coconut and Mango plants. The results show that the reflectance of the plant leave between 620nm to 700 nm drops since the chlorophyll of the plants absorbs the light in this region (orange to red). What the human eye perceives as the green coloring of green vegetation mainly arises from the high reflectance values in the 500 nm to 590 nm green region as chlorophylls of plant reflect light in these region which was discussed in a study [12]. The plant leaves used in this test are all healthy leaves and this can be observed based on the spectral graph of banana, cacao, coconut and mango plants.

For the Santol/Cottonfruit plant, the proponents also collected other color of the Santol leaf. Two Santol leaves are tested and compared, the red Santol leaf and the green color Santol leaf. The Fig. 7 illustrates how leaf pigmentation affect the spectral signature of the Santol leaf. It can be observed that in the green Santol leaf's spectral response is similar to that observed in Fig. 8 in which it peaks around the green region and have low reflectance values in in the orange-red region. In the case of the red Santol leaf; however, it was observed that the peak in the green region is less pronounced and the spectral response seemed to have been red shifted (shifted to the right).

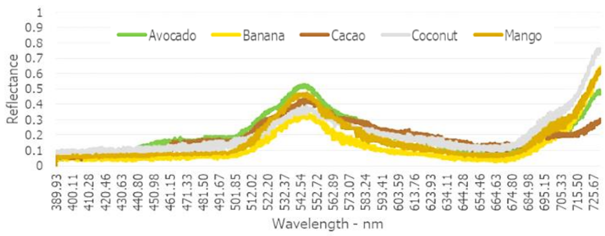

Fig. 7. Spectral signature of avocado, banana, cacao, coconut and mango

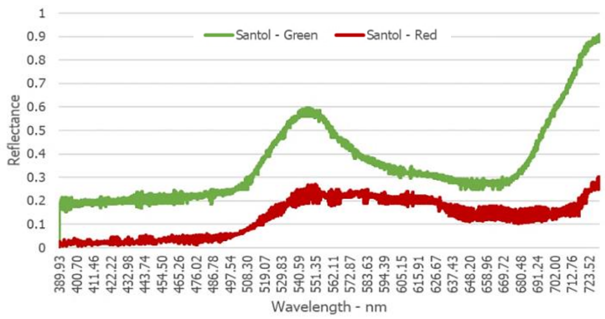

Fig. 8. Spectral signature of Santol/Cottonfruit

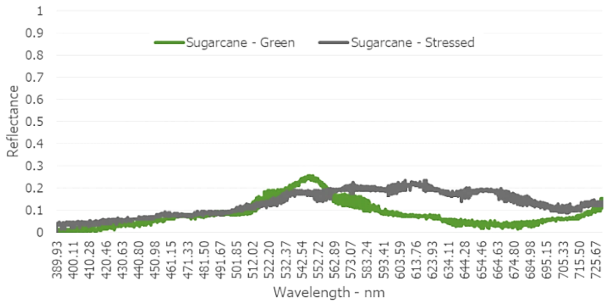

Fig. 9. Spectral signature of sugarcane

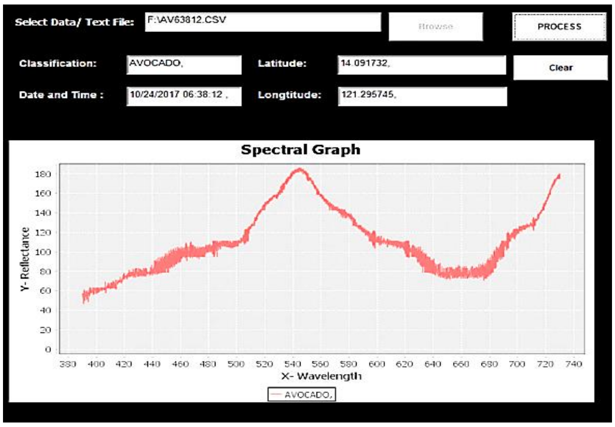

Fig. 10. Desktop application

For the sugarcane plant, the proponents tested a stressed leaf and a healthy leaf of sugarcane. The Fig. 9 illustrates the spectral response of a stressed leaf. The green sugarcane exhibits the spectral response of a healthy leaf that absorbs light in the (violet-blue) region and (orange-red) region as discussed in the previous figures. The stressed sugarcane leaf; however, can be distinguished by the high reflectance values in the (orange-red) region which means the leaf has a low chlorophyll concentration; thus, having low light absorption [13].

After the data gathering, the collected files are uploaded in the developed desktop application to review the data, as shown in Fig. 10.

IV. Conclusion

The portable spectrometer device was developed for Mapua-Phil-Lidar2 using charged coupled device array. The proposed portable spectrometer device acquires spectral signature of different plant species. In the study, it shows the scanned spectral signature of avocado, banana, cacao, coconut, mango, sugar cane and cottonfruit/santol which are considered in the Mapua-Phil-Lidar-2 crops classifications. The proposed system is composed of Atmega1284P-PU microcontroller, concave holographic grating, charged couple device array, GPS sensor, graphical LCD module and SD memory card.

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Jose B. Lazaro Jr. received the B.S. in Computer Engineering from Adamson University, Manila, in 1996, M.A. Educational Management units from University of Regina Carmeli, in 2004, Master of Engineering units from University of Santo Tomas, Manila, in 2007, and finished his Master of Science in Computer Engineering from Mapúa Institute of Technology, Manila, 2013. From 1998 to 2001 he works for Asahi-Schebel Co. Ltd. in Taiwan as a machine operator and technician. In 2004 to 2007, he joined the faculty of Colegio de Sta. Monica de Angat, where he taught various subjects in mathematics and computer science. He is currently taking up his doctoral studies in Electronics and Communications Engineering focusing on Biomedical Applications and Machine Learning for creating deterministic tools for life sciences, at the Mapúa Institute of Technology; He is also a faculty member of electronics, electrical, and computer engineering department of Mapúa University and De La Salle University.

Alejandro H. Ballado Jr. was born in Manila, Philippines in 1973. He completed his BSECE and Master of Engineering (ECE) at the Mapua University in 1995 and 1999, respectively. He has completed his course works for his Ph.D. in Electronics Engineering at the De La Salle University in Manila. His major field of study are in RF, antenna design, IoT, and communications system. He is currently the Dean of the School of Electrical, Electronics, and Computer Engineering at the Mapua University in Manila, Philippines. He was the former Chair of the Electronics Engineering Department and the Head of the Communications Laboratory in the same University. He has resented numerous papers in various conferences, i.e. IEEE, ACRS, etc. Engr. Ballado is an IEEE member for around ten years. He currently works as the Governor of the Institute of Electronics Engineers of the Philippines – Manila Chapter and served as head of various committees at the IEEE – Philippine Section.

Jann Pauline Deriquito received a degree of B.S. Computer Engineering Specialization in System and Network Administration using Linux based Operating System from Mapua University in 2018. She is a member of IEEE-MITSB (Institute of Electrical and Electronic Engineers - Mapua Institute of Technology Student Branch) and Mapua-ICpEP (Mapua-Institute of Computer Engineers). She is one of the authors of Body Posture Monitoring Using E-textile with Poor Poture Notification which is supervised by Engr. Meo Caya and Engr. Marloun Sejera.

Shawn Michael L. Lamod received his B.S. Computer Engineering from Mapua University in 2018. He is a member of IEEE-MITSB (Institute of Electrical and Electronic Engineers - Mapua Institute of Technology Student Branch) and Mapua-ICpEP (Mapua- Institute of Computer Engineers). In 2015 he is a student researcher of Mapua-Phil-Lidar2 under the supervision of professor Jose B. Lazaro Jr. working on remote sensing and GIS to analyze Light Detection and Ranging maps to generate resource maps of specific regions of the Philippines. In 2016 he took interest in space weather studies and produced a paper about monitoring sudden ionospheric disturbance under the supervision of professor Jocelyn Villaverde and Ernest Macalalad.

Brent Andrew Mendez received his B.S. Computer Engineering with Embedded Systems Specialization degree from Mapua University in 2018. He is a member of Mapua-ICpEP (Mapua-Institute of Computer Engineers). He is one of the authors of Strabismus Detection using Wearable Device with Pupil Lumination Comparison Algorithm under the supervision of Engr. Meo Vincent Caya.

Meo Vincent C. Caya was born in Ibaan, Batangas, Philippines on February 2, 1980. He graduated with a degree of Bachelor of Science on computer engineering in Mapua University, Manila, Philippines on April 2002 and pursue a higher education with the degree of Master of Engineering major in computer engineering on April 2005 also in Mapua University. Currently, pursuing a Ph.D. in Electronics major in Microelectronics in Chung Yuan Christian University, Jhongli, Taiwan R.O.C. He started as an INSTRUCTOR in the School of Electrical, Electronics and Computer Engineering in Mapua University on April 2002. At present, he's an ASSOCIATE PROFESSOR at the same university. During his tenure in Mapua University, he became a MICROPROCESSOR LABORATORY HEAD. Became a LECTURER in a specialized track for computer engineering students (Unix Track) manage by Center for Continuing Education and Special Competencies (CCESC-Mapua University). Also, he have involvement as a RESEARCHER/PROJECT STAFF in different Philippine government funded projects like the Mapua Phil-Lidar 2 Project and the Mapua Smart Bridge Project to name a few. In the April-June 2018 publication of the Journal of Telecommunication, Electronic and Computer Engineering (Scopus indexed) he published two articles regarding water quality monitoring and evapotranspiration-based irrigation. He is currently interested in the Internet of Things (IoT) application and application of computer and electronics in agriculture. Mr. Caya is an IEEE Computer Society member, and a member of a Philippine based organization ICpEP (Institute of Computer Engineers of the Philippines) which are exclusive for individuals with Computer Engineering profession. He was given a Service Loyalty Award in Mapua University for serving 15 years.