Real Time Flood Detection, Alarm and Monitoring System Using Image Processing and Multiple Linear Regression

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Real Time Flood Detection, Alarm and Monitoring System Using Image Processing and Multiple Linear Regression

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Abstract

In the Philippines, flooding, which is typically produced by excessive rainfall and strong seas, is one of the most prevalent natural occurrences. This natural calamity cannot be avoided but the good thing is, we can practice ourselves to be prepared for it. After conducting an analysis regarding the needs of people residing in Barangay Frances, Calumpit, Bulacan, it was then decided to develop a project that can help lessen the difficulty they are experiencing when they evacuate. The system uses image processing as its flood detection method. It also uses several sensors for different purposes to make it more reliable to the users. These sensors used are the rain gauge, float switch, and flow rate meter sensor. It measures two of the important parameters in flood detection namely precipitation rate (mm/hr), flood level (ft), and the flow rate (L/hr). The data accumulated by the sensors are sent immediately to the Android application so it can be used by people living in the area to monitor the flood levels in real time. To measure the reliability of the system, the flood level taken from the automated system and conventional method were compared. A small mean squared error (MSE) of these 2 data which is 0.125 was achieved.

***Index Terms* — Image processing; flood monitoring; flood detection; multiple linear regression; real time.**

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I. Introduction

Philippines is located near the equator and is surrounded by different bodies of water [1]. It is near the Pacific Ocean where the water is warm, resulting in the frequent occurence of typhoons where it often hits the Philippines due to earth's westward blowing wind nature. Floods are usually the aftermath of a calamitous typhoon, and the consequences are based on the location, volume, intensity, and timespan of rainfall [2]. Other factors may involve the tide times. Some of the common flood level monitoring are based on the marking on utility posts, river basins, and allocating closed circuit tv (CCTV) to monitor rivers and dams. Hence, the efficiency of manual monitoring is questionable since it cannot transfer the gathered data immediately. Due to the inherent fallibility of manual monitoring, there is also the possibility that the data may not be accurate.. The application of image processing can be used to lessen the casualties during these natural phenomena. Since this will immediately capture the flood and detect its level, it will be easier to disseminate information. This study aims to develop a smart flood monitoring system to detect the flood level at a certain time and immediately provide advice to the community.

Out of the 18 major river basins in Metro Manila, there are 10 that has functional Flood Forecasting and Warning System for Dam Operation as of early 2019 [3]. To cope with flood risks, the Philippine Department of Science and Technology (DOST) developed project NOAH or the National Operational Assessment of Hazards. The project NOAH utilizes the latest and most advanced technologies like 3D terrain mapping through Light Detection and Ranging (LIDAR), installation of automated rain gauges, and water level monitoring stations to provide warning to agencies and communities 6 hours prior to impending flood. Besides project NOAH, another method of flood monitoring currently exists in Marikina River, where they use ultrasonic sensors to measure the rate of change of water level and determine flood waters accurately in real time [4].

The local government of Calumpit, Bulacan is having trouble with the evacuation of residents due to the large amount of people who need their help. They use flood markers painted along concrete posts and walls as flood level indicator. In the presence of flood, evacuation and delivery of relief materials are typically delayed owing to uneven road surfaces, strong water current, and high-water level; exacerbated by daily high tide and release of waters from 3 main dams; Angat, Bustos, and Ipo dam.Their only means of disseminating relevant information regarding dam releases and flood warnings is to manually relay news with a rescue boat and a megaphone. These are the reasons why communities are unaware with the current status of the nearby dams, leading to extensive damages to properties and even human life.

This scenario give impetus for a flood warning system that could detect and monitor current flood status and immediately inform nearby residents. Hence, this paper presents a project that is designed to help the communities affected by flood in the province of Bulacan, particularly in the area of Barangay Frances in Calumpit by providing real-time water level detection through a wireless sensor network and warning system via website and to alert concerned authorities and affected individuals for an impending flood, to speed up the evacuation process and improve emergency measures.

This study aims to develop a device for flood detection, alarm, and monitoring system for flood-prone areas. It particularly aims (1) to design a flood monitoring system using Rain Gauge, Float Switch, Flow Rate Meter Sensor and Arduino microcontroller utilizing solar panel as the system's main source of power, (2) to develop an image recognition system which is composed of a Raspberry Pi and a camera that will identify the flood water-level and activate a 3-stage alarm level siren using python, (3) to create an Android application using an Internet module for water-level monitoring of the areas within the barangay, and (4) to test the efficiency, functionality, reliability of the flood detection, alarm and monitoring system.

The study covers the design of a device which is capable of detecting, monitoring, alarming, and giving notification regarding the flood level in a barangay and a rain gauge and precipitation sensor that contacts the authorities in case of an emergency. Flood level or water level are identified through observations of the residents and Local Government Authorities. They place indicators or markings on the streets or CCTVs that help them to identify the level of the water in their area. In this study, pre-programmed in the microcontroller are threshold values for the flood level. When rain gauge and an improvised flow rate meter sensor detects a rainfall and a rise in water flow, the acquired signal from the sensors will be transmitted along with the photo taken by the camera to the Raspberry Pi. The system is set to capture images which undergone image processing and depth analyzation every 15 minutes to give real-time updates.Through this, residents will know the current flood status without going outside. Furthermore, the study is cost-efficient for rural areas as the proponents aimed to use low-cost materials but will not sacrifice the accuracy, durability, and efficiency of the system. The system is also self-sustained by a solar panel and a battery so it would not burden the barangay of electrical power expenses. The study however, does not cover geographical mapping, rain forecasting, and flood prediction. Therefore, it is necessary to extend our technology not only in urban areas but also in rural areas.

II. Related Literature

A study by Tang et al. [5] on water recognition using image processing implemented water extraction which can be divided into two parts: image processing and water body extraction. It implemented C-band multi-polarization synthetic aperture radar (SAR). As a modification, our study will incorporate an Android application to inform the residents about the flood water level within the area.

The study by Hiroi et al. [6] focuses on flood monitoring and prediction using Linear Regression of deep learning method through data assimilation. It mainly concentrates on early and accurate forecasting of floods in complex water flow utilizing water-level sensors. It developed a compact sensor design which only consists of an infrared camera as its sensor, a communication interface to transmit data and an image processing server to process the images acquired. The system proposed an auto-monitoring function without pre-configuration of the information where there is no need for the dike line to be set to sense floods that results in the rise of water. The auto-configuration process offers the subsequent methods: (1) to distinguish the maximum RGB value as per the water region utilizing the infrared image, and (2) to identify the lesser RGB zone as per the riverbank region.Given the situation that the plants are not spotted in the course of the testing, the sensors disregard the plant area and regard the "upper straight line as the riverbank line" and hen calculate the lower point in the plant/vegetation region and a collection of upper points for the water level region at each image's horizontal axis. After adjustment, the system calculates the water-to-dike line difference. Flooding is indicated when both lines are 0.They used two key methods utilizing Segnet and deep learning: (1) concentrated on

CCTV cameras guarding flood-prone regions and localities and (2) several structures that analyzes satellite images [7]. An image segmentation that can be divided into four algorithms to remove the surrounding objects in the streamed video was developed by Menon et al. [8]. The four algorithm categories are as follows: (1) point-based segmentation; (2) edge detection-based segmentation; (3) region-based segmentation; and (4) hybrid segmentation combining at least two of the above algorithms.

According to Moreno et al. [9], implementing the Internet of Thing (IoT) will help prevent future disasters. Their study highlights the characteristics of data acquisition and data processing to be used. Message Queuing Telemetry Transport (MQTT) protocol is also used to send real-time data text messages, whileultrasonic Water Level Sensor MB7066 is utilized in their proposed river water level monitoring. Lastly, Sathita et al. [10] proposed an effective method for flood notification, i.e., Point of Interest (POI) by using an internet-based sensor network and a wide-area sensor application testbed that is operated by multiple organizations.

These previous works on flood detection, warning, and monitoring systems required costly sensors for remote locations.It is clear that these studies aims to develop a cost-efficient design for barangays located at provinces. Also, by automating the barangay's flood detection system, barangay workers are no longer exposed to potential risk while manually inspecting flood indicators outdoors.The previous works also did not use a siren to back up the notification system of the Android application. Using a siren instead allows the residents to hear the alarm aside from being notified on their phones. Emergency cases during a storm may happen and any means of notifying the residents is essential for their safety so placing a siren allows the whole barangay to hear the alarm besides notification the mobile application provides.

Methodology

A. System Architecture

The system design of this project concentrates on detecting and monitoring the flood level. The parameters that were considered in this study are precipitation rate (mm/hr), flood level (ft), and flow rate (L/hr).

Figure 1 shows the general block diagram of the study. This study used three sensors namely: Float switch, Rain Gauge and Flow rate meter sensor. These sensors are responsible for detecting the parameters needed and are connected to the Arduino UNO. The analog signal sent by the Arduino UNO are then sent to the Raspberry Pi along with the image captured by the camera for detecting the flood level. All data are transmitted to the cloud via internet, to the database and then to the Android mobile application.

B. Image Processing and Detection System

The image processing part of the system utilizes 5 algorithms (Figure 2).

a) *Region of Interest (ROI)* - an important algorithm which limits the size of the image taken by cropping and focusing on the interested part of an image [11], [12], [13], [14], [15] using NumPy slicing since every pixel of an image is composed of matrices.
b) *Brightness and Contrast* – a basic operation of image processing which is used to get a brighter image. The brighter image will then be converted to grayscale.
c) *Otsu's Method* – creates a threshold for converting the grayscale image into a binary image in which every pixel only represents 0 and 1. This algorithm is required before proceeding into any type of edge detection algorithms [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26].
d) *Canny Edge Detection* – the algorithm for taking the outline of the flood line which is necessary for the calculations [27], [28].
e) *Hough Line Transform* – draws a line from the edges acquired by the previous algorithm [16]. The height of the line drawn will be measured in pixels.

As shown in Figure 3, the system will check first whether there is occurrence of rain or not using a rain gauge. It will determine the rainfall amount to measure liquid precipitation over a set period. It will then look for changes in the water level as well as the flow rate of the river and calculate the water's rate of rise. If there is no rain, it will skip the first process and move on to the next. These readings will serve as the parameters for the predictive system.

Afterwards,, the program will evaluate the gathered data to anticipate flood status for the next hour (Figure). If the readings do not meet the threshold for an impending flood, the system will consider the values insignificant and go back to the first process. But if there is a risk of flooding, it will notify concerned agencies and individuals through an app that will serve as an early safety measure.

Since the line height is in pixels, it will be converted by dividing it with a constant.

$$\text{Line height in ft} = \frac{\textit{light height in pixels}}{2800} \quad (1)$$

After the said algorithms, the final formula will be:

$$\text{Flood height} = \text{image height} - \text{line height} \quad (2)$$

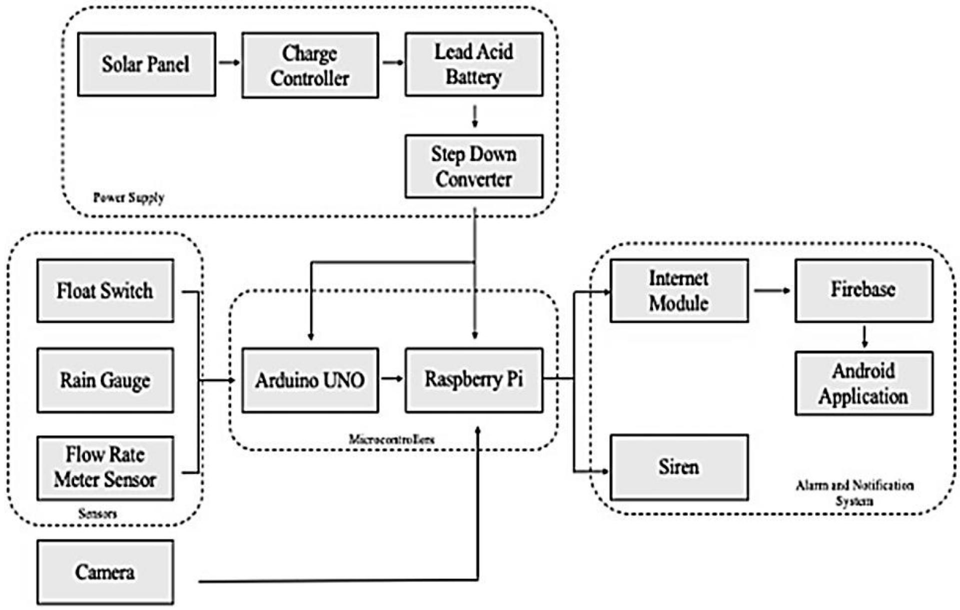

Fig. 1. General Block Diagram of the Proposed Flood Monitoring and Detection System

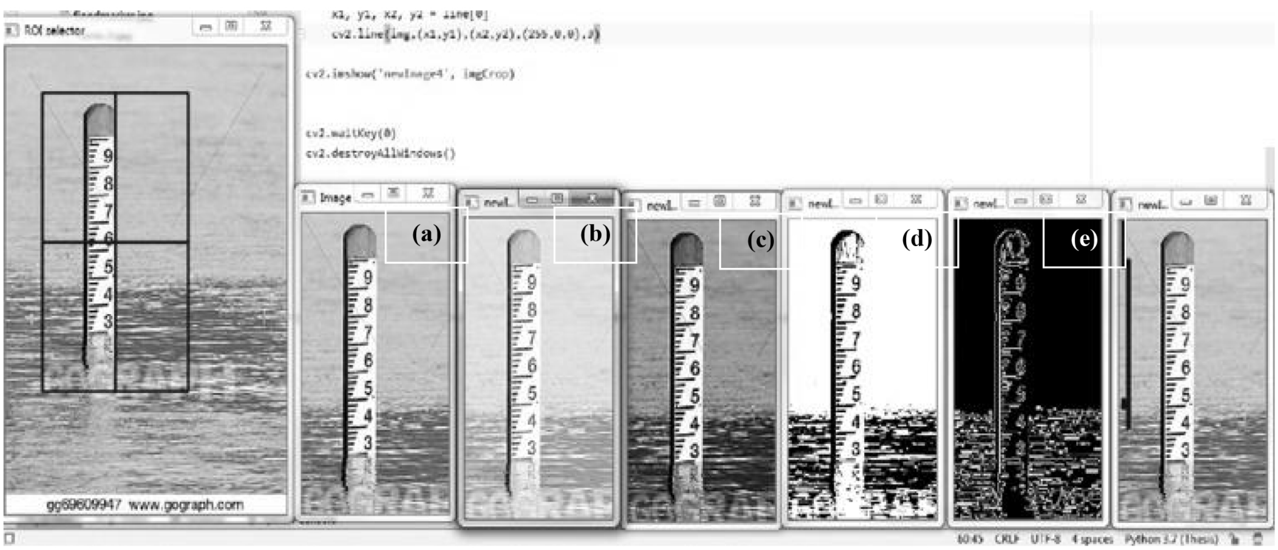

Fig. 2. Image Processing Step-by-Step Process. (a) Region of Interest, (b) Brightness and Contrast, (c) Otsu's method, (d) Canny edge detection, (e) Hough line transform

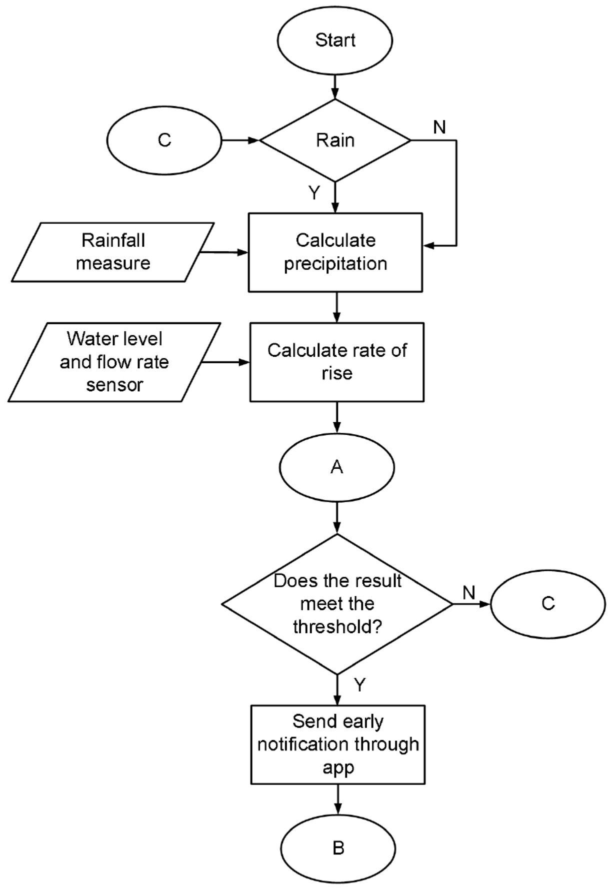

Fig. 3. Flood Detection and Monitoring Flowchart

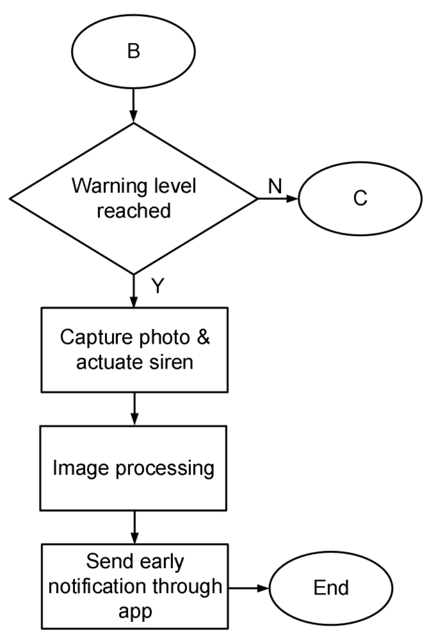

Fig. 4. Flood Alarm Process Flowchart

C. Early Prediction

The system uses multiple linear regression as the mathematical model, referring to Eqn. (3), and uses 1 dependent variable: predicted flood level and 3 independent variables: 1.) Precipitation rate - refers to the amount of water that falls in millimeter per hour (mm/hr) during a rainfall, 2.) River flow rate – refers to the entire volume of water which flows through a given location in a river or stream over a period measured in L/hr, and 3.) Present flood level – the current height of flood in ft. The program will then evaluate the gathered data to anticipate flood status for the next hour (Figure 5). If the readings do not meet the threshold for an impending flood, the system will consider the values insignificant and go back to the first process.

But if there is a risk of flooding, it will notify concerned agencies and individuals through an app that will serve as an early safety measure.

$$y = B_o + B_1x_1 + B_2x_2 + e \tag{3}$$

Where:
y = predicted flood level
B_o = precipitation rate
B_1 = flow rate
B_2 = present flood level
e = error term

Figure 6 shows the values of actual flood levels correlated to the precipitation rate, flow rate, and present flood level with predicted flood level using multiple linear regression. Once the 3 independent variables are obtained from the system, the predictive model automatically compute for the essential output el. Upon running the program in Python, the mathematical model yielded an accuracy of 91.81%; this means that the predicted values are 91.81% accurate or matched with the actual flood levels.

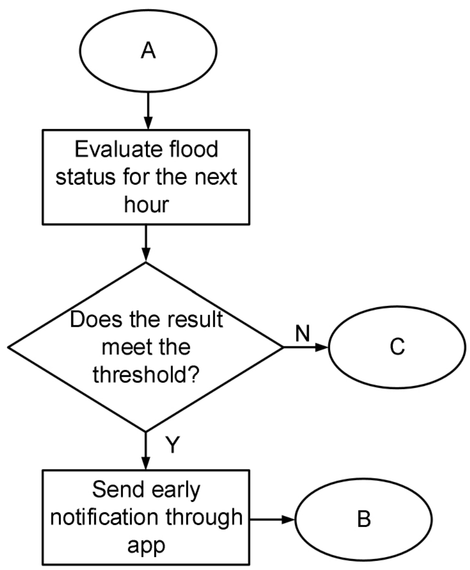

Fig. 5. Flood Prediction and Notification Flowchart

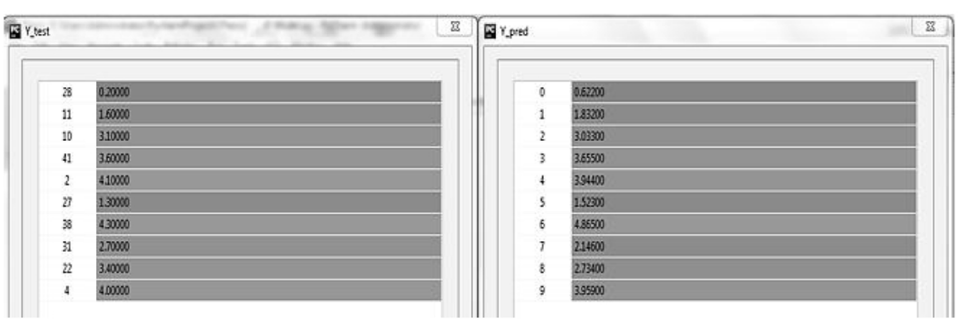

Fig. 6. Actual vs Predicted Flood Level Comparison. Actual (Left) and Predicted (Right)

D. Android Mobile Application

The SnapFlood's mobile application is made to collect all the data from the main system and display the status of the site, with or without flood, every 15-minute intervals (Figure 7). It also displays the parameters that affects the rise of flood such as flow rate and precipitation rate. The application was made through Android Studio and Python codes are used for data transmission from the microcontroller. It stores data in FireBase, a real-time database that provides developers to store data on FireBase's cloud.

The application shows a home screen with a single button named Flood Level, where all the parameters and information needed included. On the top left corner of the screen is an options button, it contains buttons for panels such as the color-coded rainfall classification and, emergency hotlines of local government authorities.

IV. Experiment And Results

The project was deployed at Barangay Frances, Purok 5, Calumpit, Bulacan (Figure 8). Barangay Frances is known as a high-risk flood zone sice it is located alongside the Pampanga River. To develop the early prediction model of the system, a large amount of data is necessary to increase the accuracy of the system. rRadings from different sensors were measured in two days and data are presented herewith (Figure 9-11).

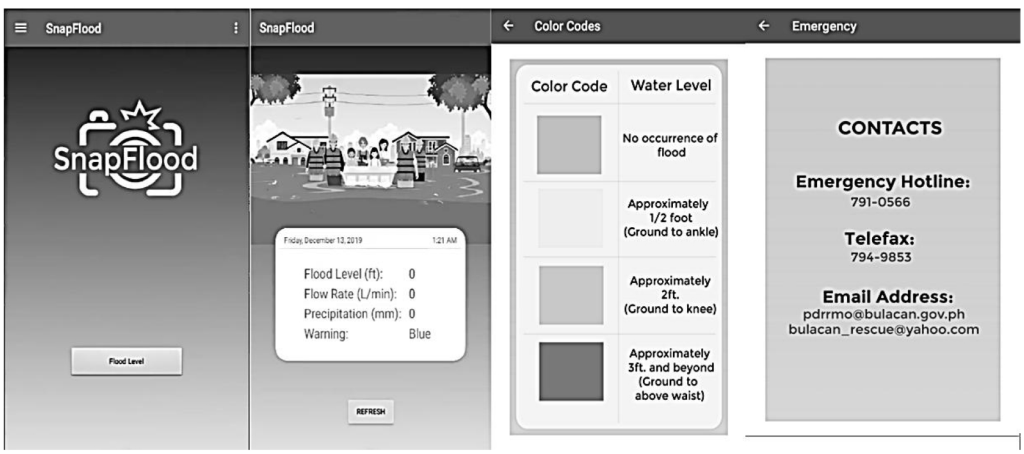

Fig. 7. Mobile Application Interface of the Proposed Flood Monitoring System (SnapFlood)

Fig. 8. Individual Setup of Flood Marker with float switch connected to the main system

Figure 9 provides the data collected by measuring the precipitation rate expressed in millimeter per hour (mm/hr) using a rain gauge. The color-coded rainfall classification also indicates how strong the rain is. Figure 10 depicts river flow fluctuation while Figure 11 shows two-day flood levels..

Figure 12 shows the regression plot of the flood level and precipitation rate. An R2 of 0.9258 or 92.58% was obtained indicating that there is a variation of flood level caused by the changes in the precipitation rate. The regression plot of the flow rate and precipitation rate are presented in Figure 13. The value of the R2 is 0.9606 or 96.06% which means that as the precipitation rate rises the flow rate also increases. Figure 14 shows an R2 value of 0.8884 or 88.84% implying that the flow rate does have a correlation with the rise of the flood level. Based on the results of Figures 12 and 14, it can be concluded that flood level can be predicted based on the changes in the precipitation rate since its R2 is higher.

The data gathered from the proposed automated method based on image processing was compared with the measured data using the conventional method. In the conventional method, manual measurement of the flood level was done using a flood post or flood marker with markings. For this paper, the null hypothesis specifies that there is no significant difference between the proposed automated method and the conventional method. The level of significance was set to 0.01. As shown in Tables 1 and 2, assuming both equal and unequal variances, respectively, t Critical < t Stat (1.984 < 0.209) and p value > a (0.835 > 0.05), which means that there is no significant difference on the means of the automated and manual results.

The comparison of the actual flood level measured using the conventional way and the predicted flood level using the system early prediction model is presented in Figure 15. The calculated mean squared error (MSE) of these 2 data is 0.125 which is small; that is, the lower the MSE, the closer the predicted values are from the actual values.

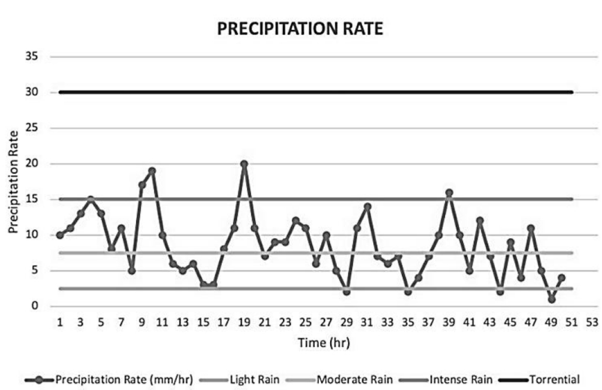

Fig. 9 - Precipitation Rate Reading with Rainfall Classification

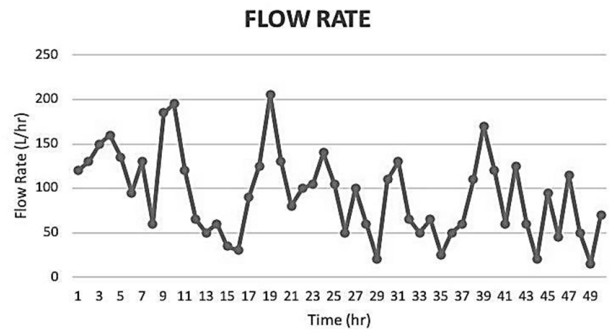

Fig. 10. Flow Rate Reading

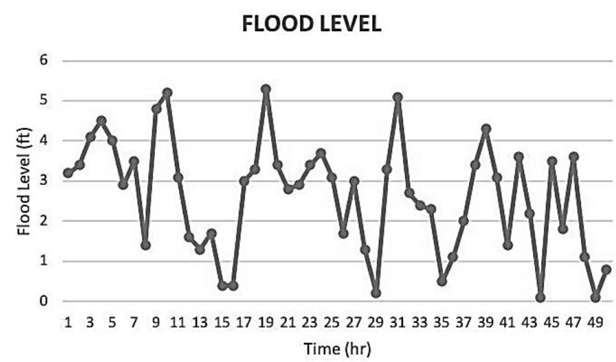

Fig. 11. Flow Level Reading

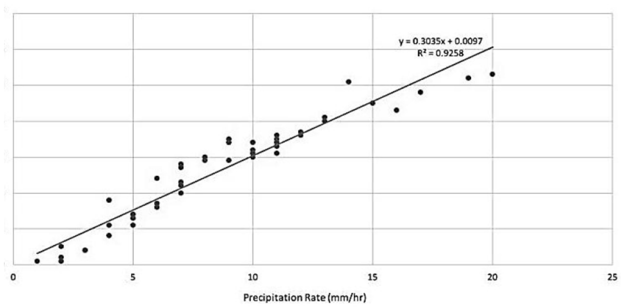

Fig 12. Regression plot of Precipitation Rate and Flood Level

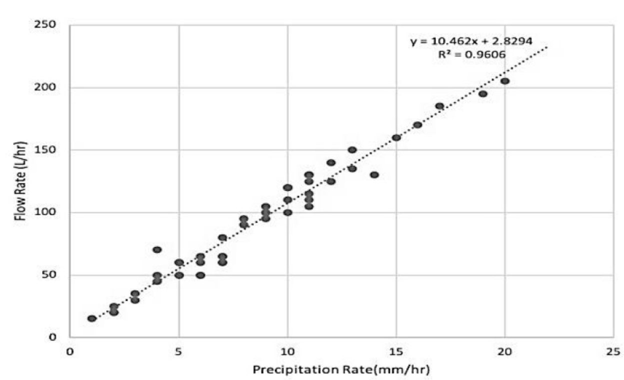

Fig 13. Regression plot of Precipitation Rate and Flow Rate

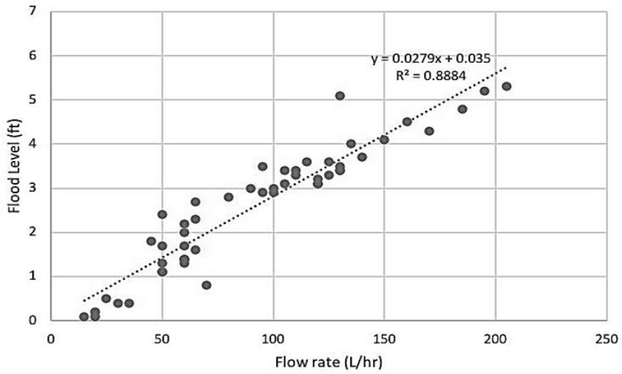

Fig. 14. Regression plot of Flood Level and Flow Rate

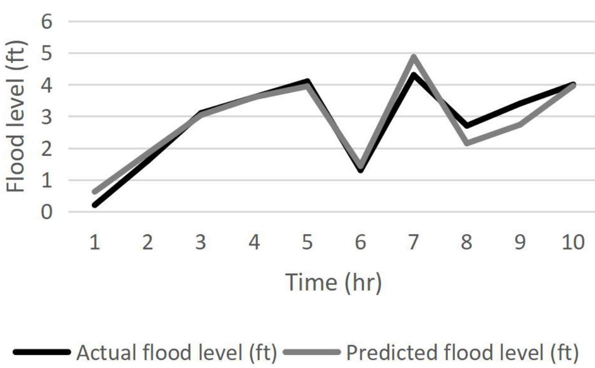

Fig. 15. Actual flood level vs. predicted flood level

Table 1
T-Test: Two Sample of Assuming Equal Variances for Flood Level

	Proposed Automated Method	**Conventional Method**
Mean	2.62	2.678
Variance	1.961632653	1.880526531
Pooled variance	1.92107959183673	
Observations	50	50
t Stat	0.209230657	
P(T<=t) two-tail	0.834702494	
t Critical two-tail	1.984467455	

Table 2
T-Test: Two Sample of Assuming Unequal Variances for Flood Level

	Proposed Automated Method	Conventional Method
Mean	2.62	2.678
Variance	1.961632653	1.880526531
Observations	50	50
t Stat	0.209230657	
P(T<=t) two-tail	0.834702494	
t Critical two-tail	1.984467455	

Table 3 shows the comparison of the previous studies. Satellite was used in [5], infrared sensors ere used in [6], web camera was used in [29], and a CCD webcam was used in [31]. Compared to our proposed study, these previous studies used sensors that are not low-cost and are not suitable for rural areas with regards to their budget.

Table 3.
Comparison of Previous Works with The Proposed Work

	[5]	[6]	[29]	[30]	[31]	[32]	Proposed work
Sensors	GF-3 SAR Satellite	Infrared Sensor	Webcam	-	CCD Webcam (320*240px)	Rain gauge, flood level sensor, soil moisture sensor, air humidity, flow meter temperature sensor	Rain gauge, Float switch, Flow rate meter sensor, Raspberry NoIR Camera
Parameters	Flood level	Flood level	Webcam	Flood Pixels, Color, Texture	Flame, Smoke, Water level	Flood level, Precipitation Rate, Flow Rate, Soil moisture, Air humidity, Temperature	Flood level, Precipitation Rate, Flow Rate
Recommendation	Small patches removal and shadow false alarm removal method.	Low-cost Sensors	Flow Rate Meter, Durable Flood Meter & Rain Gauge	Use more flood detection sensors for higher accuracy.	Include nature disaster situations (dense fog, hailstones, etc.) and doubtful criminal actions (stealing, etc.) for the systems to be more intelligent and efficient.	N.A.	More years of exposure of the device to get more datasets and to further improve the accuracy of the device/system. Improve the user interface of the mobile application to be more user friendly.
Method & Software Algorithm	Image Processing and Water Extraction Approach with Data Assimilation	Linear Regression of Deep Learning	Image Processing	Visual based event detection	Image/Video Processing	Nonlinear Autoregressive Network with External Inputs (NARX)	Image Processing using Multiple Linear Regression
Microcontroller	-	-	Raspberry Pi	-	-	MCU with Zigbee Tx	Raspberry Pi, Arduino UNO
Data Display	-	Sent to Disaster Prevention Agency	Results sent to Twitter	Digital Monitor	Digital Monitor/ Surveillance Camera	Results sent to PC	Through Mobile Application

V. Conclusion

After conducting many tests with the system and acquiring data, we can conclude that the employed devices function well and provide reliable results.The image processing of the system does its job where the camera captures the flood level in the pole then sends its data to the other interconnected devices and the Android application. Other than the image recognition system, here are the other functions of the whole project that are successfully satisfied: (1) the detection of flood using the float switch sensor and (2) proper distribution of power to the devices with the use of batteries where the solar panel is the main source and is regulated by the solar charge controller.

VI. Acknowledgment

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VII. References

[1] "Floods", Philippine Atmospheric Geophysical and Astrono-mical Services Administration, http://bagong.pagasa.dost.gov.ph/learningtools/floods?fbclid=IwAR2gwRSsPZxKDZGGm_Eg7d1CjhnNXVWlooSLfnF_h6IZ38DwCWG9g8utnUY, August 2020

[2] B. Bennett, M. Leonard, Y. Deng, and S. Westra, "An empirical investigation into the effect of antecedent precipitation on flood volume," Journal of Hydrology, vol. 567, 2018, pp. 435-445. doi: 10.1016/j.jhydrol.2018.10.025.

[3] "About Project NOAH", Official Gazette of the Republic of the Philippines, https://www.officialgazette.gov.ph/programs/about-project-noah/, July 2019

[4] J. R. Santillan, E. C. Paringit, R. V. Ramos, J. R. T. Mendoza, N. C. Española, and J. Alconis, "Near-real time flood extent monitoring in Marikina river philippines: Model parameterisation using remotely-sensed data and field measurements," in 33rd Asian Conference on Remote Sensing 2012.

[5] D. Tang, F. Wang, Y. Xiang, H. You and W. Kang, "Automatic Water Detection Method in Flooding Area for GF-3 Single- Polarization Data," in IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium, 2018, pp. 5266-5269. doi: 10.1109/IGARSS.2018.8517886.

[6] K. Hiroi and N. Kawaguchi, "FloodEye: Real-time flash flood prediction system for urban complex water flow," in 2016 IEEE SENSORS, 2016, pp. 1-3, doi: 10.1109/ICSENS.2016.7808626.

[7] H. B. Baydargil, S. Serdaroglu, J. Park, K. Park and H. Shin, "Flood Detection and Control Using Deep Convolutional Encoder-decoder Architecture," in 2018 International Conference on Information and Communication Technology Robotics (ICT-ROBOT), 2018, pp. 1-3. doi: 10.1109/ICT ROBOT.2018.8549916.

[8] K. P. Menon and L. Kala, "Video surveillance system for realtime flood detection and mobile app for flood alert," in 2017 International Conference on Computing Methodologies and Communication (ICCMC), 2017, pp. 515-519, doi: 10.1109/ICCMC.2017.8282518.

[9] C. Moreno, R. Aquino, J. Ibarreche, I. Pérez, E. Castellanos, E. Álvarez, R. Rentería et al., "RiverCore: IoT device for river water level monitoring over cellular communications," Sensors, vol. 19, no. 1, 2019. doi: 10.3390/s19010127.

[10] K. Sathita, H. Ochiai and H. Esaki, "RainWatch Project: Location-Awared Realtime Detection and Notification of Rain on Internet-Based Sensor Network," in 2009 Ninth Annual International Symposium on Applications and the Internet, 2009, pp. 259-262. doi: 10.1109/SAINT.2009.59

[11] R. P. C. Gamara, C. Tabalanza, T. V. Cruz, J. L. C. Tindugan, and P. J. M. Loresco, "Shrimp growth monitoring system using image processing techniques," Journal of Computational Innovations and Engineering Applications (JCIEA), vol. 4, no. 1, 2019, pp. 35-40.

[12] N. M. Arago, A. C. Thio-Ac, M. C. Apostol, I. J. E. De Guzman, A. E. D. Reyes, K. G. Rodriguez, and R. A. B. Toring, "Development of an Automated Cows In-Heat Detection and Monitoring System Using Image Recognition with GSM Based Notification System," Journal of Computational Innovations and Engineering Applications (JCIEA), vol. 4, no. 2, 2020, pp. 9-15.

[13] L. K. S. Tolentino, J. W. F. Orillo, P. D. Aguacito, E. J. M. Colango, J. R. H. Malit, J. T. G. Marcelino, A. C. Nadora, and A. J. D. Odeza, "Fish freshness determination through support vector machine," Journal of Telecommunication, Electronic and Computer Engineering (JTEC), vol. 9, no. 2-5, 2017, pp. 139-143.

[14] L. K. S. Tolentino, C. P. De Pedro, J. D. Icamina, J. B. E. Navarro, L. J. D. Salvacion, G. C. D. Sobrevilla, A. A. Villanueva, T. M. Amado, M. V. C. Padilla, and G. A. M. Madrigal, "Weight prediction system for nile tilapia using image processing and predictive analysis," International Journal of Advanced Computer Science and Applications, vol. 11, no. 8, 2020, pp. 399-406.

[15] I. C. Navotas, C. N. V. Santos, E. J. M. Balderrama, F. E. B. Candido, A. J. E. Villacanas, and J. S. Velasco, "Fish identification and freshness classification through image processing using artificial neural network," ARPN Journal of Engineering and Applied Sciences, vol. 13, no. 18, 2018, pp. 4912-4922.

[16] R. O. Serfa Juan and J. Kim, "Photovoltaic

Cell Defect Detection Model based-on Extracted Electroluminescence Images using SVM Classifier," in 2020 International Conference on Artificial Intelligence in Information and Communication (ICAIIC), 2020, pp. 578-582. doi: 10.1109/ICAIIC48513.2020.9065065
[17] B. Kim, R. O. Serfa Juan, D.-E. Lee, and Z. Chen, "Importance of Image Enhancement and CDF for Fault Assessment of Photovoltaic Module Using IR Thermal Image," Applied Sciences, vol. 11, no. 18, 2021, pp. 1-23.
[18] B. Kim, S.-W. Choi, G. Hu, D.-E. Lee, and R. O. Serfa Juan, "Multivariate Analysis of Concrete Image Using Thermography and Edge Detection," Sensors, vol. 21, no. 21, 2021, pp. 1-24.
[19] S. Saifullah, R. I. Mehriddinovich, and L. K. Tolentino, "Chicken Egg Detection Based-on Image Processing Concept: A Review," Computing and Information Processing Letters, vol. 1, no. 1, 2021, pp. 31-40.
[20] S. Saifullah, and A. P. Suryotomo, "Thresholding and hybrid CLAHE-HE for chicken egg embryo segmentation," in 2021 International Conference on Communication & Information Technology (ICICT), pp. 268-273, 2021.
[21] A. Yudhana, S. Sunardi, and S. Saifullah, "Segmentation comparing eggs watermarking image and original image." Bulletin of Electrical Engineering and Informatics, vol. 6, no. 1, 2017, pp. 47-53.
[22] S. Saifullah, S. Suhirman, A. T. Hidayat, and R. H. P. Sejati, "Otsu Method for Chicken Egg Embryo Detection based-on Increase Image Quality," MATRIK: Jurnal Manajemen, Teknik Informatika dan Rekayasa Komputer, vol. 21, no. 2, 2022, pp. 417-428.
[23] J. W. Orillo, J. Dela Cruz, L. Agapito, P. J. Satimbre and I. Valenzuela, "Identification of diseases in rice plant (oryza sativa) using back propagation Artificial Neural Network," 2014 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), 2014, pp. 1-6, doi: 10.1109/HNICEM.2014.7016248.
[24] J. W. Orillo, G. J. Emperador, M. G. Gasgonia, M. Parpan and J. Yang, "Rice plant nitrogen level assessment through image processing using artificial neural network," 2014 International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), 2014, pp. 1-6, doi: 10.1109/HNICEM.2014.7016187.
[25] R. S. Concepcion II, S. C. Lauguico, J. D. Alejandrino, E. P. Dadios, and E. Sybingco, "Lettuce Canopy Area Measurement Using Static Supervised Neural Networks Based on Numerical Image Textural Feature Analysis of Haralick and Gray Level Co-Occurrence Matrix," AGRIVITA, Journal of Agricultural Science, vol. 42, no. 3, 2020, pp. 472-486.
[26] R. Concepcion II, E. Dadios, E. Sybingco, and A. Bandala, "A Novel Artificial Bee Colony-Optimized Visible Oblique Dipyramid Greenness Index for Vision-Based Aquaponic Lettuce Biophysical Signatures Estimation." Information Processing in Agriculture, 2022, pp. 1-22.
[27] L. K. S. Tolentino, S. O. Belarmino, J. G. N. Chan, O. D. Cleofas Jr, J. G. M. Creencia, M. E. L. Cruz, J. C. Geronimo, J. P. M. Ramos, L. A. C. Enriquez, J. F. C. Quijano, and E. Fernandez, "IoT-based Closed Algal Cultivation System with Vision System for Cell Count through ImageJ via Raspberry Pi," International Journal of Advanced Computer Science and Applications (IJACSA) 12, no. 7, 2021, pp. 287-294.
[28] M. H. Hamd and S. K. Ahmed, "Fourier descriptors for iris recognition," International Journal of Computing and Digital Systems, vol. 6, no. 05, pp. 285-291, 2017
[29] Y. M. Akbar, A. Musafa, and I. Riyanto, "Image processing-based flood detection for online flood early warning system," 2017. doi:10.31227/osf.io/ayn2c
[30] P. V. K. Borges, J. Mayer, and E. Izquierdo, "A probabilistic model for flood detection in video sequences," in 2008 15th IEEE International Conference on Image Processing, pp. 13-16, 2008
[31] C. L. Lai, J. C. Yang, and Y. H. Chen, "A real time video processing based surveillance system for early fire and flood detection," in 2007 IEEE Instrumentation & Measurement Technology Conference IMTC 2007, pp. 1-6, 2007.
[32] T. M. Amado and F. R. G. Cruz, "Wireless Flood Monitoring Using Integrated Hydrological Sensors and Flood Prediction Via Artificial Neural Network," in 8th AUN/SEED-Net Regional Conference on Electrical and Electronics Engineering, 2015, pp. 32-33.