PHILIPPINE HYDROLOGICAL DATASET MAPPING IN BATANGAS PROVINCE USING LIDAR DATA AND DISTANCE VALIDATION USING LASER RANGE FINDER

Alejandro H. Ballado, Jr.[1,2], Ramon G. Garcia[1,2], Crystalyn N. Balaguer[1], John Mhar P. Enriquez[1], Chester Patrick Y. Pinalas[1], Gabriel Ron Russei M. Ruiz[1], Glenn V. Magwili[1,2], Jennifer C. Dela Cruz[1,2], Sarah Alma P. Bentir[2], Shydel M. Sarte[2]

[1]School of EECE, Mapúa University, Muralla St. Intramuros 1002 Manila, Philippines

[2]School of Graduate Studies, Mapúa University

ahballado@mapua.edu.ph, rggarcia@mapua.edu.ph, cnbalaguer@gmail.com, johnmharenriquez@gmail.com, pinalas@gmail.com, grrmruiz@gmail.com, gvmagwili@mapua.edu.ph, jcdelacruz@mapua.edu.ph, sapbentir@gmail.com, shydelsarte@gmail.com

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ABSTRACT: The Philippines experiences at least 20 typhoons that causes flood to cities every year. Areas near the body of water are mostly populated which became more vulnerable when a disaster strikes. Disaster monitoring and management plays a critical role in disaster mitigation. Remote sensing and GIS has been widely used to manage and identify hazard areas. Most approach to automatically creating a hydrologic model is using the geometric neighboring features. The Philippine Hydrologic Dataset for Watersheds from LiDAR Assessment (PHD) is one of the five components of the Nationwide Detailed Resources Assessment using LiDAR (Phil-LiDAR 2) to build a nationwide database for the Philippines to have a standard hydrological datasets such as streams, irrigation, wetlands, and watershed boundary. However, accuracy can be affected by spatial resolution of image and the classification method. This study present procedures in delineating three types of water bodies which are vital in urban planning such as: stream network, irrigations, and wetlands from LiDAR surveys. Acquisition of ground truth data using laser range finder done using SF-11c laser sensor connected to the Gizduino 4.1 microcontroller is also applied to validate the width from LiDAR data and actual feature using two – tailed equal variance t – test. Experiments compared the width of the classified objects from automated extraction using LiDAR Digital Elevation Model data versus ground truth using manual measurement as well as the ground truth data acquired using Gizduino 4.1 microcontroller versus the ground truth. Results show that the average values taken using the prototype and the Lidar have no significant difference in comparison to the actual measured data

1. INTRODUCTION

Philippines is a country that is surrounded by bodies of water from rivers to the sea. There are many remote sensing techniques that may help the decision makers to provide efficient and effective management by identifying flood prone areas, streams, rivers, irrigations, and wetlands with new information that could be presented, they could improve the way they approach a flood disaster (David, Sarte, Laguerta, & Ballado, Jr., 2016).

LiDAR is one of it and it stands for Light Detection and Ranging. It is a known technology that makes high resolution maps with the use of applications like airborne laser swath mapping (ALSM) and laser altimetry. Locations of objects in an environment are utilized in a position measurement system called Laser Range Finder (LRF) (NOAA, 2016). In the measurement of the distance, conventional approaches apply a laser range finder and a reference marker placed at the location of the object. (Hayes, Vu, & Zhang, 2004).

The UP TCAGP developed a source of hydrologic datasets for the Philippines (Universiy of the Philippines- Diliman, 2016). The subcomponents are streams and drainages, Inland and wetland, and Irrigation. They Compilation of data for irrigation systems, as well as the extraction of sub irrigation systems provides a more accessible source that may help in monitoring water resources

One of the five components of the Nationwide Detailed Resources Assessment using LiDAR (Phil-LiDAR 2) program of Department of Science and Technology (DOST) (Blanco, et al., 2016) is Philippine Hydrologic Dataset for Watersheds from LiDAR Assessments (Universiy of the Philippines- Diliman, 2016) which have a goal to build a nationwide database for the Philippines to have a standard hydrological datasets. In this research, the detailed mapping of the watersheds from LiDAR Surveys and delineation using Remote sensing techniques and validation using laser range finder are applied for the advancement of monitoring water resources, irrigation network modeling, flood control planning, and improving of the management of wetlands.

The main objective of this study is to create a hydrological structure in the province of Batangas, present the procedure and guidelines for extraction of irrigation network data, stream and drainage, and inland and human-made wetlands and to create a prototype of the laser range finder that is capable of measuring the width of a certain body of water.

2. RELATED WORKS

One of the techniques used in mapping is using LiDAR technology (Blanco, et al., 2016) (David & Ballado, Jr., Mapping mangrove forest from LiDAR data using object-based image analysis and Support Vector Machine: The case of Calatagan, Batangas, 2015), (Universiy of the Philippines- Diliman, 2016). The importance of spatial analysis is to create baseline of urban planning. Digital Elevation Model (DEMs) data can be used as basis in different analysis applications like flow modelling, watershed extraction, delineating wetlands, rivers, irrigations, and flood plains.

3. METHODOLOGY

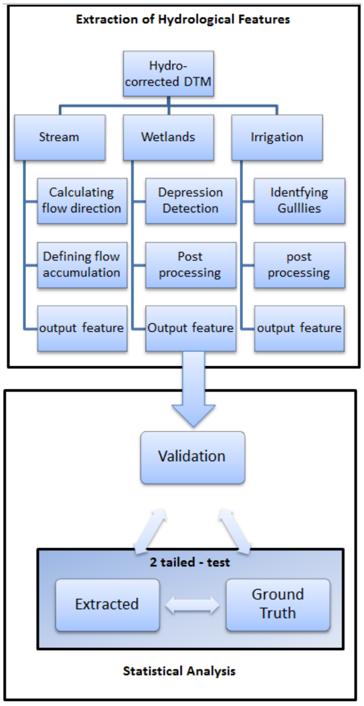

Figure 1. Implemented methodological workflow

4. EXTRACTION OF HYDROLOGICAL COMPONENTS

For extraction and compilation of irrigation networks, streams and drainage, pre-processing was initially performed. In as much as pre-processing is involved, the Digital Terrain Model (DTM) was reconditioning by calculating the possible sink. A sink is a cell where there is no adjacent cell is lower.

4.1. Stream Delineation

The delineation of stream line was processed using Archydro tools to calculate the cells contributing accumulation to the next lower cell based from the direction of the flow (Al-Muqdadi & Merkel, Automated Watershed Evaluation of Flat Terrain, 2011).

Processing started with flow direction to ensure that no gap would exist in the data which might affect the output process. Flow accumulation was then implemented which allowed us to identify the stream channels through the cells with concentrated values. After identification, the stream networks were separated from other features in the flow accumulation raster. Drainage line processing was done in order to convert the stream definition raster into a polyline feature. During this process, drainage line points can now be obtained which would be used in watershed delineation. When done with the processing, refinement and digitization of the map were executed in order to correct the slight errors during the stream extraction process. The data was further refined in order to improve its quality.

4.2. Irrigation Networks

For the extraction of irrigation features, Map Gully Depth (MGD) tool using Whitebox was primary used to map the gullies from the DTM (Universiy of the Philippines- Diliman, 2016), see Fig. 1. The calculation of the gullies are based from the primary parameters such as: maximum gully width, minimum and maximum gully depths, threshold in difference of mean elevation (DFME) The values of the raster to produce are always positive since the MGD measures depth. The higher the value, the deeper the depression, the more like to be a gully. This will be the basis of the digitization / extraction of the irrigation.

4.3. Wetlands

Depression in the DEM can be an indication of a wetland. Stochastic Depression Analysis using Monte Carlo approach with Whitebox software has been used to identify depression. To make sure that the identified depression falls under True Positive, Majority Modal Filter has been used to minimize erroneous result. After the establishment of wetlands, reclassification is used to create a raster data where wetlands have been identified using two numerical values only: 0 and 1. Any values fall inside the 0 will be identified as No Data values while 1 denotes as depression value. For LiDAR data, the standardization used was 50 sq.m. of areas of possible depression basin with no inlet and outlet. Hence, feature falls less than the 50 sq. m. will be removed by calculating the geometry. We used visual interpretation to identify the misclassification.

5. LASER RANGE FINDER USING GIZDUINO 4.1 AND LIDAR-LITE RANGE FINDER

The Laser Range Finder is a device used to measure a distance from one point to another. The prototype that the researchers are making will be used for measuring the width of the watersheds and compare it to the values obtained using the LiDAR Data. This will determine if the LiDAR Data gathered is accurate.

The device is composed of a Gizduino Microcontroller and SF-11C laser sensor. This device works with a laser beam that is emitted until it reach an obstruction and bounces back to the source of laser beam. The microcontroller will measure the time until the laser is back to the source, and through the speed of light and time elapsed, the distance will be calculated.

5.1. Gizduino 4.1 Microcontroller

Microcontroller gizduino 4.1 is similar with ATMEGA168P which is a product of arduino. It utilizes same concept as the ATMEGA168P. It can also be programmed by IDE (Integrated Development Environment) using basic programming language.

5.2. Acroname SF11C

The LightWare SF11-C produced accurate distances measurements since it uses a laser which cannot be easily affected by external factors such as: wind, pressure and temperature. The sensor directly fed information to the microcontroller. The microcontroller provides signal the sensor when to emitting laser beam then it bounces back and calculates seconds from the sensor emits light until the laser back to source. Fig. 2 described the general process of the proposed sensor in acquiring data.

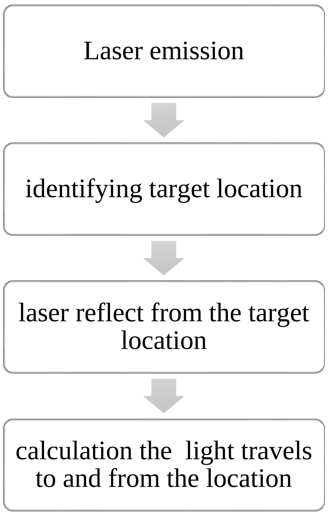

Figure 2. Workflow of distance calculation

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5.3. Connection Setup

The LightWare SF11-C make a very accurate distances measurements since it uses a laser which cannot be easily affected by external factors such as: wind, pressure and temperature. The sensor directly fed information to the microcontroller. The microcontroller signals the sensor when emitting laser pulse then it bounces back. Then the microcontroller will calculate the time from the sensor emits light until the laser back to source. The SF-11c laser sensor is connected to the Gizduino through the ports assigned in Figure 3.

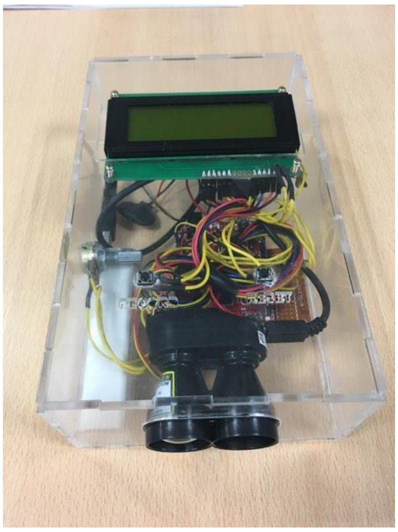

Figure 3. Prototype used during the ground validation

5.4. Calibration and Data Gathering

The data gathered through the Laser Range Finder is then being compared to the actual values provided by the LiDAR Data. Table 1 shows the data acquired for calibration. T-Test was used to analyze the mean difference of the readings between the reference data and the acquired from the sensor.

The output distance is compared to the actual measurements. Microcontroller unit was calibrated to adjust the delay constant parameter in pulling up the time elapsed for the laser to return the receiver. Changing the value of delay factor, the time elapsed for the laser to return will increase or decrease depending on delay factor the researchers set.

6. STATISTICAL RESULT

The delay is set to random value of 0.5 to 1.5and test the prototype in a controlled environment measured 5m from the wall and an increment of 5m up to 25m.

Table 1. Data acquired using the sensor

DISTANCE = 5 - METER

TRIAL	Actual distance	Sensor output
1	5	4.99
2	5	5.02
3	5	5.03
MEAN	5	5.0133
S	0	0.0208
T	-0.1597	

Where:

Confidence level = 95 %
Significance level (α) = 5%
α = 0.05
α/2 = 0.025

Table 1 shows the value of actual distance from the point. For the statistical test, the researchers used a 2 tailed equal variance t-test, for a 6 samples comparing the reference distance and prototype distance. All the values of t in are acceptable base on the t distribution table ranging -2.571 to +2.571. The hypothesis of the study accepts the null hypothesis and that the values taken using the study and the reference measurement have no significant difference.

$$t = \frac{x_1 - x_2}{\sqrt{\frac{{s_1}^2}{n_1} + \frac{{s_2}^2}{n_2}}}$$

Wherein, x_1 and x_2 are the mean of the reference and acquired data, respectively. While s_1 and s_2 are the standard deviation of the reference and acquired data, respectively. n_1 and n_2 are the total number of population of the reference and acquired data, respectively.

Table 2. T-test between the reference data, ground truth, and acquired measurement in Lian Bridge (Area1)

Lian Bridge					
Time Measured: 2:28pm to 2:44pm					
Name	Location		Width		
	Latitude	Longitude	LiDar Data	Actual Data	Prototype Data
1.1	14°2'31.78"N	120°39'5.03"E	80.29m	79m	78.71m
1.2			82.03m	79m	80.31m
1.3			76.86m	79m	78.87m
1.4			84.86m	79m	81.87m
1.5			77.33m	79m	77.92m
t-test between LiDar data and Actual Data			**t-test between Actual Data and prototype data**		
mean lidar data	80.274		mean measured	79	
mean measured data	79		mean prototype	79.536	
s lidar data	3.3331		s measured	0	
s measured	0		s prototype	1.564	
T	1.5604		t	-0.9584	

Figure 4. Location of the ground validation in Area 1

Table 3. T-test between the reference data, ground truth, and acquired measurement

Palico Bridge					
Time Measured: 12:38pm to 12:50pm					
Name	Location		Width		
	Latitude	Longitude	LiDar Data	Actual Data	Prototype Data
2.1			54.56m	53m	51.71m
2.2			54.51m	53m	53.84m
2.3	14°2'47.53"N	120°41'37.31"E	51.18m	53m	53.11m
2.4			53.72m	53m	54.92m
2.5			55.66m	53m	52.99m
t-test between LiDar and Actual data			**t-test between Actual data and prototype data**		
mean lidar data	53.926	°	mean measured	53	
mean measured data	53		mean prototype	53.314	
s lidar data	1.6832		s measured	0	
s measured	0		s prototype	1.1806	
T	1.596		T	-0.6462	

Figure 5. Location of the ground validation in Area 2

Table 4. T-test between the reference data, ground truth, and acquired measurement in

Tagaytay-Nasugbu Bridge					
Time Measured: 3:07pm to 3:34pm					
Name	Location		Width		
	Latitude	Longitude	LiDar Data	Measured	Prototype Data
3.1	14°3'36.29"N	120°42'23.67"E	49.32m	50m	51.48m
3.2			49.70m	50m	52.74m
3.3			49.69m	50m	49.34m
3.4			51.31m	50m	52.97m
3.5			46.22m	50m	49.38m
t-test between LiDar data and Actual data			**t-test between Actual and prototype data**		
mean lidar data	49.248		mean measured	50	
mean measured data	50		mean prototype	51.182	
s lidar data	1.8591		s measured	0	
s measured	0		s prototype	1.7574	
T	-1.2332		t	-1.9938	

Figure 6. Location of ground validation in Area 3

Table 5. T-test between the reference data, ground truth, and acquired measurement in

KaytitingaBridge					
Time Measured 12:05pm to 12:31pm					
	Location		Width		
Name	Latitude	Longitude	LiDar Data	Actual Data	Prototype Data
4.1			26.44m	27m	25.94m
4.2			26.53m	27m	25.59m
4.3			27.88m	27m	26.19m
4.4			25.98m	27m	26.03m
4.5	14'1'42.64"N	120'43'5.17"E	26.03m	27m	28.44m
t-test between LiDar data and Actual data			**t-test between Actual data and prototype data**		
mean lidar data	26.572		mean measured	27	
mean measured data	27		mean prototype	26.438	
s lidar data	0.7704		s measured	0	
s measured	0		s prototype	1.1405	
T	-1.0903		T	1.1767	

Figure 7. Location of ground validation in Area 4

A two tailed equal variance t-test, for 10 samples the acquired data and reference data, and acquired data versus ground truth data. Results show that t values ranging from -2.262 to +2.262 proved that the values acquired using the prototype and the LiDAR data have no significant difference in comparison to the actual measured data.

7. SUMMARY AND CONCLUSION

The LiDar data were given by UP Diliman DREAM and were processed and analyzed with the use of Digital Terrain Model (DTM). Streams and drainage were delineated based on the flow accumulated in each cell. Irrigation network features were identified using the identification of the gullies produced based on the sudden change in the terrain. Wetland features were classified by calculating the depression in the given area. The delineated features have been validated using the Gizduino 4.1 Microcontroller and SF-11C laser sensor to assess the delineated width of the classified objects using the remote sensing techniques. A two tailed - test has been used to assess the accuracy of the research. Results show that the proposed study provides accurate results.

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