Presented at the DLSU Research Congress 2016
De La Salle University, Manila, Philippines
March 7-9, 2016

Automatic Flood Detection Using the Video of Static Cameras

Martin Joshua P. San Miguel and Conrado R. Ruiz, Jr.
College of Computer Studies, De La Salle University
**Corresponding Author: conrado.ruiz@dlsu.edu.ph*

Abstract: Regional heavy rainfall is usually caused by extreme weather conditions. Consequently, heavy rainfall often results in the flooding of rivers and the neighboring low-lying areas, which is responsible for a large number of casualties and considerable property loss. The existing weather forecast systems focus primarily on the analysis and forecast of large-scale areas and do not provide precise instant automatic monitoring and alert feedback for small areas and sections. In this paper, we propose a method to automatically monitor the flood level of a specific area based on video surveillance systems using image processing methods and computer vision techniques to provide instant feedback on flooding events. OpenCV, which specializes in real-time computer vision, is used for motion tracking and image processing. The system can track objects and analyze if its flood based on a set of features. The proposed method can better meet the practical needs of disaster prevention than large-area forecasting. It also has several other advantages, such as flexibility in location deployment and it does not require specialized equipment. The results offer prompt information and reports for appropriate disaster warning and response in small localized areas.

Key Words: flood; early warning system; image processing; video surveillance; computer vision

1. INTRODUCTION

Flooding has become more frequent in Manila because of deforestation of mountains, clogged waterways and canals, and poor urban planning. When a large amount of water cannot be drained in time within the rainfall area, we face river overflow or urban inundation, which frequently causes serious problems such as large number of casualties and a considerable property loss. Therefore, effective near real-time hydrological information is extremely important for flood warning.

The developed countries in the world are using a variety of weather forecasting systems to assist disaster prevention, relief, and evacuation, in order to drastically reduce the number of casualties and the amount of economic loss caused by disastrous weather conditions. However, these forecast systems are normally based on predictions featuring a widespread region and a long lead-time. For both precipitation and flood forecasts, the results are not necessarily in line with the real situation and it is difficult to obtain precise results for small local areas, because of the various uncertain factors in the natural climate system like the complex interactions between hydrology, monsoon, ocean currents, and clouds. Therefore, many studies are currently being conducted with the aim of improving these forecast models. At present, it is still not easy to achieve reliable accuracy for precise regional flood forecasting in a given small area.

The focus of this study is the detection of flood in a video sequences that is being fed by a static video surveillance camera. Image segmentation is used for removing the surrounding objects, such as buildings and the geographical background. Computer vision techniques are used for object detection.

2. RELATED WORK

In the paper, “An Autonomous Earth Observing Sensorweb”, the authors describe a network of sensors linked by software and the internet to an autonomous satellite observation response capability. This system has been used to implement a global surveillance program of multiple science phenomena including: volcanoes, flooding, cryosphere events, etc. (Chien, et al., 2006)

For “Sensor Network Applications”, it discusses recent developments in wireless network technology and miniaturization now make it possible to realistically monitor the natural environment. These systems can provide new data for environmental science, such as climate models, as well as vital hazard warnings such as flood alerts. (Martinez, Hart, & Ong, 2004)

The paper, “Near real-time flood detection in urban and rural areas using high resolution Synthetic Aperture Radar Images” describes an automatic algorithm using high resolution Synthetic Aperture Radar (SAR) satellite data that builds on existing approaches, including the use of image segmentation techniques prior to object classification to cope with the very large number of pixels in these scenes. (Mason, Davenport, Neal, Schuman, & Bates, 2011)

The study by (Borges, Mayer, & Izquierdo, n.d.) propose a new image event detection method for identifying flood in videos. Traditional image based flood detection is often used in remote sensing and satellite imaging applications. Experiments illustrated the applicability of the method and the improved performance in comparison to other techniques.

In the Philippine setting, Dr. Sandra Geronimo-Catane, a respected geo-hazards expert, has clinched funding from the Department of Science and Technology that seeks to create a cheap but effective gadgets for flood and landslide monitoring. At the end of the experiments, the group wanted to determine a specific warning level or cut-off level (when soil is about to erode) that automatically triggers a loud siren. This serves as a warning that there will be an imminent landslide. (abs-cbnnews.com, 2009)

While Dr. Catane's landslide warning system is still in the experimental stage, another group of scientists has already developed a low-cost and effective flood-warning device. The UP College of Science, with the help of scientists like Dr. Carlos Primo David of NIGS, has developed a contraption that sends flood warnings via cellphone-like device. The device's main component is a tipping bucket that collects rain water and measures exactly how fast or slow rain falls via a sensor. The tipping bucket is hooked up to a monitor that is also hooked up to a GSM modem. The GSM modem acts like a cellular phone that can send and receive text messages and calls. At any time, people can send texts or prompt "missed calls" to the modem to get information on rainfall data. (abs-cbnnews.com, 2009)

“BeWarned” from National University, is a real time push notification, where the users are notified for incoming disasters which provide the basic information about the specific disaster (i.e alert level, location, and duration) and the information on the nearest evacuation center. (National University)

3. METHODOLOGY

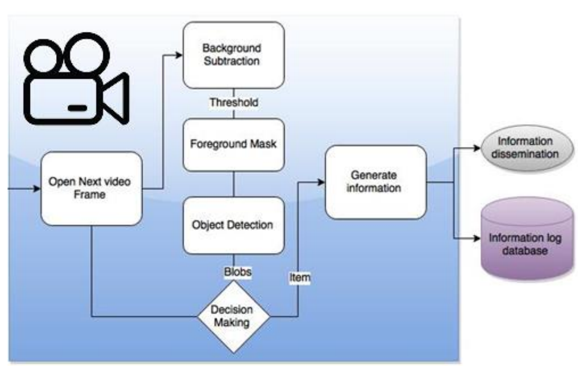

Figure 1 Architectural Diagram

Figure 1 shows the architectural diagram of the system to detect floods. First, the system masks the region of interest and the points in the mask are predefined. After getting the mask of the image and the current frame of the video sequence, the system will normalize the luminance of the images to get the same distribution for every frame. Second, it will convert the two images to a grayscale form before subtracting the current frame from the background model. The system will then perform a binary thresholding of the difference for blob detection purposes, this is done to detect objects that are not part of the background. Next, the system will get the size of the blob by computing for its area. If size is greater than area of interest it will mask blob to the current frame and reference flood image. Lastly, it will now compute for its color histogram of the current frame and the reference flood image and then the system will compare its histograms. If it passes this test, the system will then compute for the mean pixel intensity of the blob on the current frame and reference image of flood. If it passes this second comparison, the system will now flag the frame as an image with a flood. There are four main considerations when identifying floods these are: position, size, color and texture.

3.1 Position

One common characteristic of flooded regions is that they are usually located in the lower and middle parts of an image. When executing operations on the image a mask is used to focus on only the regions of interest in the current frame being considered.

Fig. 2 Masking process to set the position. Original frame (left), Mask region(right), Mask in original frame(bottom)

The flood region is set a priori by setting the ‘flood region pixels’ to 1 and the ‘non-flood region pixels’ to 0, as illustrated in Fig. 2. By focusing on predefined regions, we can lessen the problem of distinguishing between non-flood related objects like sidewalks, trees, etc.

3.2 Lighting Condition

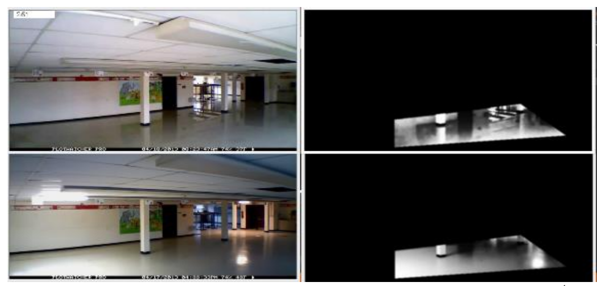

Fig. 3 Lighting Normalization. Current Video frame (top-left), Current Video frame normalize(top-right), Background Image (bottom-left), Background Image Normalize(bottom-left)

Frames from a stream or video sequences will sometimes have a large spike in brightness, and then return to its normal brightness level in subsequent frames. This is an important concern in the implementation of our algorithm. A fairly naive solution done by the system to address this, we normalize the video frame-by-frame. The system converts the images into the YUV color space, perform histogram equalization on the Y channel, and then convert back to RGB. The equations used for the conversion are

$$Y' = W_R R + W_G G + W_B B = 0.299R + 0.587G + 0.114B$$
$$U = U_{\mathrm{Max}} \frac{B - Y'}{1 - W_B} \approx 0.492(B - Y')$$
$$V = V_{\mathrm{Max}} \frac{R - Y'}{1 - W_R} \approx 0.877(R - Y')$$

(Eq.1)

where the constant values are set to

$$\begin{aligned} W_R &= 0.299 \\ W_G &= 1 - W_R - W_B = 0.587 \\ W_B &= 0.114 \\ U_{\mathrm{Max}} &= 0.436 \\ V_{\mathrm{Max}} &= 0.615 \end{aligned}$$

The normalization process will produce iris regions, which have the same constant dimensions, so that two images of the same iris under different conditions will have characteristic features at the same spatial location. And then converting the image and frame into a grayscale, this produces an effect shown below. The brightness of the two images in the right side is more similar than that of the two original images, this two images will now be used in the background subtraction.

3.3 Size

One indicator that the blob detected inside the region of interest is indeed a flood is size. Generally, if blob occupies a significant area of the region of interest it is flagged by the system as a potential flood candidate. We set the threshold to 70% of the area occupied by the pixels of the blob.

Fig. 4. Current Video Frame (left), Image with Flood (right)

In Fig. 4, the green box represents the region covered by the contour. If the detected blob pass the condition of the size feature, it will be used as a mask on the original frame and the reference image of flood. As seen in the figure above, the images inside the windows named “1” and “2”, are part of the blob that was taken for the green boxed area.

3.4 Color

We only consider only the homogeneous regions that are flood candidates. We use image masks to focus on the regions of interest and calculate the color histogram of the area. Shown in the Fig. 5 is the color distribution of the blob.

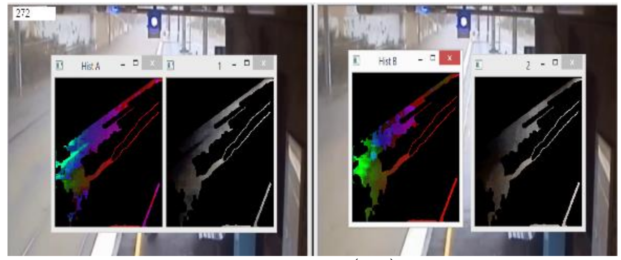

Fig. 5. Current Video Frame (left), Reference Image of a Flood (right)

After getting the results from calculating its histogram, the system will compare the results of the current frame from the video sequence and the reference image of a flood. For comparing histograms, the method used in the system is the “Bhattacharyya distance”, given by

$$d(H_1, H_2) = \sqrt{1 - \frac{1}{\sqrt{\bar{H}_1 \bar{H}_2 N^2}} \sum_I \sqrt{H_1(I) \cdot H_2(I)}} \quad \text{. (Eq. 2)}$$

This measures the dissimilarity of the color distributions, H_1 and H_2. The range of the result of the Bhattacharyya distance is between 0 – 1, 0 means perfect match and 1 means mismatch. If the result from the Bhattacharyya distance is less than 0.2 the system calculates the mean pixel intensity of the extracted blobs, if the pixel difference is less than 5.5, the system can confirm that it detected a flood.

3.5 Texture

Part of the problem in texture analysis is mathematically defining a texture. One way to define a texture is by considering a statistical approach. Considering texture as a quantitative measure of the arrangement of intensities in a region, the system will differentiate the average or mean pixel intensity of the current frame from the video sequence to the image with flood. Generally, flood textures are smooth compared to smooth, compared to coarser road or street textures.

Fig. 6 shows the process flow of the system and summarizes the steps involved in the flood detection.

ISSN 2449-3309

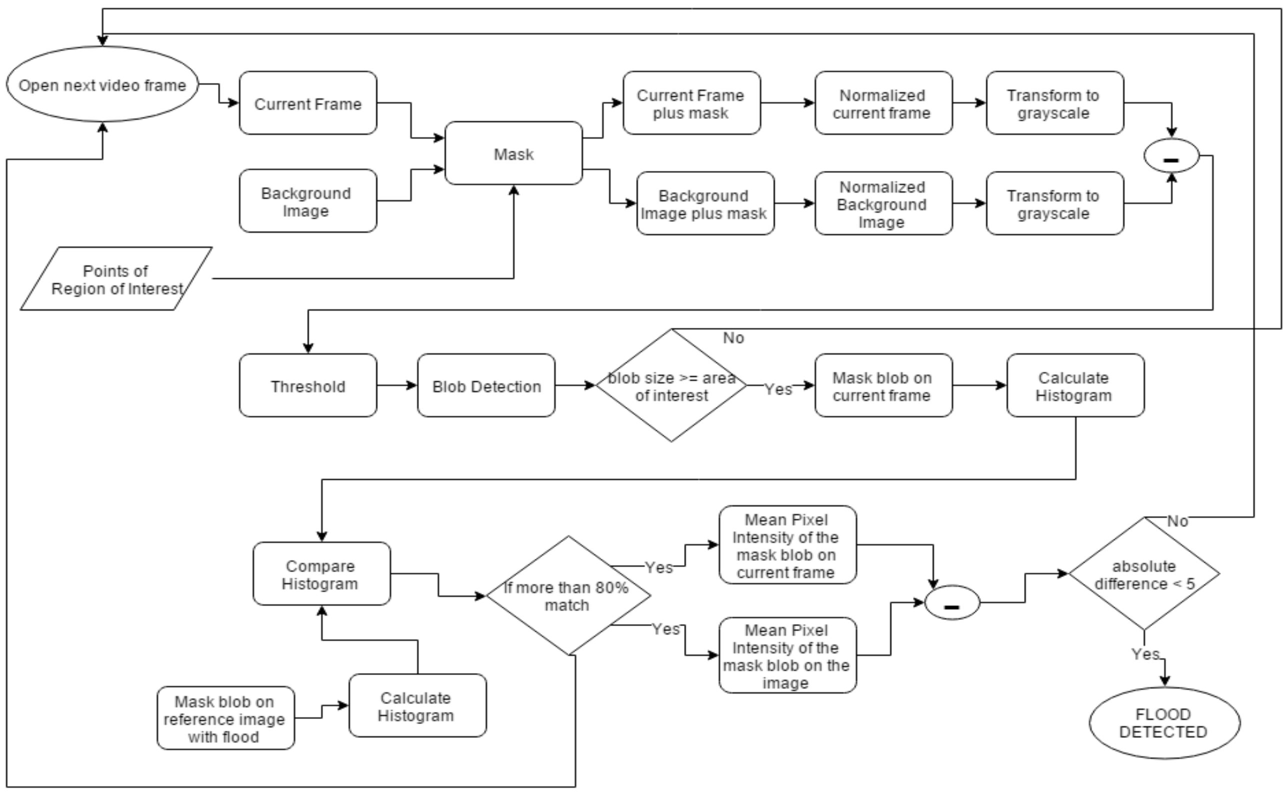

Fig. 6. Flood Detection Process Flow

5. Implementation Details

The system utilizes Visual Studio Community 2013 as an integrated development environment for C++ and an open source library of programming functions called OpenCV. The system also uses XAMPP, an open source cross-platform web server solution, to act as a local server for a MySQL relational database.

Visual Studio is used to develop computer programs for Microsoft Windows, as well as web sites, web applications and web services. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silverlight.

OpenCV, which specializes at real-time computer vision, is used for motion tracking and image processing in this project. The OpenCV library contains hundreds of functions that support the capture, analysis, and manipulation of visual information fed to a computer by webcams, video files, or other types of devices. Simple functions might be used to draw a line or other shape on a screen, while the more advanced portions of the library contain algorithms for detecting faces, tracking motion, and analyzing shapes. (Grimmick, 2015)

XAMPP stands for Cross-Platform (X), Apache (A), MySQL (M), PHP (P) and Perl (P). It is a simple, lightweight Apache distribution that makes it extremely easy for developers to create a local web server for testing purposes. Server application (Apache), database (MySQL), and scripting language (PHP) are all included in XAMPP. MySQL, which is open source, is the world's most popular database management system. It powers everything from hobbyist websites to professional platforms like WordPress. (Mikoluk, 2013)

5. RESULTS & CONCLUSION

Flood detection thru static cameras was successful with the aid of OpenCV libraries for image processing. Based on the results on the four video sequences that we have tested, the system was able to react to a timely manner appropriate for its situation. Examples of frames with flooded regions are shown in Figure 6.

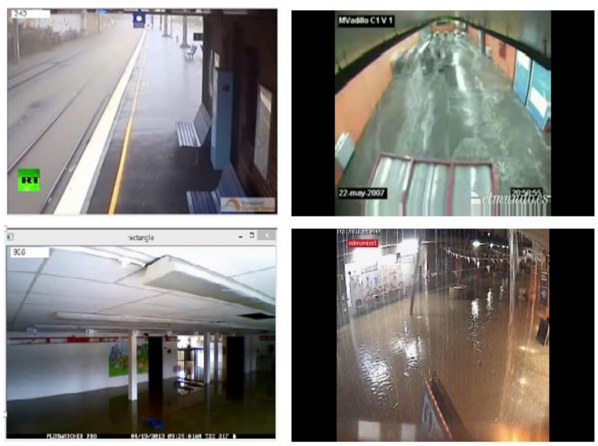

Fig. 6. Frames with flooded regions from video surveillance.

The system also has an information dissemination module that sends out an SMS message to all the contact numbers in a database once a flooding event has occurred.

It is highly recommended to use a Bayes classifier to combine the features of floods to further improve the flood detection of the system. Because some features have better classification power than others, a Bayes classifier would be able to identify the proper weights and discriminate better between two classes, and consequently reduce the detection error rate.

6. ACKNOWLEDGEMENTS

The videos used were taken from YouTube. The video of the train station flood was from ABC News - Australia, the flooded Visitor Centre was from the Eden Project-UK and the subway flood was from CCTV of Madrid Metro.

7. REFERENCES

abs-cbnnews.com. (2009, October 12). UP scientists inventing flood warning systems. Retrieved from www.abs-cbnnews.com: http://www.abs-cbnnews.com/lifestyle/10/12/09/scientists-inventing-flood-warning-systems

Borges, P. V., Mayer, J., & Izquierdo, E. (n.d.). A Probabilistic Model For Flood Detection. Journal of Hydrometeorology, 8(4), 897-909.

Chien, S., Cichy, B., ... & Baker, V. (2006, June). An Autonomous Earth Observing Sensorweb. In Sensor Networks, Ubiquitous, and Trustworthy Computing,2006. IEEE International Conference on (Vol. 1, pp. 8-pp). IEEE.

Grimmick, R. (2015, July 10). What is OpenCV? Retrieved from www.wisegeek.com: http://www.wisegeek.com/what-is-opencv.htm

Martinez, K., Hart, J., & Ong, R. (2004, August 16). Sensor Network Applications. IEEE Computer, 37(8), 50-56.

Mason, Davenport, Neal, Schuman, & Bates. (2011). Near Real-Time Flood Detection In Urban And Rural Areas Using High. Geoscience and Remote Sensing, IEEE Trans. on, 50(8), 3041-3052.

Mikoluk, K. (2013, September 18). XAMPP Tutorial: How to Use XAMPP to Run Your Own Web Server. Retrieved from blog.udemy.com: https://blog.udemy.com/xampp-tutorial/

National University. (n.d.). national-u.edu.ph. Retrieved from NU's "BeWarned" placed third @ DevCon Devise Mobile Apps Competition: http://national-u.edu.ph/nus-bewarned-placed-third-devcon-devise-mobile-apps-competition/