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Riverbank Monitoring using Image Processing for Early Flood Warning System via IoT

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Abstract: This paper is presented a system that monitor the river water level by using computer vision with image processing and IoT. This system is developed to detect riverbank level and river water level by applying image processing where edge detection technique is applied on both images captured by video camera. The flood severity level is determined by comparing the river water level and the riverbank level. Then, the determined flood severity is upload to IoT platform. A notification is sent the people when the flood severity level reached certain critical level via Telegram app which one of the social media applications. The available Raspberry Pi 3 Model B is used as a controller in this system hardware device with the Raspberry Pi 5MP camera module. The IoT platform used is Ubidots where the user can be notified through it. The main contribution of this work is on the integration of computer vision with IoT Cloud as an early flood monitoring system in responding to climate change by determining the flood severity level and alert the community on the flood severity condition. Experimental results shown that it is viable approach to combine computer vision with an artificial intelligent image processing and the IoT Cloud platform. The work makes a comparison of the Canny Edge Detection technique and the threshold technique for determining the water level and the river bank level. This system also had been tested in lab (indoor) environment and outdoor environment to check the suitability of this system to operate at the real environment.

Keywords: Image processing, edge detection, IoT platform, Raspbian, Ubidots

1. Introduction

Natural disaster is a phenomenon that repeatedly happen every year and bring a negative impact on our economy and people life with it. In Malaysia there are several natural disasters such as haze, landslide, flood and forest fire. Flood phenomenon disaster is the most frequently happening compared to the other disaster where it also gives the worst effect to our economy compared to other disaster [1-3]. This forces the government to allocate huge budget for flood disaster management. If losses caused by floods can be reduces, the budget for flood disaster management can be reduce and can be used to develop the country. Furthermore, the economic losses due to unexpected flash flood also keeps happen. If the flood incident keeps repeating in future and without any plan to resolve it, economic growth of a country can be stunted. Therefore, this flood problem needs to be handled properly to enable a prosperous and modern Malaysia.

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Nowadays, the area near river basin especially in urban area are exposed to flash flood occurrence. A real time flood forecasting system is required for predicting the occurrence of flood in the urban downstream area. The river waterline edge level is useful in classify the flood severity level and for predicting flood occurrence in downstream area for early flood warning system. Currently, the determination of water levels near riverbank is performed manually on-measurement site [4],[5]. This process requires experienced human inputs hence it is a very laborious, time consuming and error-prone. Image-based water-level measurement techniques have been proposed to automaticaly obtain the water level from measurement site. However, this approach require good lighting conditions and clear image quality to detect water edges and then convert them to water-level results. On contrarily, for an outdoor application, lighting conditions can either inadequate or excessive in nature, thus require a robust framework to accurately detect the riverbank waterline edge.

In order to minimize the impact because of climate change that could possibly cause flood, an early flood monitoring system is implemented to ensure the sustainable development in SDG plan. This system needs to monitor the river water level and determine the status of flood severity and notify the targeted user when the river water level keeps increasing to the dangerous level during the rainy season. This should help people that stay in the area that near the river or the area the flood incidents frequently happen to make early preparation to face this kind of natural disaster. The flood monitoring system also should give early warning or prediction to the targeted users in order to reduce their economic loss. The system can assist people in the residential area that near with river to alert when river water level increase. It will help them to make preparation to facing the flood disaster by keep their important documents and valuable items in safe place. Normally, every residential in Malaysia have their own resident organization, this help them to make a preparation and flood management plan in their own resident area. The information receives can help people to make early preparation for facing this natural disaster.

Here some current survey on IoT-based flood monitoring using computer vision and AI [6],[7]. The various implementation of work on flood and disaster monitoring system work using IoT [8-15]. There is also a flood monitoring with notification alert via SMS [16] and android application [17]. Furthermore, an edge computing device with an AI-enable is a new direction [18] for early flood monitoring and prediction [19-23]. Therefore, we opted to implement a flood monitoring system with IoT and image processing enabled on edge computing device with computer vision and alert to user. The paper is structured as follows: the next section will explain the proposed system and methodology followed by results analysis and discussions, and the paper will be concluded in the final section.

2. Proposed System and Methodology

2.1 Overall System

This system can be divided into two part which is IoT Edge Computing device part and IoT Cloud Platform part as shown in Figure 1.

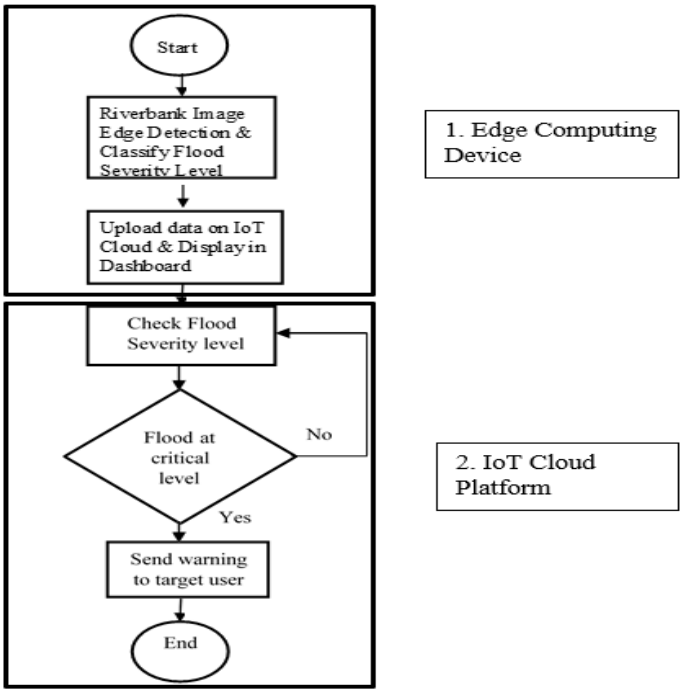


Fig. 1 - Overall system of Riverbank Monitoring System and flowchart

The IoT edge computing part is placed at the monitoring site. The device starts capturing the image from video camera streaming. The image of riverbank is been processed for detection of the edge of riverbank and water level in order to know the flood water level status. The flood severity level is sent to IoT Cloud Platform. In the second part of this system, the flood severity level data collected is upload and stored into Ubidots as IoT Cloud platform. The collected data is display on Ubidots Dashboard. The flood severity level is processed and an alert notification is sent to authority and people when the water level at critical stage via Telegram app or e-mail. If the water level at the normal stage the system, the IoT platform do not send any notification to user. The riverbank monitoring system for early flood mitigation is design to monitor and give the warning to the resident that stay near the river.

The Figure 2 shown the position for the edge computing device. The IoT based edge computing device with Raspberry Pi, 5MP camera module with Wi-Fi connectivity is installed at the high place where it can monitor the river water level clearly without any view blockage. Initially, the device is battery powered device and for real implementation to utilized electricity directly from the TNB. The Raspberry Pi 3 model B is used as the controller in this system. Raspberry Pi 3 is small device with the ability of computer [24]. On the Raspberry Pi itself has the slot for the Pi camera to capture and record the real-time streaming video. The operating system used is Raspbian OS for the Raspberry Pi that support multitasking computing on the edge. The operation in the Raspberry Pi is programmed using Python and OpenCV. These are among criteria of using this microcontroller as compared to other microcontrollers. The coding is saved in the microcontroller for the process of the system. These This device can be used to run an image processing technique and IoT technology. After coding were execute and run in the Raspberry Pi the camera will take place and do the analysis for water level detection. After the analysis is done then, the camera will capture and process for the next step that is analyses the image the flood severity level. Hence, the flood severity level data that been deduce from the analyses the image is send to the Ubidots IoT platform.

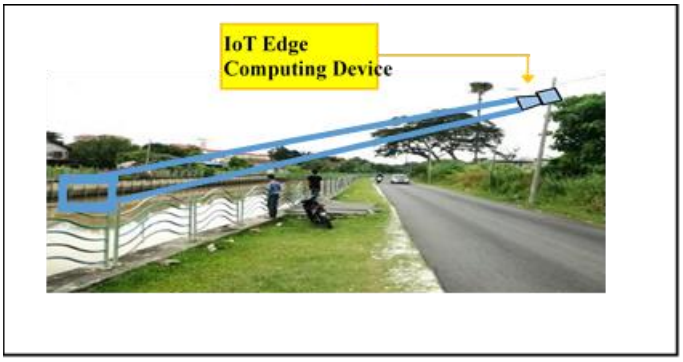


Fig. 2 - Outdoor location of the IoT edge computing

2.2 Riverbank Edge Detection and Classification

The OpenCV library software [25] is used in this project work. It be started by Gary Bradsky and release on 2000. It can support the algorithm for Computer Vision with Machine Learning where the multiple programming language such as C++, Java and Python can be used. In Canny Edge Detection technique is used to detect the edge in the image or video. In 1984, John F, Canny had develop this technique. The Gaussian Filter is used to reduce the noise that capture by camera. The Sobel kernel is used to get the horizontal direction (Gx) and vertical direction (Gy). This technique is used to detect riverbank. The unwanted pixel is removed when the gradient magnitude and direction from image capture is calculated. The final stage is hysteresis thresholding where it be used to decide which edge are considered as real edge. Two value of threshold values which is minVal and maxVal as guide to select the real edge.

$$Edge\_Gradient\ (G) = \sqrt{G_x^2 + G_y^2}$$

$$Angle\ (\theta) = \tan^{-1}\left(\frac{G_y}{G_x}\right)$$

Next, to detect the river water level edge, the histogram backproject technique is used. The histogram was created based on the ROI (region of interest). The colour histogram be use in order to get a better in detecting the object based on ROI. The targeted object has been normalizing before apply the backproject function. This technique is used in this system in order to detect the level of river water.

Threshold is one of the important elements in this system where it is used to make a simple segmentation. It is used to differentiate between the object that want to be analyses and background of the image capture. The threshold value is set as border to make a comparison for pixel of object and background in the image captured. The image pixel value that greater than threshold value can be assigned one value and the pixel that lower than threshold also be assign to another value. The pixel value is assigned with a new value that will change the image to black and white image. This technique is a basic step to help this system finding the edge of the riverbank and river water level.

Hough line detection is the technique to detect any shape of the object in the image. For this project, it will detect the water level. If any straight line in the image is detected, then it is going to show as the level indicator. The line represents in the mathematical form such as y=mx+c or ρ=xcosθ+ysinθ. From this equation this function will determine either the line is straight line or not. The linear Hough transform is a popular line detection algorithm and widely used for lane detection. This technique can be used to help system to differentiate the riverbank and river water. The Hough line technique is used for this system to draw the line for edge of river bank and river water level. For this system it been used to detect the riverbank where it can help the system to differentiate between riverbank edge and the edge of river water level.

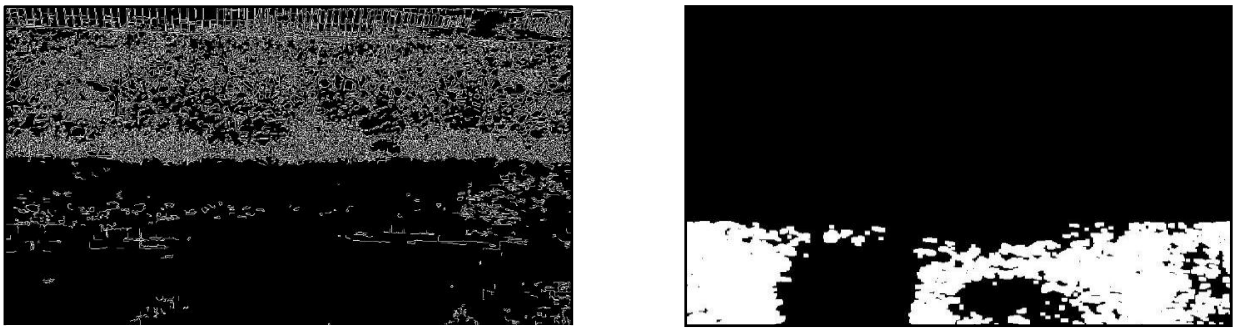
2.3 IoT Cloud

The IoT is a new generation technology that been apply nowadays where it had presented the "Industrial Revolution 4.0" where the technology in the industrial been move to a next stage. The IoT with the real name is Internet of Things is based on the combination of machine to machine (M2M) communication method, cloud computation and the modern Web-based framework [26],[27]. The Ubidots IoT platform is use where to collect and give the warning to the residential for example on gas leakage [28]. It provides internet of things (IoT) platform that can link the hardware and software for monitoring, controlling and automatic process for electrical [29] and water metering [30]. This platform providing the dashboard where the data that send from hardware can be monitor by user. It can be display in graph, table, text and another widget that be offer by this platform. This feature can be used to display the data in systematic way.

3. Result and Discussions

3.1 Waterline Edge Detection

In this section, two type of image processing techniques were compared. The effectiveness of both techniques is discuss based on the simulation when applying in this system. The Figure 3(a) shown that the Canny edge detection is used to detect the edge. It shown that there are some noises detected. In this technique, the line will be form if the edge form is nearly completed in single line although had noise surround it.



(a) **(b)**

Fig. 3 - Result edge detection for (a) using Canny edge detection; (b) using Histogram techniques

The Figure 3(b) shown how the histogram technique is used to detect edge. The white color is the area of water. The technique detects the ROI and change it into white color and the unwanted area will be turn to black color. In comparison, the canny edge detection is more suitable for this application compare to histogram technique. The histogram technique is more sensitive to light exposure compared to Canny edge technique. Therefore, any changes of light and the direction of it will affect the area detection where it difficult to form the line on image result.

The outdoor test result results will be shown below from original image in Figure 3(a). The comparison of the image processing technique will be discussed base on the result of the system. Figure 4 shown the output of the system in form of image where the system had been tested in outdoor environment. It had detected the edge of the riverbank and river water level and draw the edge line on the captured image. The red line is referred as riverbank edge and the yellow line is shown as the edge of river water level. The red line is draw based on the edge that been detecting by the canny edge detection technique. To draw the yellow line, like in the image, the threshold technique is use. The coordinate of both lines was referred for system to determine which stage that water level been place. The output in form of the image from system can be seen as shown in Figure 4.

Fig. 4 - Riverbank Edge (Red line) and Waterline Edge (Yellow Line) from outdoor location of the IoT edge computing

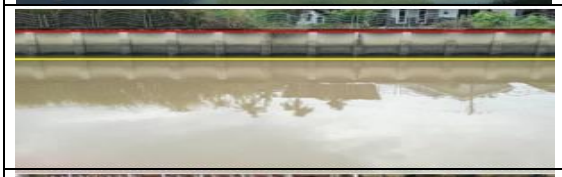
Riverbank Image	**Distance of detected water level edge from original water level edge**	
	Canny technique (Red line)	**Threshold technique (Yellow line)**
	20 Pixel	13 Pixel
	5 Pixel	10 Pixel
	13 Pixel	17 Pixel
	8 Pixel	30 Pixel
	11 Pixel	24 Pixel
Total pixel different from actual pixel location	**57 pixel**	**94 pixel**

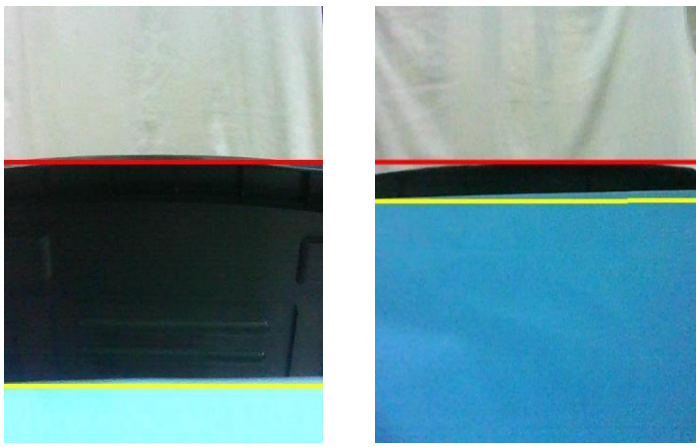
Fig. 5 - The comparison between Canny and Histogram/Threshold technique for detecting the edge of the riverbank and river water level

Figure 5 shown the comparison between of two techniques for detecting the edge of the riverbank and river water level. The comparison is based on the actual edge pixel location of riverbank and river water level with the pixel location of the edge detected by image processing technique. The red line is drawn by the system is the edge of riverbank using Canny edge detection technique whereas, the yellow line is drawn using the threshold technique is the edge of river water level. The comparison above shown that the Canny edge detection technique gave the closest water edge detection compared to the threshold technique. The total pixel location deviation from the original image location for edge that detected by canny technique is 57 pixels compared to actual pixel location.

The different pixel location for the edge that detected by threshold technique is 94 pixels compared to actual pixel location. Thus, the Canny technique is more suitable to apply to this system compared to threshold technique.

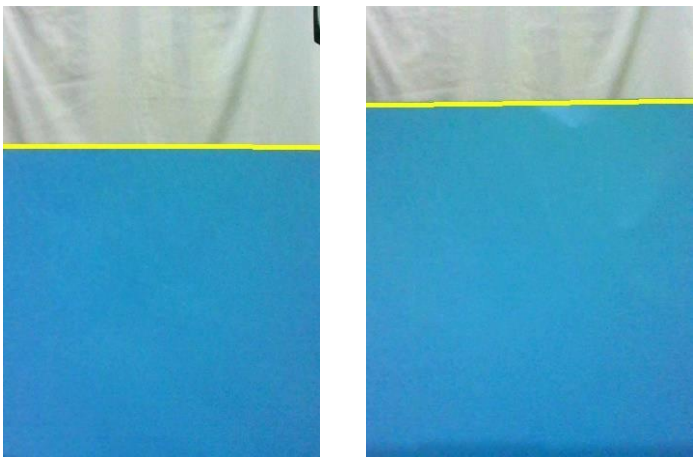
3.2 Flood Severity Classification

In this system, it needs to detect the edge of riverbank and river water level. The image captured is processed with the image processing technique to detect both edges. The edge that detected by this system is displayed on the LCD screen where the user can watch either this system operates correctly or not. Initially, both techniques applied to detect edge unable to differentiate between the edge for riverbank and river water level. Therefore, this system drawn the line on the original image captured with different color to differentiate between the line for riverbank and river water level. The method is used the color to differentiate between them. This method used the value of color in the pixel of the image where the threshold technique will be applied to the other pixel that has the same value. The region of interest (ROI) method will be used to get the pixel value. The pixel value that places under the region of interest (ROI) will be determine and used as reference to find other pixel that has same value. The other pixel that did not has the same value as the reference pixel is changed value where the color is transformed to black. In the lab test section, the system is test in the indoor environment to check that the system can function properly in detecting the edge. The canny edge technique and threshold technique is utilized during this test. The system is also been tested to determine the flood severity based on the waterline level is correctly detected. This mean that the system already combines the image processing technique and the algorithm that been used to detect flood severity level.



(a) **(b)**

Fig. 6 -Flood Severity classification result: (a) normal stage model; (b) Warning stage model



(a) **(b)**

Fig. 7 - Flood Severity classification result: (a) Flood stage 1 model; (b) Flood occur stage model

The Figure 6(a) and 6(b) until Figure 7(a) and 7(b) shown the results for the system testing in the lab environment. The black color is represented as riverbank area and the blue color is represent as river water area. The land area is decided to used white color. This test is designed to evaluate the performance of the classification algorithm of this system in recognizing the flood severity level based on edge of the riverbank and edge of river waterline. The line of riverbank edge and river water level line been compared to determine the flood severity level.

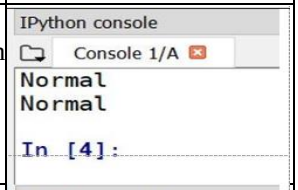
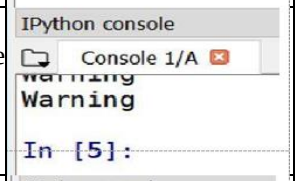
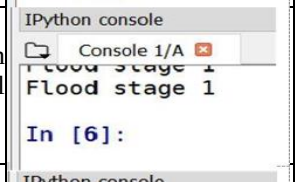
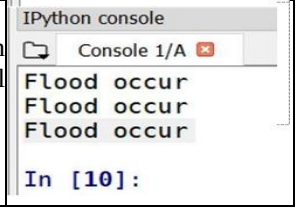
Figure	Info	Output
Figure 6(a)	Water level lower than riverbank limit.	
Figure 6(b)	Water level near the riverbank	
Figure 7(a)	Water level higher than riverbank but not in critical level	
Figure 7(b)	Water level higher than riverbank where it in critical level	

Fig. 8 - Flood Severity classification result: (a) Flood stage 1 model; (b) Flood occur stage model

The flood severity level is divided by four categories which is normal level, warning level, flood early-stage level and flood occur level. Figure 8 shown the result from the lab test where the system can classify the status of the flood severity level correctly. The lab environment condition makes the system can easily detect the edge that been capture from the camera.

3.3 IoT Cloud Notification to User

The Ubidots IoT platform can be used to send the notification to the targeted user. The message will be sent through the Telegram app, thus provide the simplest way for the targeted user to be notified. In this system, the user which is local authority and resident that stay near the river location will get the notification when the river water level reach certain level. Early warning will help them to make a preparation for facing this natural disaster. Figure 9 shown the notification that been send through the Telegram app. The status of river water level is stated in the notification. This kind of notification will help public and local authority make a preparation to face the flood disaster. The notification through the telegram app still can be receive by the targeted user although they are far from their home as long as they had the internet connection in their mobile phone.

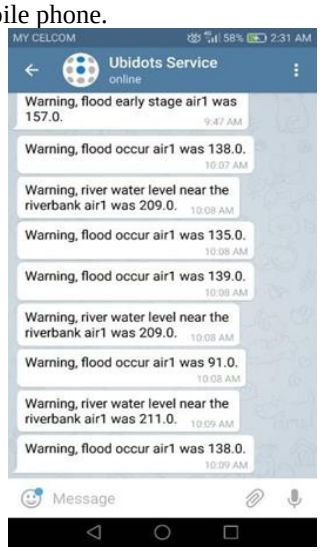


Fig. 9 - Ubidots notification to users on flood occurrence

4. Conclusion

As conclusion, this system can be used to monitor and detect the river water level to recognize if the flood phenomena happen. The system is applying the image processing technique to detect river water level. The Ubidots is a IoT platform that be used to upload the data of river water level. The notification will be sent to user through Telegram by using this IoT platform. This platform also can recognize the statues of the river water level. This system will help to make sure the residential that near with river will alert when river water level rise to certain level. It will help them to make a preparation to face the possibility of flood. Thus, the risk to face this natural disaster can be reduced. The Raspberry Pi 3 Model B is used as controller where the image processing technique is utilized and control the process for collecting the data from the camera and uploading it to IoT platform. The camera is used in order to get the input of water level. The image recognition used to detect the image of riverbank where the system can differentiate the edge of riverbank and river water level. Base on the observation, this system can be function well in outdoor environment. This observation base on the system performance during the outdoor test, the image processing part to detect the edge and the internet of things (IoT) part in displaying the detail on the with send the notification through the Telegram app.

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