Flood Finder: Mobile-based automated water level estimation and mapping during floods

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Abstract. Every year, Southeast Asia faces numerous flooding disasters, resulting in very high human and economic loss. Responding to a sudden flood is difficult due to the lack of accurate and up-to-date information about the incoming water status. We have developed a mobile application called Flood Finder to solve this problem. Flood Finder allows smartphone users to measure, share and search for water level information at specified locations. The application uses image processing to compute the water level from a photo taken by users. The photo must be of a known reference object with a standard size. These water levels are more reliable and consistent than human estimates since they are derived from an algorithmic measuring function. Flood Finder uploads water level readings to the server, where they can be searched and mapped by other users via the mobile phone app or standard browsers. Given the widespread availability of smartphones in Asia, Flood Finder can provide more accurate and up-to-date information for better preparation for a flood disaster as well as life safety and property protection.

1. Introduction

In 2011, Thailand experienced great flood caused by several tropical storms[1]. This flood is considered to be the world’s fourth deadliest disaster. It inundated 6 millions hectares of land. Almost one hundred thousand houses were damaged, 813 people lost their lives and more than 13 million people were affected by this flood. The World Bank estimated that this flood resulted in damage to Thailand worth 1,440 billion baht which is the highest damage from a flood that has ever happened in Thailand.

Many efforts have been made to develop a system for flood disaster response, such as Thai Flood [2], FLOODAWARE [3] and FLOODsite [4]. Some systems such as the Thai Flood rely on staff to capture the data then send it to a central server, so that the site will be able to provide information to users. This method is costly and time-consuming. Due to the fact that there are insufficient staff, the reliability and accuracy are usually low and it is hardly possible to retrieve data from different locations. Other methods available require a custom made sensing device such as discussed by Sirivitmitrie et al. [5] and Malabanan and Mariano. [6]. These systems require a special instrument to measure water levels which are not feasible to use over wide areas. Thus, it is not possible to get information from many places in the areas of interest.

This paper focuses on our flood monitoring system, Flood Finder, which is based on the idea of distributed information sources. Given the widespread availability of smartphones nowadays, our solution uses a mobile device as a measuring device instead of requiring manual estimates or any special instrument.

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Flood Finder is a mobile application that was developed to provide users the ability to measure and share the water levels at their current location. The system uses image processing along with statistical calculation. Users can measure the water level simply by taking photos of a partially submerged reference object. The resulting water level is reliable since it comes from machine calculation rather than human estimation. This water level will be sent to the central server, which will become a pool of reliable information that comes from many locations. Users can also use Flood Finder to access this server and find out the water level for places in which they are interested.

2. Methodology
2.1 Application Structure
Flood Finder is a mobile application which has an ability to measure, share and search for water level information at any given location. The application doesn't require any internet connection when measuring the water level. However the internet connection is required when sharing and searching.

![Figure 1. Block diagram of Flood Finder.](image-url)
To measure the water level, users will need to take a photo of a known reference object. Users must select a template that matches with the object being captured and align it to the real object on screen. New reference object templates can be added manually by application users.

![Image of a vehicle in flood water](image1.png)

**Figure 2.** Screenshot of the image capture screen.

After finishing measuring the water level, the application will determine the current location of users by using GPS then it will upload data to the central server. Other users will then be able to find and display this information on a map.

![Map showing water level information](image2.png)

**Figure 3.** Screenshot of the map shown the water level information in the application

### 2.2 Methodology for measuring the water level

(i) Flood Finder captures an image from the camera built-in to the mobile device. The application will provide a template to help users to align and shoot the object. The image will then be cropped and rotated based on the template chosen. It is users’ responsibility to ensure that they choose the right template for the object being captured.

![Image after cropping](image3.png)

**Figure 5.** Image after cropping based on the template.

(ii) We then use k-means clustering to cluster the image into areas that have homogenous color and texture. According to the experiments, it could be concluded that the optimal number of clusters($k$) is 8.
(iii) After the image has been segmented into $k$ classes, we use a row differencing method as explained below to find $m$ candidate water level lines. The result of the subtraction will be 0 if the 2 pixels have the same color thus count of 0 valued pixels in a row will be high (~ equal to image width) if we're in a homogeneous area, and low if we are in a row that is a segment boundary.

```c
for currentRow = img.rows -> 1  // skip row 0 (the first row)
    subtract the value of each pixel in currentRow from the pixel above
    count number of pixels in the result that has RGB value (0, 0, 0)
    put into an ascending sorted list  // keep the top 10 lowest count
```

(iv) Our experiments have shown that the candidate lines usually group into some $n$ finite bin such that $n < m$. Thus we use an adaptive grouping method based on $Z$ (the standard normal distribution)

```c
create list of pair of rowId and corresponding z
sorted ascending by z
put rowId of the first pair in the list into the first bin
foreach pair in the list start at the second pair
    if pair.z - previousPair.z > 0.1
        advance to the next bin
    put pair.rowId into the current bin
```

(v) After we get the final candidate line, we do a statistical analysis on the pre-processed image from step (i). Experimentation has shown us that part of the image covered by water normally has a fairly homogeneous color and texture thus will have low variance value (around 10 - 20). So we can examine the variance of the area below each line and find the line where the variance value declines into this region. We consider this to be the line making the top of the water.

| Row |  
|-----|
| 1   | 167  |
| 2   | 166  |
| 3   | 168  |
| 4   | 169  |
| 5   | 182  |
| 6   | 181  |
| 7   | 193  |
| 8   | 183  |
| 9   | 178  |
| 10  | 196  |
vi) After determining the row that is the water level line, we could calculate the real water level based on the recorded reference object aspect ratio and height.

![Figure 9. Image illustrating the scaling process](http://www.toyota.com.au/corolla/specifications/ascent-sedan-manual)

### 3. Result

(a) ![Image](image_url)

(b) ![Image](image_url)

(c) ![Image](image_url)

(d) ![Image](image_url)

(e) ![Image](image_url)

(f) ![Image](image_url)
4. Conclusion

This paper presents an alternative method for monitoring and measuring the water levels during a flood using a mobile device. Given the widespread availability of smartphones nowadays, using a mobile device is an easy and efficient method to gather information from every location. The water level is obtained from a picture of some known reference object taken by a device’s built-in camera by using the image processing methodology discussed in section 3 of this paper. The results suggest that the water level obtained by the proposed algorithm has enough accuracy to allow people to make judgments about safety and appropriate actions during a flood.

Reflection is the main concern for the performance of this algorithm, since parts of the reference object reflected in the water are hard to distinguish from the object itself. Aside from reflection, accuracy also depends on the color and texture of the reference object. The closer the colors of the object and the water are, the more the accuracy of the image processing algorithm will suffer, leading to inaccurate measurement of the water height. Thus, it is important to choose reference objects and scenes that reduce these problems.

References

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