Flood Modelling Using Flooding Patterns and Spatial Autocorrelation

Purpose
In the last 20 years, flooding has been the most common natural disaster, accounting for approximately 50% of all weather-related disasters. The city of Peterborough also experienced its most serious flood on July 15 in 2004. Therefore, the aim of this project is building a flood model to predict the potential flood risk area in Peterborough, Ontario.

Methodology
The project is composed to six steps: data collection, geoprocessing, pattern finding, model building, model evaluation, and calculation of the spatial autocorrelation measure (Figure 1).

Data Collection
The data consists of the Digital Elevation Model (DEM) data at 30 metres, image data of flood damaged-area (2004) in Peterborough, topographic map data of Peterborough, and Dissemination Area data. The DEM data is collected from the Scholars Geoportal and the imaged data of the flood damaged-area (2004) is obtained from the report of Ontario Centre for Climate Impacts and Adaption Resources (OCCAR). The topography map of the study area is provided by
the Land Information Ontario (LIO) and the dissemination area data, which indicates the uniform population size (Guide, 2001), is collected from Statistic Canada to identify severely damaged-areas due to the flood in 2004.

**Geoprocessing**

Geoprocessing is performed on the DEM data and image data of the flood damaged-area. The DEM data is used for creating the stream layer, which shows the water flow on the surface, by using the ArcGIS Hydrology Tool. Figure 2 indicates the stream orders classified by the number of tributaries and all links without any tributaries are assigned as Level. The stream order is increased when streams of the same order intersect.

![Figure 2. Classified six stream levels](image)

In addition, the Georeferencing technique is applied to match image data to the study area and the raster calculation is performed to extract the red parts in the image which represent flood damaged-areas in 2004. Extracted pixels are then converted to points as shown in Figure 3.

![Figure 3. Georeferencing and converting red pixels to points](image)
Pattern Finding

The distance between each of the six stream levels and points is calculated to see how damaged-areas are related to the different stream levels (Figure 4). Based on this measurement, the breaking point at each level is defined by R. The breaking point is defined when the difference of distance rapidly increases. This pattern assumed that the flood damaged-areas occurred within the breaking point range from each stream level. The six breaking points are created by using the damaged-area data which is based on total rainfall accumulation of 9.5 inches (Ward, 2004). Therefore, a division of each breaking point by 9.5 created the breaking points per inch and those are used as multipliers for six different linear equations.

Figure 4. Distance measurement between streams and points

Model Building

Based on the assumption, the concept of the flood model is built as it shown in Figure 5. The input of the model is an accumulated amount of rainfall and this number is multiplied by six variables (breaking points per inch). Next, a buffer layer for each stream level is created and the six buffers are merged into one buffer. The integrated buffer is returned as an output which represents the flood risk area boundary.

Figure 5. The concept of the flood model
In order to make an automatic model, ModelBuilder is used. The blue box in Figure 6 shows the same process as explained by Figure 5. The green box indicates the execution of the flood model, requiring only the amount of rainfall accumulation. When the OK button is clicked, all steps are processed automatically and a flood risk area boundary layer is created as shown in Figure 7.
Model Evaluation

9.5 inches, which was reported as a total rainfall accumulation during floods at Peterborough in 2004, is used as an input value in the flood model to determine how many actual damaged-areas are included in the model’s output. The total damaged-area is 6.47\(km^2\) and the overlapped damaged-area is 5.95\(km^2\). Therefore, the result covers 92.10% of damaged-area, so the flood model is quite reliable.

Spatial Autocorrelation measure

Spatial autocorrelation is then used to investigate the detailed pattern. The flood damaged-area is overlapped with dissemination area, and the damaged rate in each feature of dissemination area is calculated. The created flood damaged-rate map is utilised for measuring spatial autocorrelation. In the case of the spatial autocorrelation, the Local Getis-Ord G-Statistics is used to identify how similar and dissimilar the damaged-rate values are clustered in the dissemination area (Figure 8).

Figure 8. Spatial autocorrelation measure
Results

The predicted flood risk area map is created by the flood model and spatial autocorrelation as shown in Figure 9. The blue boundary represents the prediction of the overall flood risk area based on the input of 9.5 inches. Additionally, the measurement of the spatial autocorrelation shows more details about which specific areas are clustered with high damaged rates. Moreover, high risk areas with 99% confidence have more probability to be damaged by floods than 90% and 95% confidence.

This flood model is powerful for creating the flood risk area map dynamically and simulating various flooding scenarios. Non-professional users can also execute this model without difficulty because the flood model only requires the rainfall accumulation number. In addition, the combination of the model’s output and the result from spatial autocorrelation measure help to focus on high-risk areas. Furthermore, these results give cognition of flood risk area and expected to be used to alert urgent notification in advance to the residents of the vulnerable areas before flooding.
Peterborough Flood Risk Area Map
(Rainfall Accumulation: 9.5 inches)

Legend
- High risk-90% Confidence
- High risk-95% Confidence
- High risk-99% Confidence
- Flood Risk Area Boundary

Figure 9. Final result
References
