Beyond conventional hazard maps: Assessing flood impacts using real-time data from smart devices

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Summary

This paper presents a flood impact assessment following a storm event during early October 2021 in Newcastle upon Tyne, UK. Floods represent one of the most catastrophic natural hazards worldwide. While flood hazard maps help to identify areas at risk and to prepare emergency response plans, they mostly provide static information (e.g. flood extent for a 1 in 30 year flood). This research develops a model that integrates various statistical and spatial data from heterogeneous sources into a hazard map and augments it with dynamic real-time data from internet-enabled devices to improve analysis and decision support for impact assessment.

KEYWORDS: real-time data, hazard maps, flooding, emergency services, geospatial database

1. Introduction

In line with the United Nations' Sustainable Development Goal 11 to make cities inclusive, safe, resilient and sustainable, cities and the environment need to be equipped with the ability to better respond to and be prepared for unforeseen events, including flooding (United Nations, 2015). Hazard maps help to identify vulnerable areas by covering the geographical areas which could be flooded based on probability consideration and flood parameters, such as extent, depth and velocity. However, the currently available hazard maps tend not to provide flood managers with real-time insight, as they represent a static snapshot of an area at a specific point in time.

The aim of this research is to develop a geospatial hazard map using both static and (near) real-time data streams, such as flood warnings, river and sea level measurements from the Environment Agency (2021), rainfall data from the Urban Observatory (2021), and traffic data from the Tyne and Wear Urban Traffic Management and Control (UTMC, 2021). The underlying hypothesis is that an integrated spatial data approach can improve the significance of hazard assessment and provide decision makers with quantitative measures about the extent of future risks in different locations (Li et al., 2020).

2. Background

In England, every year 2.4 million buildings are at risk of flooding from rivers or the sea and another 2.8 million from flooding by surface water (Environment Agency, 2009). To be able to assess possible damage and mitigate further risks, data on population, buildings, roads, land use, and crops is required (Defra, 2012). In recent years, these static datasets have been augmented by increasingly available real-

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time data due to the growing number of internet-enabled devices (Transforma Insights, 2020). Near real-time traffic and environmental data collected from sensors can be used to inform on the current status of traffic incidents and changes in the environment. As the data required for real-time hazard assessment may be heterogeneous and reside on various distributed platforms, Cloud Computing and Big Data technologies can help to connect to different sources, enable information sharing and transform data for stakeholders in a timely manner (Xiao et al., 2017).

3. Methods

The core of the dynamic hazard map is a geospatial database, integrating heterogeneous and distributed data sources, such as: buildings (OS, 2019), traffic volume (Urban Observatory, 2021), information on current traffic incidents, accidents, events and rainfall (UTMC, 2021), flood extent and river levels (Environment Agency, 2021).

The geospatial database is modelled using ESRI ArcGIS Pro 2.5 software with the Spatial Analyst and 3D Analyst as main extensions. Data is loaded into the database either directly, through a standardised REpresentational State Transfer Application Programming Interface (REST API) service or the data interoperability tool FME. All data extraction, transformation and analysis steps are performed in the integrated Jupyter Notebook environment of ArcPro 2.5 using core Python libraries, ArcPy and ArcGIS API, for spatial queries. This research develops a scenario in which the Environment Agency's RoFSW (Risk of Flooding from Surface Water) dataset is used to assess critical infrastructure that could be flooded in a 1 in 30 year flood event and is augmented with real-time traffic data to identify areas that pose further risks, such as lane closures due to flooding or road incidents. The final output is a dynamic hazard map in the form of a dashboard.

4. Results and methods

This section demonstrates how stakeholders involved in flood management can use the developed hazard map to assess the impact of flooding on critical infrastructure, such as buildings and roads and enhance their analysis through real-time weather and traffic updates. The following event serves as an example:

From late Monday 4 October to Wednesday 6 October 2021, Newcastle was hit by a heavy storm. This hazard event brought damaging winds, sustained periods of rain and widespread flooding in large parts of North England. During such a hazard event, different stakeholders are involved in the management and response: those providing flood-related data, those responsible for the operational response in the different phases of the flood, and those dealing with the different impacts of the flood. Spatial queries can be performed using the underlying geodatabase model to support stakeholders in the following scenarios:

- **Scenario 1:** Assessing storm impacts on critical infrastructure in flood-prone areas;
- **Scenario 2:** Assessing real-time traffic volume and pedestrian footfall (indicator of the number of people potentially at risk); and
- **Scenario 3:** Assessing the impacts of concurrent real-time incidents on the wider transport network.

Both the statistical results and the geographical outputs for each scenario (1-3) can be combined and integrated into a dashboard application that can be accessed by different user groups for hazard impact assessment. For illustration purposes, **Figure 1** shows the integrated analysis for scenario 3, where real-time flood events were logged and other impacts, such as blocked roads and closed lanes, were reported:

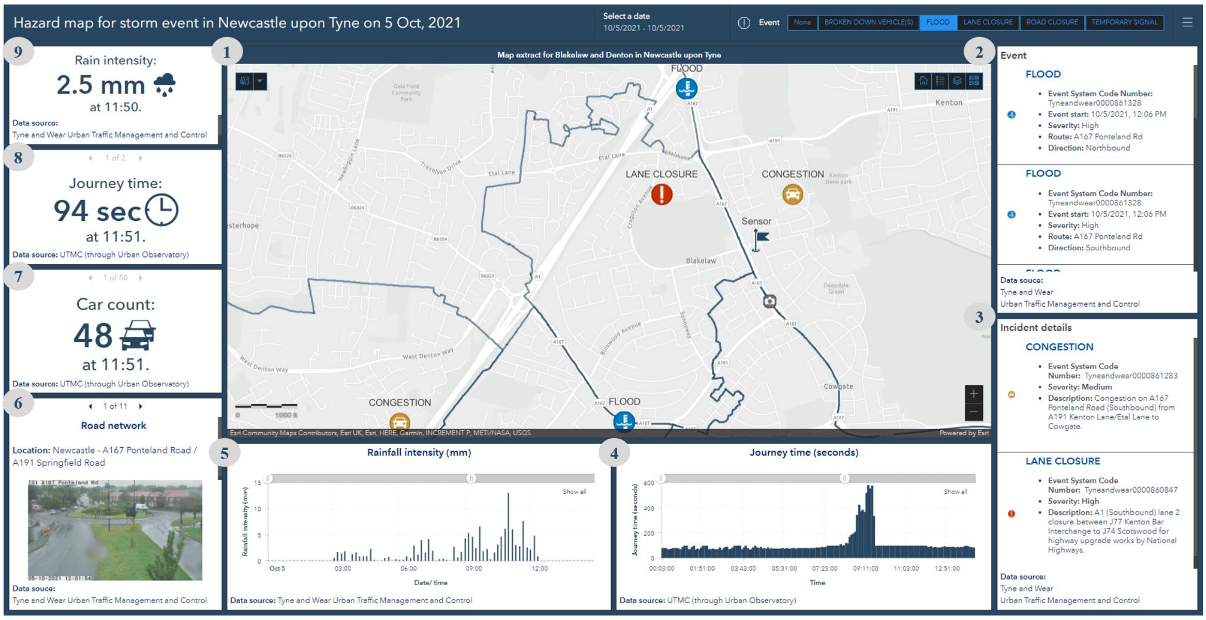

Figure 1 Assessing flood impacts using a dynamic hazard map for the storm event in Newcastle upon Tyne on 5 October 2021 (own figure, developed using ArcGIS Operations Dashboard).

The individual components of the integrated assessment include the following:

1. **Map:** Map extract for Blakelaw and Denton in Newcastle where different incidents were captured between 11am and 1pm on 5 October 2021.
2. **Events:** List of recorded events and their impact on the transport network in different directions.
3. **Incidents:** List of recorded incidents within the map extent.
4. **Journey time:** Graph visualising the average journey time (seconds) over a set link distance using Automatic Number Plate Recognition cameras for the previous four minutes. The value for a specific point in time is represented in the key performance indicator (KPI) in **(8)**.
5. **Rainfall intensity:** Graph visualising the rainfall intensity (mm) measured in Newcastle over time. The value for a specific point in time is represented in the KPI in **(9)**.
6. **Road network:** CCTV systems provide images from different cameras on the road network.
7. **Car count:** KPI showing the number of cars driving into the city.

This integrated dynamic hazard assessment provides stakeholders with a real-time overview of incidents and traffic events in addition to existing flood hazard maps. In a next step, this dynamic hazard map application can be further enhanced by sending an automatic flood alert when a certain threshold is reached at a specific location or by notifying traffic managers when an accident site has been cleared and traffic can resume.

5. Summary

This research integrates heterogeneous data from different sources in a common geospatial hazard map, designs a flood geodatabase and offers analytical capabilities. The integration of real-time data from sensors on rainfall, river and sea levels, and traffic can help to assess the changes in the environment during hazardous flood events. This research can be reproduced and transferred to other cities that have similar data collected from internet-enabled sensors. The current flood depth dataset can be replaced by customised flood output models, e.g. CityCat (Glenis et al., 2013). Using spatial relationships, further data can be integrated into the database and enriched with further contextual data about the study area and assets impacted. The analytical queries can be performed at different scales (e.g. ONS Census reporting units). By merging knowledge from different domains and enhancing conventional hazard maps through dynamic (real-time) data, stakeholders involved in flood management can gain a holistic overview and make better decisions for emergency planning and response.

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Biographies

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