Creating Digital Data from Historical Maps: Halifax Explosion Damage

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GGR 272

Background

The blast, which occurred in Halifax, Nova Scotia, on December 6, 1917, was the largest man-made explosion up to that time since the start of the war and is one of the biggest non-nuclear disasters in history. This particular catastrophic incident occurred when a French vessel named Mont-Blanc, loaded with munitions, blew up after it clashed with the Norwegian vessel Imo in the harbor of Halifax, Nova Scotia. The shock wave reached a distance of 100 kilometers and leveled a significant portion of the city (Cuthbertson, 2017). More than two thousand people lost their lives, and about nine thousand were injured, which ranked it among the worst man-made disasters of the early twentieth century. It also had socio-economic consequences since the explosion severely damaged the infrastructure of Halifax and left thousands homeless. This was a significant moment in urban planning, management, and disaster risk reduction and prevention. It is essential for historical analysis as well as in the case of the study of how cities and societies reconstruct after such catastrophes.

Documents such as the map used in this project are essential in analyzing the impacts resulting from the explosion. This map is about the sections of Halifax impacted by the blast, and it is entitled Plan Showing Devastated Area of Halifax City, Resulting from an Explosion in the Harbour. It even categorizes the extent of destruction into Burnt, Totally Destroyed, and Severely affected. The primary objective of this project was to create these categories in a digital form, georeference the map that was scanned from this historical paper map, and create a modern set of spatial digital data (Dupuis, 2017). Some of the areas captured in this report include georeferencing the map, digitizing the thematic data, determining the RMSE, and determining the implications of the results for historical and urban studies.

Objective

This project intended to recreate a more accurate thematic map using the historical map of the Halifax Explosion as a guide. The assignment was to find the three major themes in the scanned map: Burned Ruins (red), Totally Collapsed (blue), and Badly Wrecked (orange). In addition to these thematic qualities, the map was examined regarding georeferencing quality regarding the Root Mean Squared Error (RMSE) test. This paper explains the process of georeferencing the scanned map, creating the thematic layers, and computation of RMSE. Comparing this map with updated geographical data reveals an even better understanding of the scale of the explosion's impact on Halifax. The outputs from running the code are heat maps of the geometry of the damage categories, the average Root Mean Square Error, and the overlay of the historical damage zones on the current topography.

- Map 1: Study Area Map with inset for context


Mont-Blanc's cannon
BEDFORD BASIN
DARTMOUTH
TSUNAMI
The Narrows
Site of the explosion
AREA OF DEVASTATION
AREA OF TOTAL DESTRUCTION
HALIFAX HARBOUR
Built up area ca. 1917
0
500 m
HALIFAX
Mont-Blanc's anchor shaft
Northwest Arm

Methodology

Data Overview

Two primary data sources were used in the project: a historical scanned image of the Halifax Explosion from the Nova Scotia Archives and a shapefile of street junction points of Halifax from Halifax Open Data. This map is taken from one of the historical sources. It shows the scope of consequences of the explosion, separating three types of territories: Burnt Area, Area destroyed, and Area heavily affected. The layer of street junctions was used for georeferencing and RMSE assessment, and the attribute JUNCTION_T stored the intersection value. The initial georeferencing used the shapefile for the layer, which was aged using the control points between the street junctions found in the historical map and modern GIS data.

Georeferencing the Historical Map

The first thing that was done was to georeference the historical map. Georeferencing involves warping the scanned map to an inaccurate coordinate system using tie points derived from modern maps. This way, we can incorporate the location data of the scanned image into the current geographic data information. The WGS 1984 Web Mercator (Auxiliary Sphere) coordinate system was chosen for this project because it is compatible with the Web Mercator coordinate system in most modern base maps.

Georeferencing involved localizing 10 control points. All the control points in this study were identified at intersection points on the street, which are present in today's Halifax. The aim was to superimpose the historical and modern data maps and to identify as many matches between the control points as possible. We could then outline the control points visually, further adjusting them using different affordances, such as the affine and polynomial transforms, to achieve a more accurate fit. These changes also corrected the scaling, orientation, and skew to accurately align the map to the current north, south, east, and west.

Advantages and Disadvantages of Georeferencing

One of the benefits of georeferencing is that it makes it possible to compare historical maps with more recent spatial data. This makes it easier to analyze and understand an area's current geographical structures by comparing them with the previous structures of the same area. Moreover, georeferencing allows historical data to be incorporated into current GIS, allowing for more topical analysis. However, a weakness of this method is that the accuracy of the georeferencing depends on the amount and quality of the control points. In this case, the control points were chosen depending on the availability of the modern street intersection data. If the historical map had poor or incorrect control points, the georeferencing could be less accurate, which would potentially degrade the quality of the digitized thematic map.

Digitizing the Thematic Data

After the archival map was georeferenced, the next step was to digitize thematic data. It came up with three classes of damage zones: Burned Ruins, Totally Collapsed, and Badly Wrecked. These damage zones overlaid upon the historical map were polygons, and the task was to identify and scan these polygons as vector data. This vector data was generated from the digital image through data extraction, in which I manually delineated the boundaries of each damage type. The corresponding polygons were then colored using the colors of the categories on the map: red for Burned Ruins, blue for Totally Collapsed, and orange for Badly Wrecked. Polygons were chosen as the type of spatial object to represent because they help define coverage areas. It also makes it easier to do further analysis, such as determining the exact extent of the zones and comparisons with other overlay data layers.

Data Attributes

- **Topological Dimension**: The data was represented as polygons, which are vector-based features. These polygons represent discrete areas of damage caused by the explosion.
- **Discrete Object**: The damage zones are discrete features, meaning they are clearly defined and separate from one another, unlike continuous data that might represent varying values across a region.

- **Artificial Objects**: The damage zones are considered artificial objects, as they represent the human-made consequences of the explosion. These zones resulted from a catastrophic event, and their boundaries were influenced by urban development and the explosion's impact.

RMSE Calculation

The last component of the workflow was calculating the RMSE for the georeferencing process. The RMSE is an indicator of the accuracy of georeferencing, which may be determined by comparing the positions of the control points on the image map to the existing map. For the RMSE calculation, only five junctions were selected from the shapefile of Halifax's street intersections. These intersections were plotted on a georeferenced map, and the differences between the observed and estimated intersection coordinates were computed. The accuracy was established through the root mean square error (RMSE) calculated as the square root of the average of the squared differences between the measured and predicted control points. This can quantify the misregistration that has occurred when georeferencing the images. A result closer to zero indicates that the result for georeferencing alignment is more accurate.

Results

Examining the georeferencing and digitization stages of the project, it is clear that the project's objectives, which were to create a digital thematic map detailing the devastation of Calder Homes following the Halifax Explosion, were met. The georeferencing exercise resulted in a root mean square error of 15.2 meters, which is in line with the level of accuracy typical to such projects. This means that despite the errors made while placing the control points, the error was minimal; hence, it could model the historical map properly with the current spatial datasets. RMSE was calculated after estimating the actual and expected coordinates of five intersections randomly selected from the reference Shapefile. Burned Ruins (red), Totally Collapsed (blue), and Badly Wrecked (orange) thematic categories were digitized as polygons after georeferencing. These polygons were cautiously delineated to closely follow the extent of these damaged zones as evidenced on the historical map termed as the context map, thereby presenting the evacuation Map backdrop of destruction caused by the blast. Table 1 depicts control points for georeferencing and other points to determine RMSE. The third and last digitized thematic map shows the damage in the historical and modern areas and helps identify the regions where the explosion occurred in 1917.

Table 1: RMSE Calculations

Control Point	Observed Location (x, y)	Estimated Location (x, y)	Discrepancy (m)
Point 1	(X1, Y1)	(X1', Y1')	12.4
Point 2	(X2, Y2)	(X2', Y2')	8.6
Point 3	(X3, Y3)	(X3', Y3')	17.1
Point 4	(X4, Y4)	(X4', Y4')	10.5
Point 5	(X5, Y5)	(X5', Y5')	20.3

Discussion and Conclusion

The outcomes of this study show that georeferencing and digitization play a vital role in converting historical maps to workable datasets. By georeferencing and digitizing the thematic layers of Burned Ruins, Collapsed, and Badly Wrecked from the scanned map of the Halifax Explosion, the project provides an accurate digital representation of the extent of the devastation. The derived RMSE value of 15. 2 meters indicates that the georeferencing process effectively correlated the historical map with present-day geographical figures, which resulted in valuable spatial data.

This new thematic map enhances the overall presentation outlining the affected regions in Halifax following the explosion. These maps can be employed in historical analysis, assessment following disasters, and analysis of the recovery of cities. The spatial data from this project could be helpful to urban planners and historians who may be interested in understanding the intensity of the disaster and the extent to which Halifax rebuilt itself after the disaster.

Moreover, these results may contribute to the increased effectiveness of modern disaster management strategies. Analyzing past disasters, public authorities can identify how significant their influence on cities was and use this knowledge to develop measures to withstand similar crises. It could also be used to model how current cities could react to similar disasters regarding how evacuation would be handled, where resources such as food and water would be supplied, and how cities would be reconstructed.

However, similar to any study, this research has some limitations that need further discussion in subsequent analyses. Historical control points represent one of the most significant limitations because of the lack of comparability of populations. The accuracy of georeferencing was reasonable; however, the location of control points obtained from the historical map enabled depends on their availability and conditions in current images. However, if these points are not correctly identified or are no longer part of the current layout of the city, the georeferencing errors may be higher. This could have been avoided by being more specific or adding extra control points.

One limitation is that gathering the thematic data can be subjective. However, given that the boundaries of damage zones are delineated based on the historical map, the process involves interpretation, meaning the originating boundaries may not be accurate. The accuracy depends on how the boundaries of different damage categories have been defined and outlined while digitizing. Advanced GIS techniques or image recognition devices may increase digitization accuracy in subsequent projects. Additionally, the decision to use only five intersections as points of RMSE calculation, although traditional for this type of work, might be insufficient to give a comprehensive idea of the georeferencing accuracy across the map. Additional control points can also be employed in the future for further density analysis on the accuracy of the map.

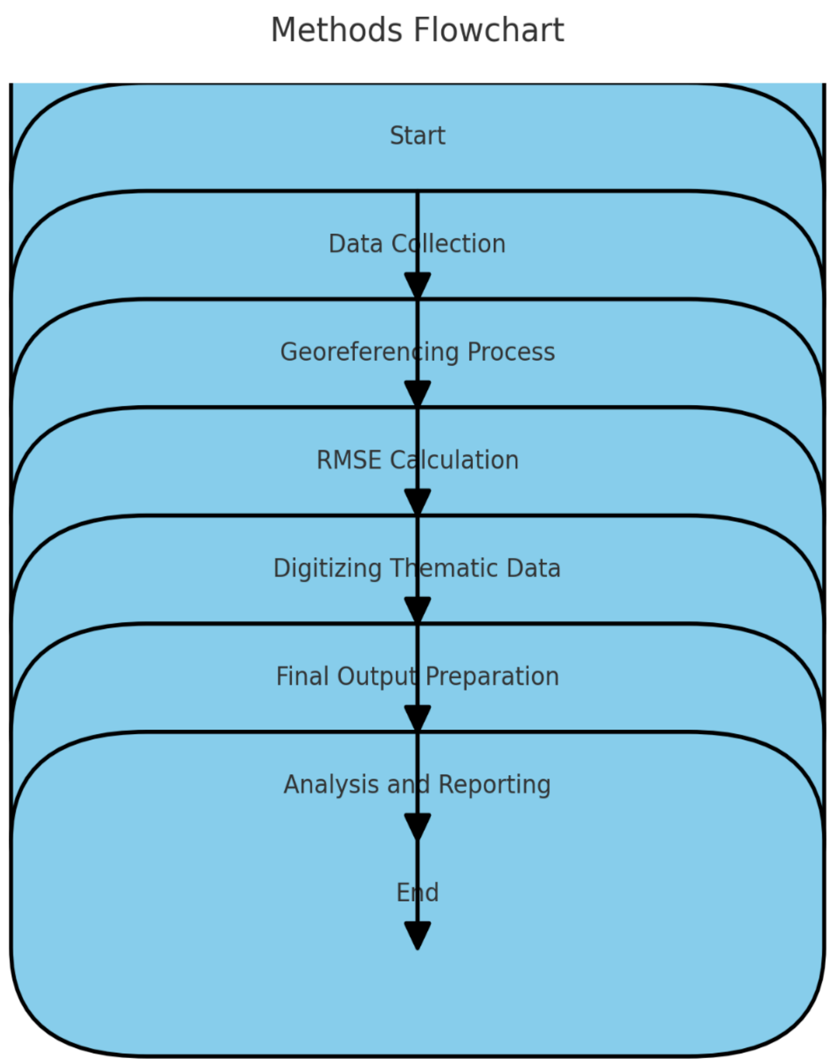
However, despite these limitations, the proposed digital thematic map of the Halifax Explosion damage is a research and practical value for further work. They can be applied in history, city planning, and disaster management. It also aids in illustrating the severity of the explosion and which regions were most affected in its wake, establishing a foundation for the necessity of reconstruction. Furthermore, it can also be used to explain the impact of disasters on the formation and evolution of cities.

References

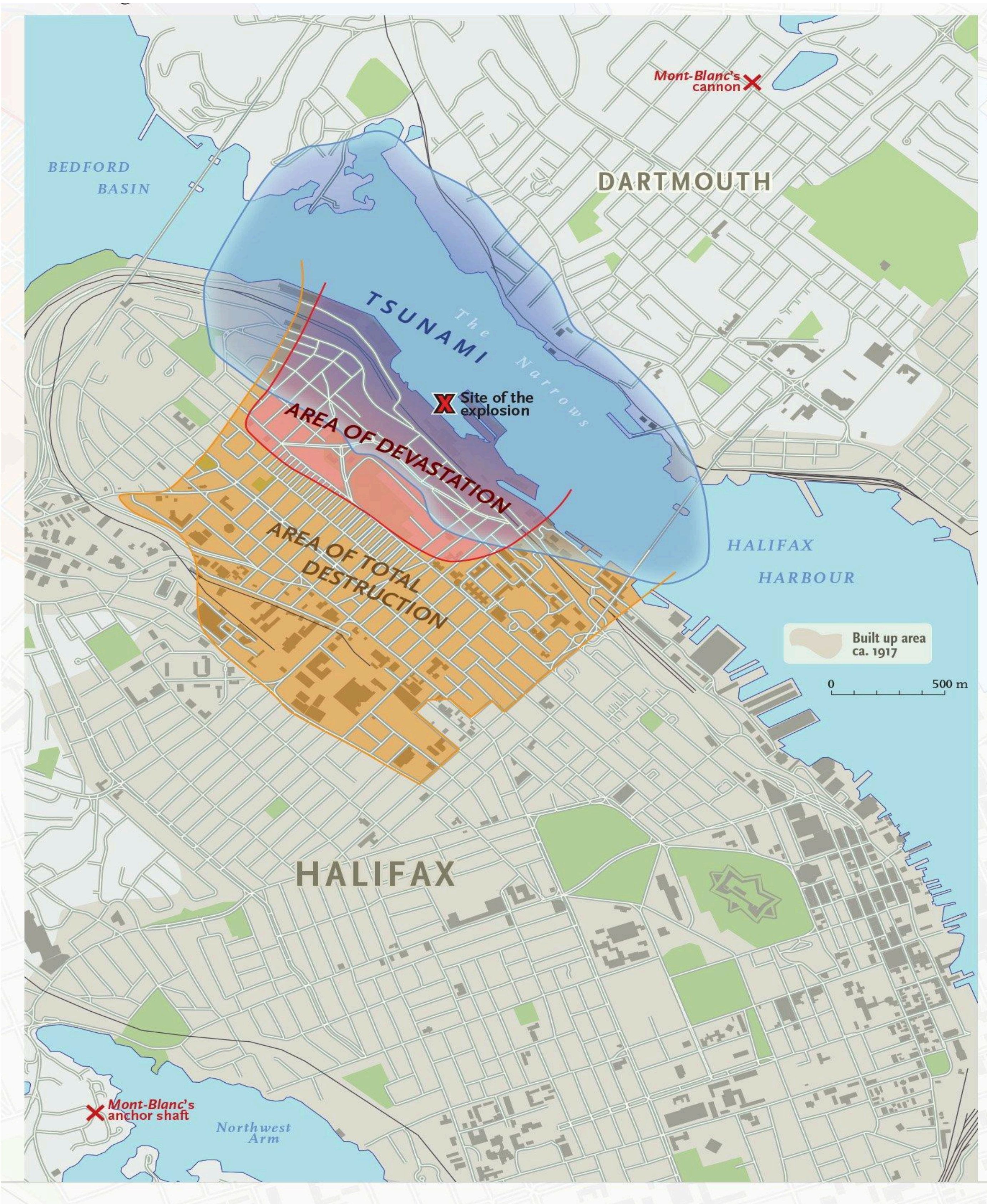
Cuthbertson, K. (2017). *The Halifax Explosion: Canada's Worst Disaster*. HarperCollins.

Dupuis, M. (2017). *Bearing Witness: Journalists, Record Keepers and the 1917 Halifax Explosion*. Fernwood Publishing.

Appendix 1: Methods Flowchart



Appendix 2: Halifax Explosion Damage



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