RESEARCH ARTICLE

Development of an Outline Detection Tool (ODT) in QGIS environment for risk mitigation applications

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Abstract: Vision techniques are presently developed, within a GIS environment, to detect any type of structural and infrastructure damage caused by natural catastrophic events. The aim of this paper is to report on the implementation of a software tool which is able to identify the border of any system that could be damaged by a negative event. The potential of an open source tool named "Magic Wand" is investigated in order to create an innovative procedure which allows to quickly select buildings and artefacts in disaster areas. The pixels of satellite images are the input that the tool requires. Some examples are presented in order to provide the main features of the proposed function.

Keywords: catastrophic events, QGIS, satellite images, development, vision technique

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1. Introduction

The enhancement for quality and performance of urban service is pursued by a smart city by introducing digital technologies or information and communication technologies (ICT). Sectors that have been developing smart city technology include transport and traffic management, energy, water and waste. This requires the availability of a tool for effective learning processes regarding urban innovations in such specific fields of urban development. The specific character of this tool is that the input must cover not only single snapshots but a wide area, covering the urban area of interest.

A comparison of pre- and post-event satellite images allows a large-scale knowledge acquisition and can be achieved by integrating GIS technology and image processing techniques[1–3], within a single user interface environment. The software environment recently used in the literature for this purpose is Quantum GIS (QGIS)[4,5], an open source Geographic Information System that adopts the Qt toolkit and C language, with an easy-to-use graphical user's interface (GUI). QGIS[6] is also released under the GNU General Public License and so the user can inspect and modify the source code. Thus, one has access to a GIS program that is free of cost and can be freely modified.

This paper outlines the main additions to this existing software environment towards the realization on the target applications: to quickly and easily locate all the systems that could have been modified. This is especially of interest for collecting information on the damages suffered as a consequence of any natural disaster.

Currently, the procedure of system location may only be achieved manually through the creation of a layer reproducing the geometry of the structures affected by the catastrophic event under investigation. The task can be time-consuming in case of wide areas, with the further drawback of being unable to detect accurately those damages that occur across neighbouring systems.

The additions are not designed and implemented by scratch, but the ideas already implemented in different image management software are imported and modified in the particular QGIS environment. This is followed by a detailed documentation of the outline detection tool potential follows with focus on how to handle the available options. Results for a case study are finally presented.

2. State of the Art

Remote sensing is founded on the collection of data with those devices, which are not in direct contact with the object of the study. Satellites are the main platforms utilized in remote sensing and mount several devices able to acquire images. The satellite pictures are digital images composed by pixels and, when a picture is analyzed, each pixel is associated with a value corresponding to the intensity of radiation reflected from the observed object. After that, in order to analyze the collected information, geographic information systems (GIS) are used. They integrate hardware, software and data in order to capture, manage and analyze all geographically referenced information. A system like this one stores geographic information as a collection of layers that can be related each to the other through connection and geographical overlap[7].

The current procedure allows loading pre-event and post-event satellite images with a plugin, based on Google Maps, that automatically georeferences the satellite image. After loading the addresses, the creation of layers over the two pictures follows. These layers are made by general geometric entities as points, lines and polygons that are gathered as shape file. Operations of this kind are very difficult because the building of the layers has to be carried out manually, is time consuming and requires high accuracy. For this reason, it is necessary to simplify the way through a new tool designed to select areas of the image based on colour similarity. The main goal of this paper is to develop an automatic selection method, which is based on ideas already implemented in different image management software and applications, but imported and modified for the QGIS environment. The final step consists of comparing the layers of the two satellite images. Several authors and software houses are working in order to develop a tool to compare images for specific application fields, but almost all of them are under copyright and do not offer user-friendly facilities. Therefore, a geoprocessing tool, as described in Section Four, is desirable since it belongs to the class of open source software and is already included inside the QGIS environment.

3. Available Techniques and Tool Elements

The following elements will be used in building the target software tool:

(i) An algorithm able to identify the cluster of pixels, which belong to a given object. Provided the object is defined by its border, the algorithm is referred to as “region-filling algorithm”,

(ii) An editor able to manage pixels by operations as replacement, sum, subtraction and intersection. （Outside the QGIS environment, the existing tool is called “Magic Wand”）,

(iii) A geoprocessing tool by which comparison of images are carried out, and

(iv) The ability to conduct further handling of the pixel systems, by which the image is linked to a database. This is usually achieved by using hierarchical layers.

In the remaining of this section, after a short overview of the QGIS features, item (i) is detailed, while the other items are analysed in Section Four.

3.1 QGIS Summary

Within the GIS environment, several tools are made available to the user. The macros that the user builds are here referred to as “plugins” and “Plugin Builder” represents the tool to build them. Indeed, the basic configuration information used by the tool to create the template files can be specified within the main dialog. After that, it is necessary to work within the tool folder inside of the plugin directory. The directory structure of the new tool presents many files, and in particular, a “.ui” file and a “.qrc” file that have not yet been compiled into Python modules. Therefore, through the “make” command, two statements are printed which are the required commands to compile the appropriate resources and GUI files. Going back in QGIS and loading the Outline Detection Tool (ODT) introduced in Section Four, an empty dialog appears. The ODT comes with an options dialog where some important functions are located, thus one edits the “.ui” file associated with the project by “Qt Designer”, which allows the user to select the available steps in a menu. Once the tool dialog is configured, the source code has to be written in the C++ language and placed in the same workspace folder. To manage pixels, several operations are available to estimate the distance between two pixels or to introduce a scalar measure of any of them. The software environment is summarized in Figure 1.

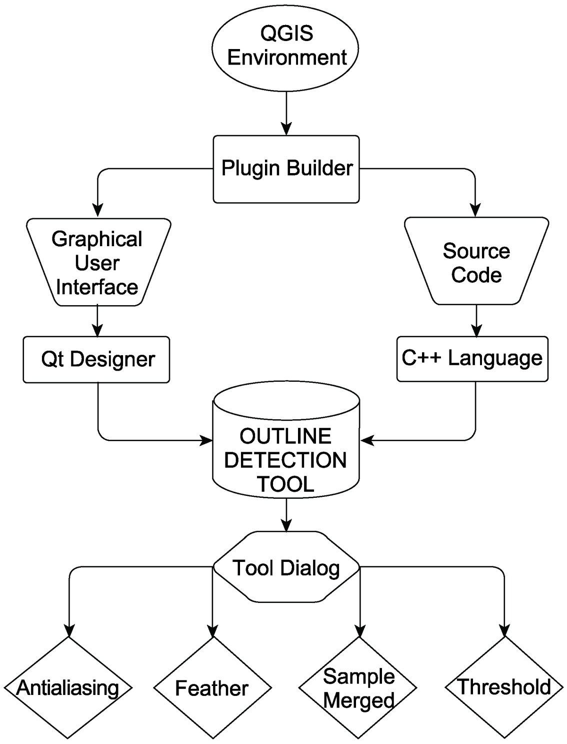

Figure 1. QGIS and its libraries for the tool implementation.

3.2 Region-filling Algorithms

In this subsection, attention is focused on region- filling algorithms in order to understand the main problems to be solved and the originality of this paper.

3.2.1 A Short Overview

There are many algorithms available in the general software libraries and one of them is the linear-time algorithm[8]. Linear time algorithm relies on contour labelling and filling. For contour tracing two techniques could be used: either the edge following or the border following. Unfortunately, the linear-time algorithm has low computation cost and its correctness has still to be proven[9]. There are also other region-filling algorithms such as those on raster graphics, on binary raster images and algorithms for filling the region represented by a quad tree. However, these region-filling algorithms are only used for filling simple regions and do not include the ability to detect holes during the filling process. An efficient algorithm for region-filling on the bin codes is presented[10], and for region count, another algorithm is presented[11]. This algorithm improves the deficiencies of seed fill algorithm, such as column method and recursive method, but its drawback is that the processing time depends on the size and geometry of the input image. Therefore, after a detailed analysis of existing algorithm in literature, the algorithm called "flood fill" is chosen as the most effective method to apply in the present framework.

3.2.2 "Flood Fill" Algorithm

The algorithm used in this paper to determine the selected pixels is a "flood fill" algorithm that employs a loop and a stack of line segments to keep track of the pixels that need to be examined. In this algorithm, the selection is achieved by a horizontal line segment at a time, as illustrated in Figure 2. The algorithm starts out searching to the left and right of a specified point, looking for adjacent pixels with the same colour that one wants to select, and the search stops when one meets a pixel that does not match the specified colour (Figure 2(A)). A line segment is created and this line of pixels is pushed into the stack for later processing (Figure 2(B)). Then the algorithm loops until the stack is empty, processing each line segment on the stack one at a time. For each line segment encountered, it walks the points directly above (Figure 2(C)) and below it (Figure 2(D)), repeating the line search as at the beginning of the algorithm. Any line segments found in this search is added to the stack until this one is depleted and, at last, in order to ensure the algorithm does not loop back on itself, a map is used to mark which pixels have already been examined[12].

1	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0
0	0	0	1	0	0	0	0
1	1	1	0	0	0	0	0

(A)

0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(B)

1	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

(C)

1	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0
0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0

(D)

Figure 2. "Flood fill" process.

4. Tool Capabilities

In a large number of applications, the selection tool, called “Magic Wand”, is designed to select areas of the current image based on colour similarity. When using it, it is very important to pick the right starting point in order to obtain the best result. The “Magic Wand” is a good tool for selecting every object with sharp edges but it is also useful for selecting an area within a contour. It works very well for selecting an area with a solid colour, which could be buildings or roads, because it makes selections based on specifying a seed pixel in the image. The seed is the first selected pixel, and the pixels directly adjoining the seed are included in the selection, if their colours are sufficiently close to the colour of the seed. This creates a second set of selected pixels and the process is repeated with the neighbouring pixels of the second selected set, and so on, until no more pixels can be added[13]. Figure 3 shows an example in which, by clicking in a spot of the buildings, the tool selects all contiguous pixels whose colours are similar to the starting point.

Figure 3. Example of use of “Magic Wand”.

The “Magic Wand” is a conceptually attractive tool because it automatically makes the selection by grouping pixels that are similar in colour and that are spatially connected, being grown from a seed pixel. This feature allows the developing of the innovative Outline Detection Tool (ODT), within the QGIS software, to identify every structure that is located in the area affected by a catastrophic event by creating a specific layer that will be used in a geoprocessing tool called “Intersect” in order to compare the satellite pre- and post-event images.

4.1 Editing Utilities

In order to manage the ODT, depending on the quality of satellite images, an options dialog is created with “Qt Designer”, as described in Section Three, where some important functions such as Antialiasing, Feathering, Sample Merged and Threshold are located and can be used inside the QGIS environment. These options are displayed in a new window as soon as one activates the tool and on the top of dialog, there is the possibility to replace, add, subtract and intersect the current selection. This procedure is very useful in those cases where the area to be analysed has a high crowding of structures and you need to make many operations to select the buildings affected by a disaster.

4.1.1 Antialiasing

The “Antialiasing” is a technique used to improve the digital image relating to the area of interest by smoothing jagged edges on curved lines and diagonals. It has a basic role in carrying out selections and this one is another feature imported by the “Magic Wand” tool. In Figure 4, this concept is shown through an array of pixels that has been partitioned into two regions by a selection edge marked with a dashed line. However, due to the slope of the selection and the finite area of the pixels, some of them that are on both sides of the selection edge are only partially selected (Figure 4(A)), and what happens to this set of pixels is important for the aesthetic presentation of the selection’s edge.

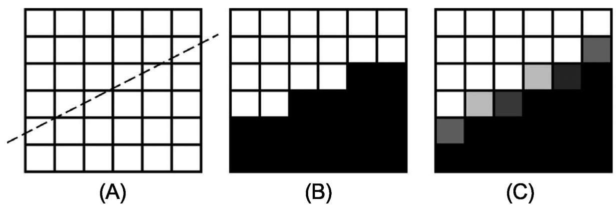

Figure 4. How “antialiasing” works.

Assuming that white represents the selected pixels and black the unselected ones, Figure 4(B) shows what happens if pixels are included in the selection when more than 50% of the pixel is above the selection edge and unselected otherwise. It is worth noticing that the selection edge obtained by applying this rule produces a staircase effect on the edge. This staircase effect, known as “aliasing”, makes the edge look harsh. Figure 4(C) shows the concept of “Antialiasing”. Here white represents a pixel, which is fully selected, black represents a pixel that is fully unselected, and grey represents partially selected pixels, where the level of grey indicates the percentage of the pixel that falls inside the selection. Thus, a lighter value of grey indicates a more fully selected pixel and a darker value a less selected one that has the effect of visually smoothing the staircase effect illustrated previously.

4.1.2 Other Specifications

As mentioned at the beginning of the section, in the options dialog, other editing utilities are placed in order to easily set up all the features that the tool has to consider searching the "seed" pixels. In particular, a selection edge treatment like that described above is also added. It is called "Feathering" and works by changing the value of pixels as a function of their radial distance from the selection edge. The transparency of a subject increases moving outward from the edge and decreases moving inward to it, while the rate at which the transparency changes is determined by the feather radius. For instance, if the value is fifty, one means that there is a feathering effect up to fifty pixels away in both directions from the selection edge. "Select Transparent Areas" is an option that gives the ability to select areas that are completely transparent and that otherwise would never be included in the selection. Alternatively, "Sample Merged" can be used when one has several layers in a raster, and the active layer is either semi-transparent or is set to another layer mode than normal. In the last case, the colours present in the layer will be different from the colours in the composite image. If the "Sample Merged" option is unchecked, the tool will only react to the colour in the active layer, while if it is checked it will react to the composite colour of all visible layers. As already described, the "Magic Wand" uses a search algorithm based on the colour of a seed pixel and a specified threshold value. Moreover, all contiguous pixels that have colour values that are less than the threshold from the seed are included in the selection and the "Threshold" can be specified in the options dialog. Finally, with "Selection by", it is possible to choose which component of the raster that has to be used by the tool to calculate the similarity. The components one can choose are red, green, blue, hue, saturation and value.

4.2 Geoprocessing Tool

A further required tool has to cover the image georeferencing. The QGIS software offers a geoprocessing environment that can be used to call native and third-party algorithms from QGIS, making the spatial analysis tasks more productive and easy to accomplish. It is possible to perform spatial data analysis on spatial databases and other OGR supported formats. Within QGIS environment are currently offered many functions such as vector analysis, sampling and geometry, but, in order to introduce the case study, the tool named Geoprocessing requires a brief illustration. The operation that is employed for the case study and presented in this paper is called "Intersect" because it overlays layers such that output contains areas where both layers intersect.

5. System Architecture

The implemented ODT exploits the features shown in the previous sections to speed up the identification process of all structures in the area affected by a natural disaster. The name of the tool describes its function that is to link the automatic selection of every shape found in a satellite image (i.e., buildings, hospitals, schools, roads, etc.) before and after a catastrophic event in order to detect the geometrical differences of the layers and, therefore, the damage occurred. Indeed, the ODT requires at least two images as input and produces several items as output in the form of layers, whose specifications are given in the input or can be included later, as shown in Figure 5. The satellite image

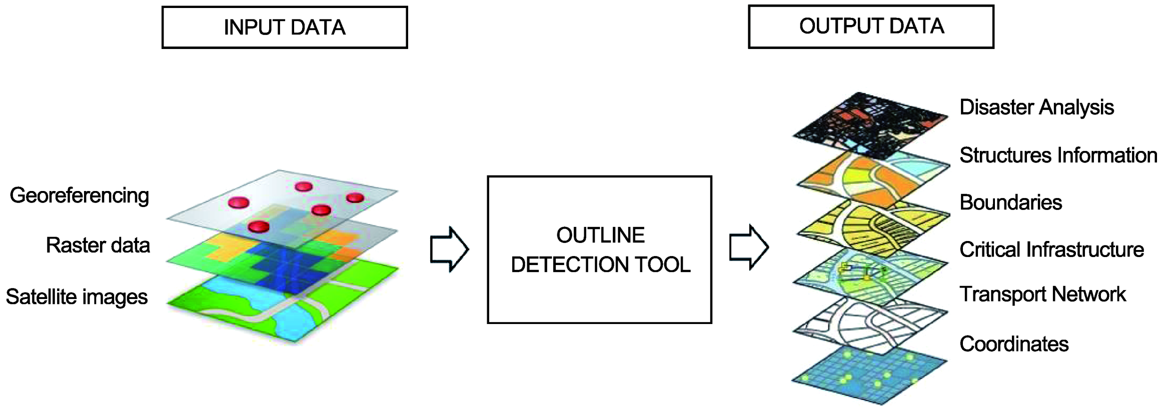

Figure 5. Input and output layers.

is loaded in the software QGIS by its raster model. This is a grid of pixels characterized by its coordinates in the grid and a scalar. Next step is the georeferencing by adding cartographic information and any coordinate system. In the georeferencing, a minimum of four reference points is required.

After that, the user activates the ODT and collects a set of similar items whose set is put in a layer. One can distinguish line links as those, which characterize the transportation infrastructure layers from the isolated bodies, which can represent residential buildings, industrial buildings or simply urban squares. This makes clear that the ODT must be associated with a database where the suitable information is stored. In this way, each layer comes with all the bodies identified. A comparison of layers of the same nature resulting from two successive images allows one to achieve a dynamic knowledge registering modifications and updates.

6. An Illustrative Example

Figure 6(A) and Figure 6(B), taken over the Philippines, show the scale of devastation Typhoon Haiyan caused in the city of Tacloban during November 2013. For the area under investigation, a layer of the structures to be analysed is created. Once the Outline Detection Tool (ODT) is available, the user clicks on a point in the image. The tool finds all the pixels around that point that are similar in colour, given a tolerance level, and selects them. Clicking in the middle of the buildings, the developed tool selects all pixels connected to it and draws marks around it. From here, the user can produce a copy of the selected pixels into the suitable layer using the command "Add Feature" in the menu.

Pre-event and Post-event Layers Comparison

This operation is performed by the geoprocessing tool called "Intersect" within the QGIS environment and it is also important to clarify that the higher the image, the better its resolution, and thus a higher accuracy of the estimation will be. In addition, Figure 7(A) and Figure 7(B) show the layer of interested buildings for the pre-event (green) and post-event (yellow) satellite images respectively.

After the comparison between the pre-event and post-event images, various scenarios are defined and it is possible to manage rescue teams in order to reach, in the quickest way, the damaged buildings (e.g., private

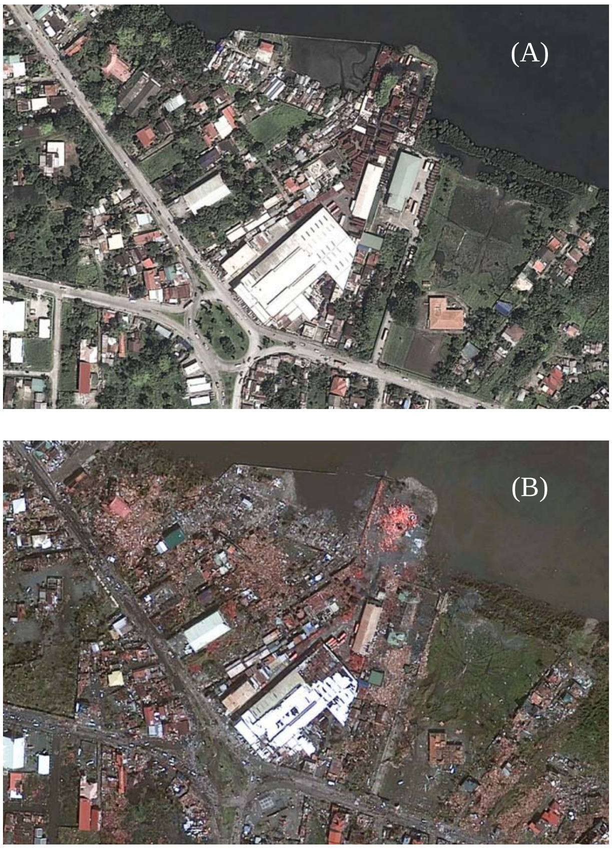

Figure 6. Pre-event (A) and post-event (B) satellite images.

houses, hospitals, schools, hospices, etc.). Moreover, a first guess for the cost of reconstruction of these buildings could be formulated, in order to estimate if it is more convenient to repair them, or to demolish them to facilitate the operations for future reconstruction. In Figure 8, the result of comparison between the layers related to pre-event and post-event satellite images is shown. The damaged building are coloured in red.

7. Conclusions

After any catastrophic event, such as earthquakes, strong winds or explosions, damage assessment can be carried out easily through the comparison of pre-event and post-event satellite images. These pictures are digital images composed by pixels, which represent the input for the layers that reproduce the shape of each structure and that are intersected to assess, visually and immediately, the damages produced by a natural disaster. The main difficulty is to define with accuracy the outline of each element involved. The ODT adopted in this paper represents the best solution; it automatically groups pixels that are similar in colour,

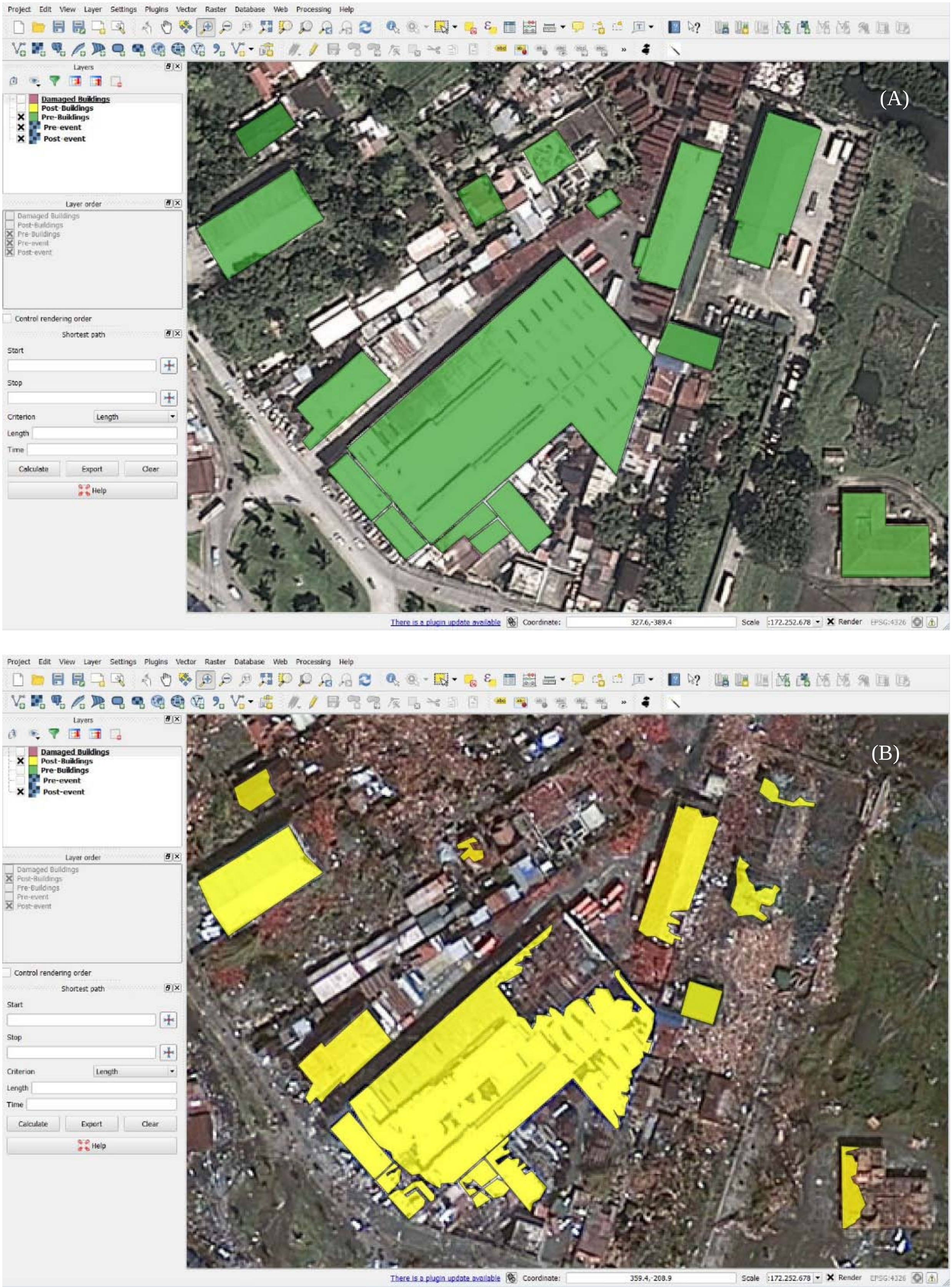

Figure 7. Pre-event (A) and post-event (B) layers in the QGIS environment.

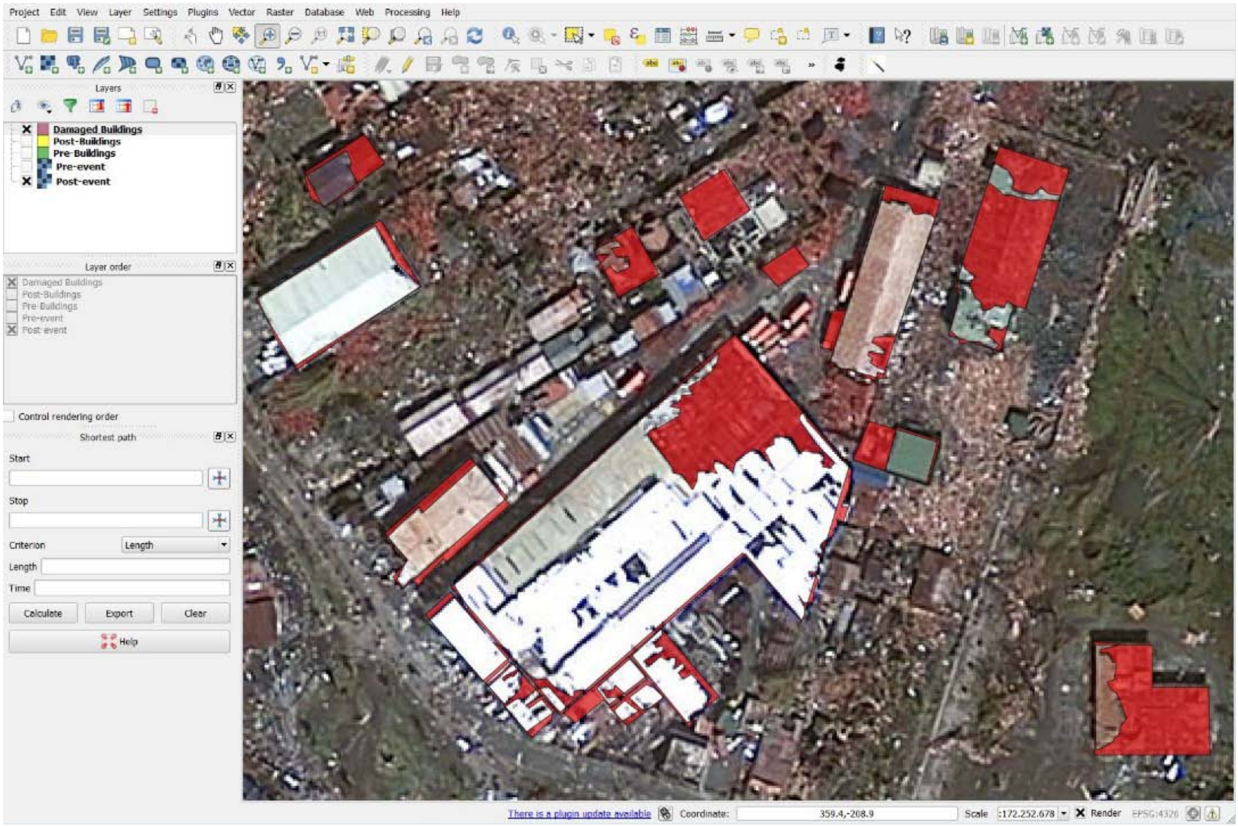

Figure 8. Intersection of layers: damaged buildings.

starting from a “seed” pixel required to initialize the search.

This paper shows the development of the ODT running within the QGIS software environment to extract, in the shortest time possible, buildings and transportation network infrastructure that are located in the affected area. This facility could be useful in the mitigation of the effects induced by catastrophic events of any nature towards the development of smartness within emergency management.

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