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Demonstrator of domino effects incl. routing analysis for Alpago region, Italy

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Extended abstract:

Introduction

The further development of assets mapping is among the key objectives of the Copernicus project IncREO (Increasing Resilience through Earth Observation). With substantial work done already in SAFER (Services and Applications For Emergency Response) assets mapping on a national scale is relatively well-advanced (e.g. Basic European Assets Map product). However, service and product solutions particularly addressing the regional and local scale including a stronger focus on the use of Earth Observation data were lagging behind a bit and are thus now in the centre of IncREO's assets mapping developments. These developments relate to the Assets Map Plus (AM+) product extended by a routing analysis relevant to evacuation measures and by the development of a domino effect demonstrator resulting in information on damage potential derived from the AM+ product. The test area chosen are the Alpago communities in the Veneto region of NE Italy. As to the rationale of these developments the AM+ product is mainly addressing local institutional stakeholders in the disaster management, civil protection and spatial planning domains. It provides valuable reference information such as number of population per residential building, urban area and critical infrastructure. For the final AM+ product the "third dimension" is also considered by using terrain information and calculating the building volume. Very High Resolution optical EO data is used as background for providing additional information as accurate as possible. Another line of development is a demonstrator showing the effects of an earthquake causing a landslide. This demonstrator is a software tool simulating and showing – in a simplified manner – the potential concatenation of an area's prevalent natural hazards including its related impact on population and assets. The demonstrator helps in visualizing such "domino effects". Thanks to a user-friendly interface the demonstrator is adaptable and can relatively easy be populated with other area's data (recent data, historical data, user data). This set up enables a use of the demonstrator beyond IncREO contributing to a sustainable solution in terms of impact assessment and identifying a region's potential hot spots. Finally, the assets map plus can be used as a reference for a routing analysis with the objective to identify and locate safe spots as a mitigation measure for an area hit by a natural disaster (e.g. flood, landslide) which would cause bottlenecks or impassable sections of the area's road network. It is also suited for providing spatial planning authorities with assets information related to the most probably disaster events. For performing the routing analysis outputs from the domino effect demonstrator can be used as starting point (e.g. road obstacles, damaged bridges etc.). Output of the routing analysis is not only identifying the best remaining routes from A to B taking into account blockages but also the estimation of traffic density per road segment as a function of the area's population and corresponding number of motor vehicles.

Data

The domino effect demonstrator (DED) needs to be "fed" with a limited number of layers which is in line with the philosophy of such tool: Providing an easy to use and a user friendly way of simulating a domino effect.

However, for initiating the DED, the user has to provide the following data:

- The hypocentre location (either hypothetically or to be taken from historical earthquake databases). Also, magnitude and depth of seism must be entered by the user, allowing him/her to design multiple scenarios.
- A soil map describing the soil type; for each soil type an erodibility index and rank must be given. This step requires knowledge from the field and is one of the parameter that needs to be adjusted by the user. The more detailed the map, the more accurate the results.
- A Digital Terrain Model (DTM); the higher the resolution, the more accurate the results.
- The river footprint; the demonstrator takes into account the distance to the river which can increase the probability of landslides to be triggered.
- The building footprints with related asset value, which can be either derived from house prices databases or from the Basic European Asset Map (BEAM) product.

For the use case of Alpago, Italy, the soil map and river footprint were provided by the ITN CHANGES project, the house prices were derived from the POI database with support from the Chies d'Alpago Community in locating building types, the DTM was provided by Airbus DS Geo SA and building footprint were derived from OpenStreetMap database and corrected using Pleiades imagery provided by Airbus DS Geo SA as well.

The routing analysis was also designed to be an easy to use solution and requires three mandatory types of inputs:

- The road network, which needs to be topologically corrected (for each road intersection a vertex or a node must result) and of course updated according to the most recent imagery.
- The building footprints with related volume, which can result from another tool further described later and using a Data Surface Model (DSM).
- The safe spots where to population is to be evacuated (e.g. sports field or similar sites)

Another capability of the routing analysis is to take into account obstacles on the road network, such as damaged bridges, impassable roads due to flood or landslide event, to find an alternative evacuation route.

In this sense, the routing analysis can be used as a complementary tool to the domino effect demonstrator by directly using the outputs, namely the areas impacted by landslides, as impassable areas.

Here again, the road network information was provided by the ITN CHANGES project, the safe spot locations were provided by the Civil Protection of the Veneto Region (CPV).

Material and Method

Domino Effect Demonstrator (DED)

The DED is running on ArcGIS © ESRI and therefore calls functions gathered in a processing chain built using the ModelBuilder. However, for further development an open source solution, such as QGIS, has been considered to make it available to a wider panel of users.

The DED is composed of two models combined together. It allows assessing on one hand the earthquake intensity and the corresponding potential damage areas (and the way the seism is perceived by the population) and on the other hand the landslide extents. Next, the two models are linked to get the probability of the resulting triggered landsides. Finally the elements at risk (roads, buildings) are crossed with the disaster extents in order to assess the impact of such event. According to available information at the road and building scale, various statistical summaries can be derived, such as affected population and corresponding number of cars, monetary values of affected residential buildings etc.

In view of further developments the DED has been designed in a way, that users will be able to include their own data, such as an intensity map for earthquakes and / or a landslide probability map.

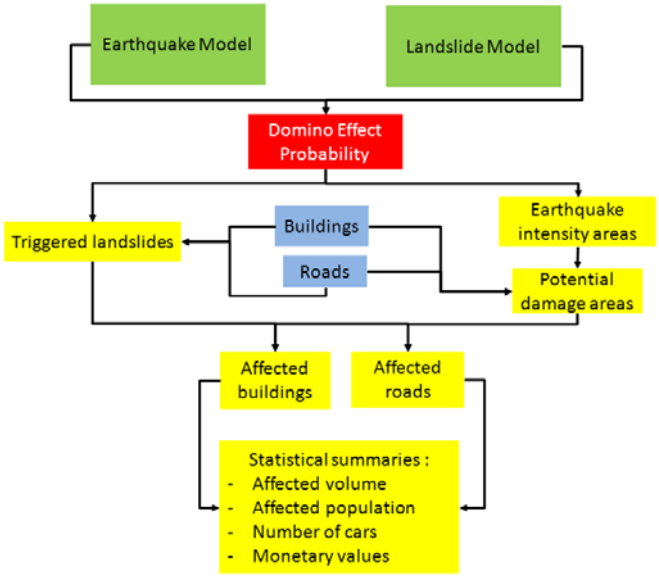

Figure 1: Domino effect demonstrator (DED) workflow; buildings and roads layers are entered as inputs and then crossed with the outputs from the DED to derive statistics

Routing Analysis using demonstrator outputs

Software requirements here are as for the DED, requiring in addition the Network Analyst extension to work properly. Applying the routing analysis using QGIS is an alternative as well.

The complementarity of the routing analysis results from the possibility of using the affected roads and the affected buildings from the demonstrator as inputs. The affected roads then become potential obstacles and the affected buildings are the places to evacuate first.

However, in order to determine the population living in buildings, the building volume information is a mandatory input. If the height of the building is missing from the initial data, the building footprints must be first pre-processed in order to obtain this volume information. Using a Data Surface Model (DSM) and the building footprint, the mean height of the building can be derived.

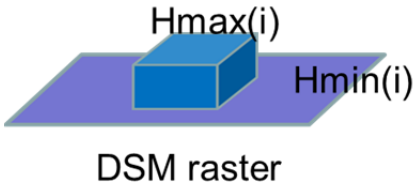

Figure 2: Workflow to derive building volume from DSM and building footprints; $volume$=area(i)x($Hmax(i)-Hmin(i)$)

Corresponding to the building volume, population figures are then derived from specific population functions that are previously calibrated according to the area (mountain village, country town, urban centre…).

As output, the routing analysis provides the potential total number of cars that would be driving on each road section in case the affected buildings would have to be evacuated. This simple analysis allows outlining the road sections that would be the most suited ones for evacuation. In combination with the affected road information as provided by DED, the routing analysis allows to identify the buildings whose occupants would not reach the safe spots due to impassable roads. Such information is key for preparedness and prevention measures!

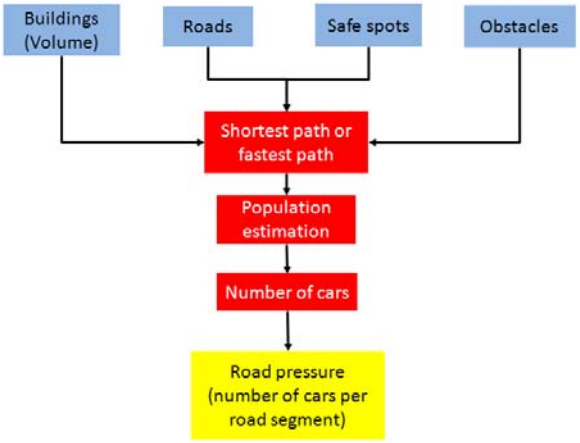

Figure 3 : Routing analysis workflow; buildings, roads, safe spots and obstacles are entered as inputs, then the most suitable path is determined and number of cars is derived according to the estimated population figures

Results

The work performed resulted in so-called products “mock-ups” which were presented to the Alpago communities users during a workshop (WS) in May 2014. The feedback received has been taken into account for revising the product (adjustment of area of interest, production of a map as pdf etc.) and to provide the users again with the updates.

These prototypes were then presented during a user validation WS in October 2014 (see map example below).

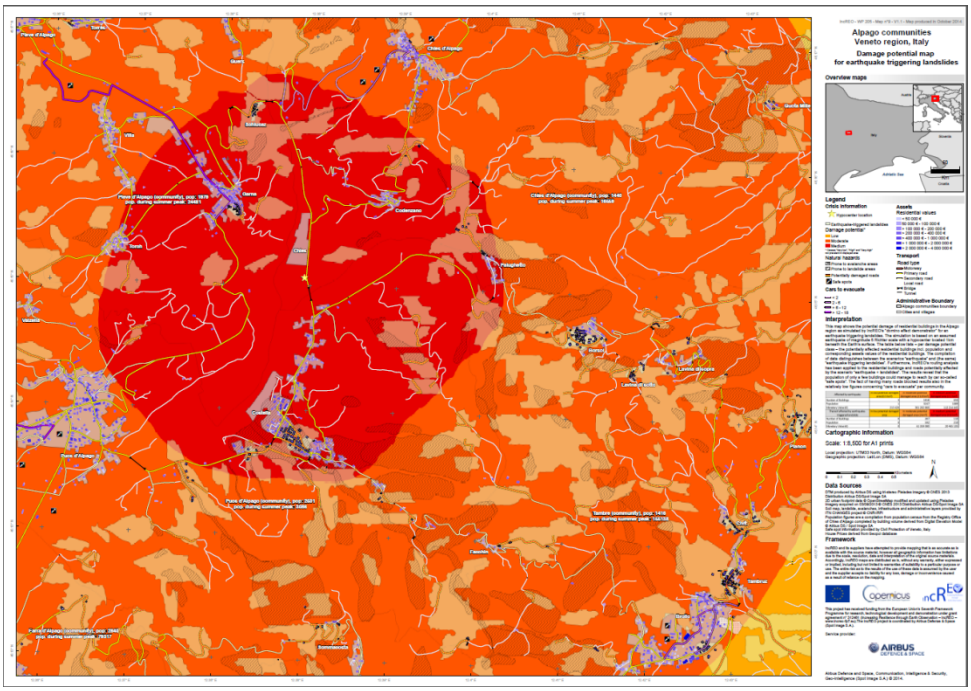

Figure 4 : Final product derived from the outputs of the demonstrator simulating earthquake-triggered landslides.

In the course of this WS, the users acknowledged that the DED and routing analysis approach is an efficient way in an easy to use manner to quickly simulate a series of possible events in order to compare the respective result for getting a better understanding of the geo-physical processes and potential consequences within an area. It's worth mentioning here that the main intention of the DED and the routing analysis is the readiness for operational use allowing even not GIS experts to operate it and to make queries.

The CPV confirmed the usefulness of the products created (e.g. for spatial planning, training) and acknowledged their geo- information contents. They also expressed interest in having a map as shown for example in Figure 4 on the regional scale, which is possible given the data situation and using GIS methods.

Conclusion

The domino product as developed by Airbus Geo DS in the frame of the Copernicus project IncREO will require some extra developments mainly for the simulation of the disasters. However, already the current stage of development including the products shown to the users resulted in positive feedback and acknowledgement of the work done for the Alpago communities.

Due to software constraints some of the involved users are limited the operation of the IncREO work done. That's why the provision of the solutions as presented here by the use of public domain GIS software has been designed accordingly. This would enable them to uptake the use of the IncREO results and also to add value to these geo-information products by implementing their own user data for continuously improving their database for decision-making in the context of disaster prevention and preparedness.