Extraction and Visualization of 3D Building Models in Urban Areas for Flood Simulation

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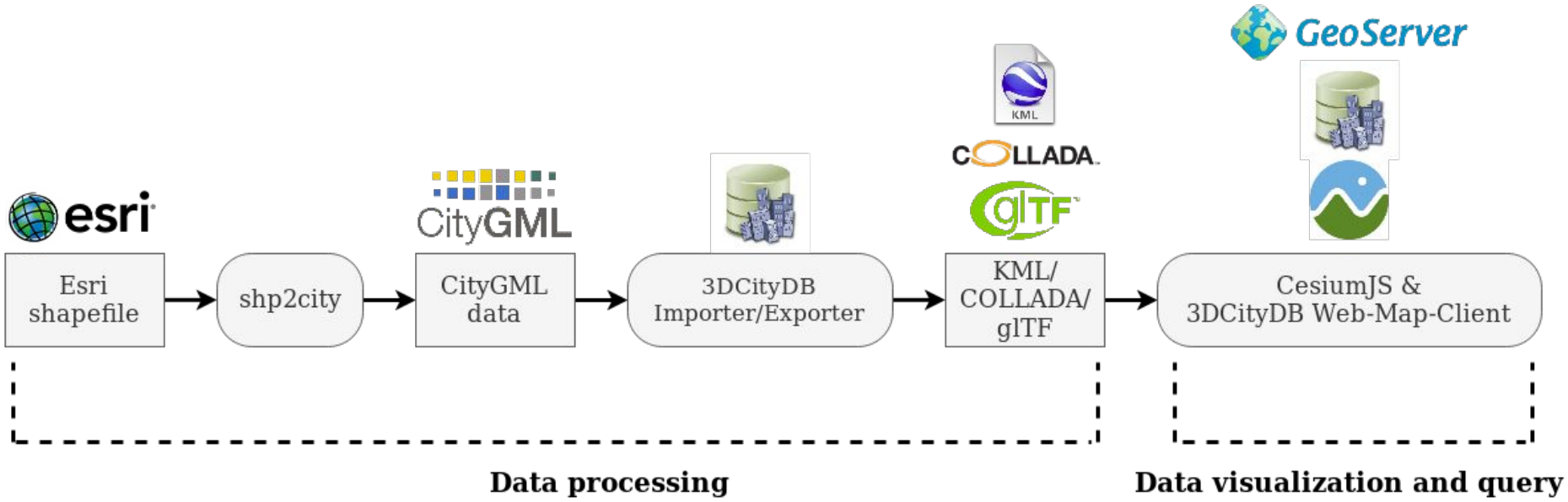
10/05/2019

Flood simulation using 3D Web GIS

URBAN-GEO BIG DATA

- As a result of climate change and urbanization, millions of people are exposed to the risk of floods.

- We visualized 3D buildings and simulated floods on a virtual globe to aid the domain experts and decision makers in developing **adaptation and mitigation** strategies for the threats of floods.



URBAN GEO BIG DATA project

URBAN-GEO BIG DATA

- The project aims to contribute to improving the exploitation of new data from earth observation and mobile sensors, for a better understanding of several urban dynamics.

- It extracts information from data and represents it for better comprehension, aiming an improved public engagement and more efficient decision making.

- The urban dynamics studied are:
  - visualisation and query of
    - **3D city models**
    - deformation of multiple years
    - volunteered geographic information (VGI) regarding land cover
  - visualisation and analysis of soil consumption, land use and land cover data of multiple years
  - mobility

- It focuses on five Italian cities: Milan, Turin, Naples, Padua and Rome.

URBAN GEO BIG DATA project

- Politecnico di Milano is responsible for building the Web GIS that enables to visualise, query and analyze the research outputs, including 3D city models.
- University of Padua works on creating 3D city models using Esri shapefiles.
- URBAN GEO BIG DATA is a Project of National Interest (PRIN), funded by the Italian Ministry of Education, University and Research (MIUR)—id 20159CNLW8.

shp2city

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- shp2city converts cartographic data that contains building information in Esri shapefile format to CityGML format.

- shp2city is a **Python** package that uses mainly GeoPandas and lxml Python libraries.

- The height of prism equivalent to the eaves height is required to generate a CityGML model with a level of detail 1 (**LOD1**). If the shapefile does not have the eaves height, CityGML model is generated with a level of detail 0 (**LOD0**).

- The attributes in the shapefile can be added to the CityGML data to enrich the thematic information.

- We validated the generated CityGML model using two external tools developed by the 3D geoinformation research group at TU Delft: val3dity (https://github.com/tudelft3d/val3dity) and CityGML-schema-validation (https://github.com/tudelft3d/CityGML-schema-validation).

- Besides the command line tool shp2city, we developed a web tool **ZCityGML**.

Conversion from CityGML to KML/COLLADA/glTF

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- **3DCityDB** is an open source software that allows to import, manage, analyze, visualize, and export CityGML data.

- In this work, we used the CityGML data generated through shp2city software.
- The data is currently generated for Milan, Naples, Padua, and Turin.
- Using **3DCityDB Importer/Exporter**, we imported the datasets into the PostgreSQL database extended with PostGIS. Then, using the same tool, we exported them to KML/COLLADA/glTF.
- Moreover, using the Spreadsheet Generator Plugin (SPSHG), we exported the thematic data of 3D objects into tables in CSV format and imported the data into **Google Fusion Tables**. As a result, it is possible to query each building and display its attributes in a box using the **thematic data** stored in the Google Fusion Tables.

Visualization of KML/COLLADA/glTF

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- 3DCityDB software comes with **3DCityDB Web-Map-Client**, which serves as a web client for 3D visualization and interactive exploration of arbitrarily large semantic 3D city models.

- 3DCityDB Web-Map-Client implements various extensions to the CesiumJS library:
  - allows visualizing large and tiled data in glTF format
  - supports highlighting 3D objects on mouse-over and mouse-click
  - implements a cloud-based online spreadsheet API, i.e., the Google Fusion Tables API to query thematic information of 3D objects

- When a user clicks on a 3D object, the linked Google Fusion Table is queried for the respective row, and all of its attributes are displayed in a box.

Virtual globe

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- Six **basemaps** are added to the virtual globe:
  - Bing Maps Aerial
  - Mapbox Satellite Streets
  - OpenStreetMap
  - CARTO Dark
  - Stamen Terrain
  - Stamen Watercolor

- We used VR-TheWorld Server to construct **terrain**. It provides digital elevation model (DEM) with a 90-meter resolution for the entire globe, including bathymetry. Since the buildings in CityGML data also have the altitude values, we could place the buildings on the terrain, the elevations don't match perfectly. On the web GIS, it is also possible to simulate the **sun**, which enables to visualize shadows of terrain and buildings at different times of the day and year.

Visualization of KML/COLLADA/glTF

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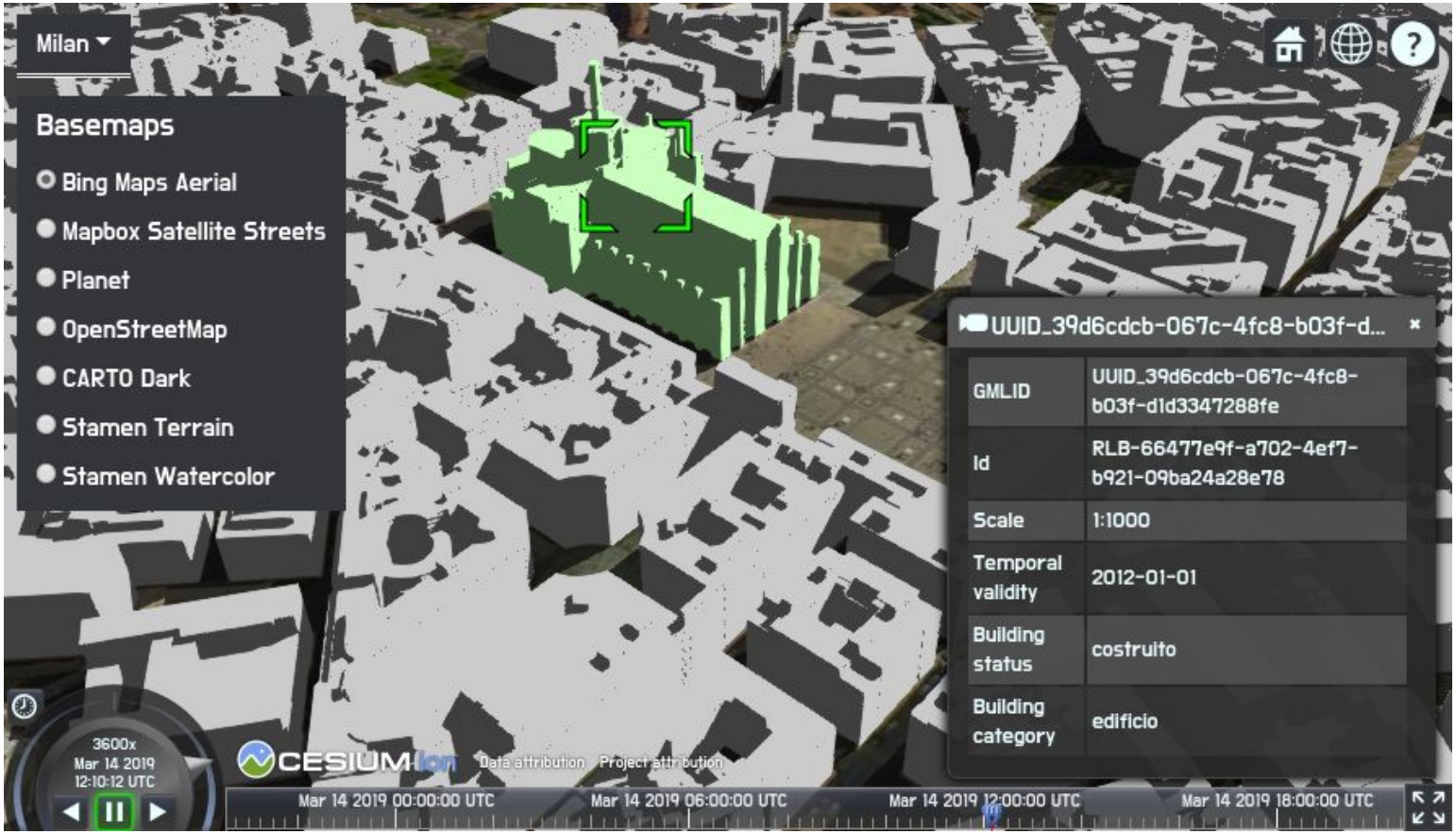
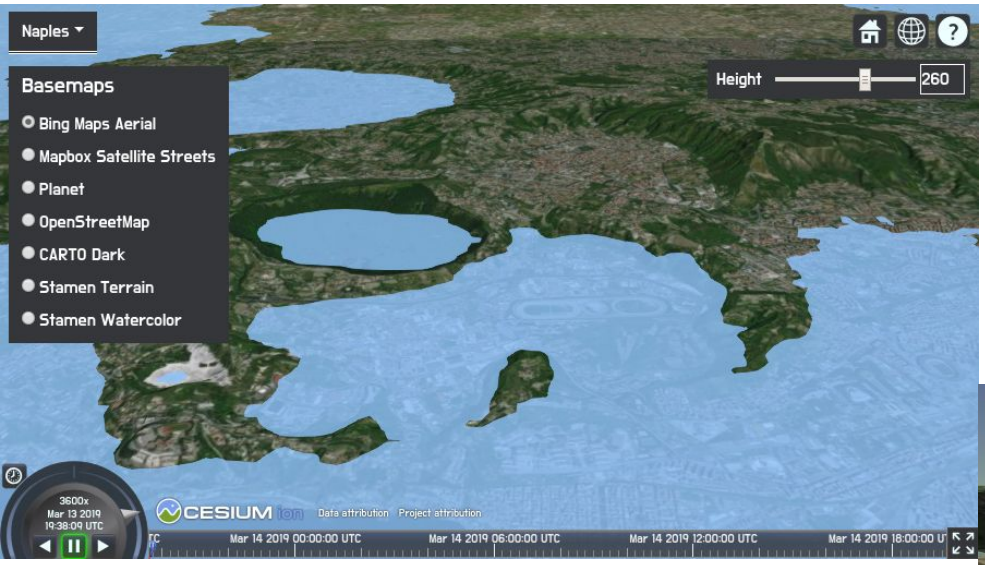


Visualization and query of Milan Cathedral

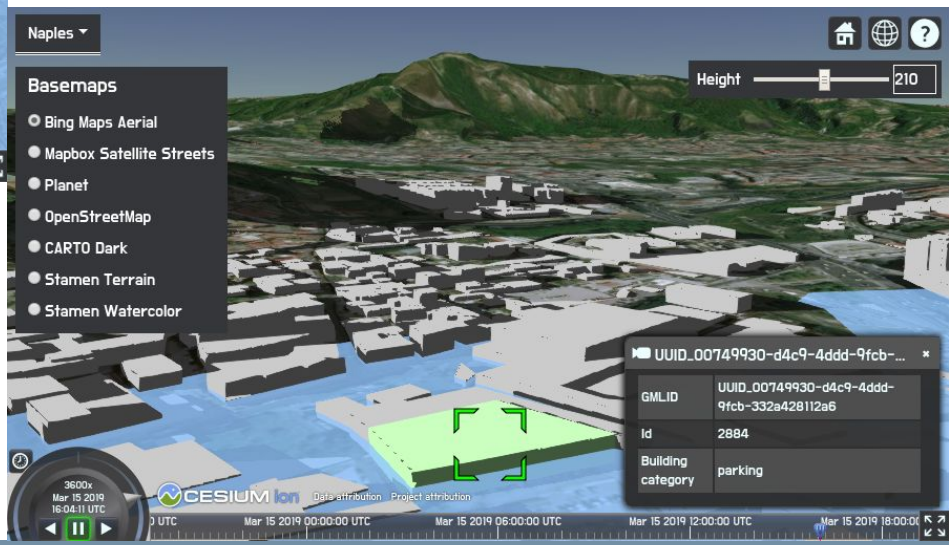
Flood simulation in Naples

URBAN-GEO BIG DATA

- We placed a semi-transparent polygon on the ellipsoid surface of the virtual globe and let the users change the height of the polygon in meters.



Flood simulation in Naples



Flood simulation in Naples with 3D buildings visualization and query

Flood simulation in Milan

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- The flood risk map published by Lombardy region of Italy as open data (http://www.geoportale.regione.lombardia.it/en/home) is integrated into the web GIS using Web Map Tile Service (WMTS) in GeoServer.

- We used a 5-meter digital terrain model (DTM) of Milan instead of a 90-meter DEM to increase the accuracy of the flood simulation. This dataset too is published by the Lombardy region of Italy as **open data**.

- Integration of the DTM to the virtual globe requires:
  - creating terrain tiles in quantized-mesh-1.0 format (https://github.com/ahuarte47/cesium-terrain-builder/, https://github.com/AnalyticalGraphicsInc/quantized-mesh)
  - using a server to host the tiles (https://github.com/geo-data/cesium-terrain-server)

- The source code of the web GIS of URBAN GEO BIG DATA project is open and available on GitHub at **https://github.com/kilsedar/urban-geo-big-data-3d**.

Flood simulation in Milan

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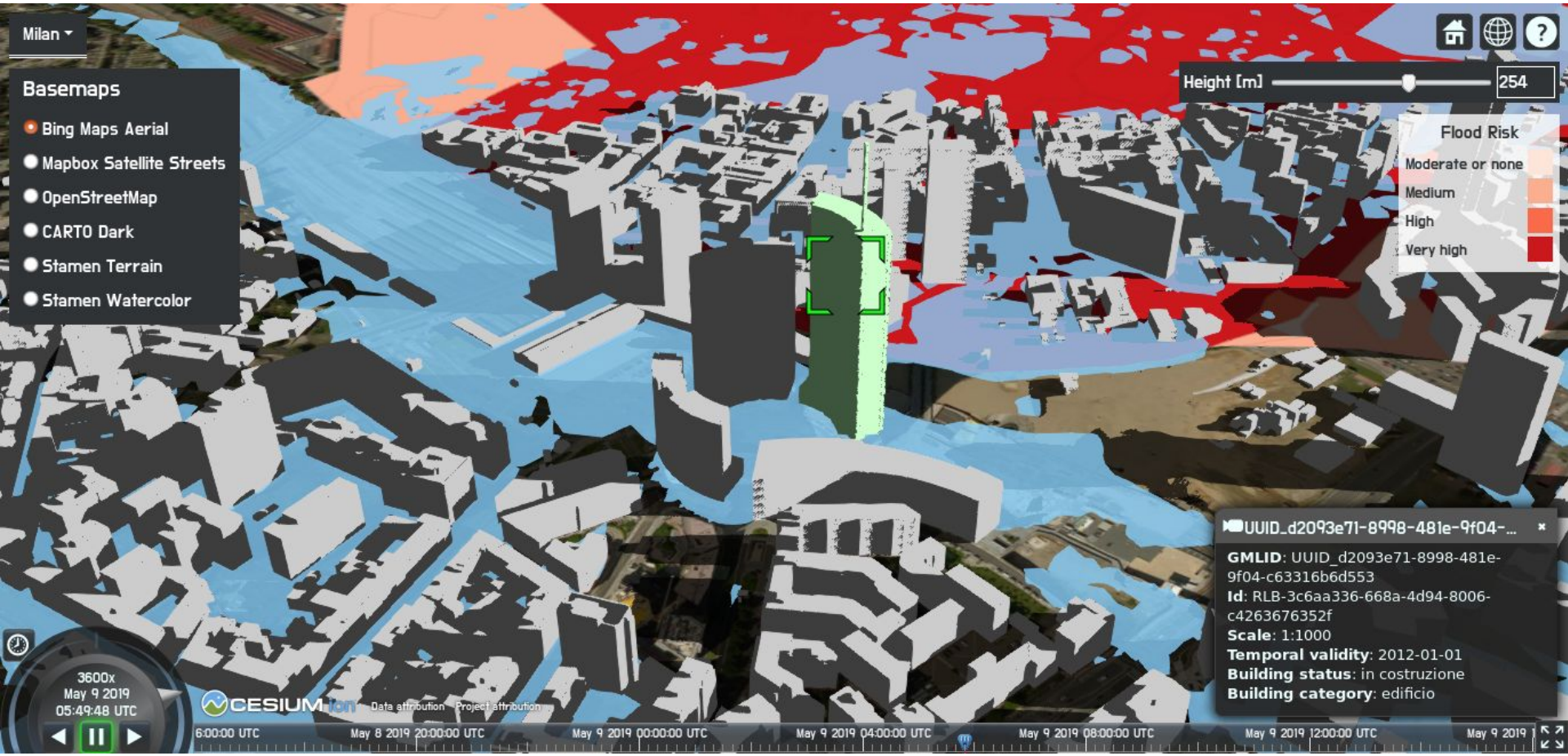

Flood simulation in Milan with flood risk map and 3D buildings visualization and query

Conclusions

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- This article introduces a tool (shp2city) that converts Esri **shapefile** to **CityGML**.
- The results of this conversion (3D models of buildings) can be successfully visualized and queried on a **virtual globe**.
- **Flood simulation** can be integrated into this system.
- Simulating floods in three dimensions can aid in the **decision making** process regarding developing adaptation measures and mitigating the effects of floods.

Future work

- CityGML could be converted to **B3DM**.
- **Hydrodynamic modeling tool** will be used, so that other variables than terrain height can be taken into consideration in the flood simulation.

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