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The Experience of Parametric modeling design GIS: An Abruzzo hamlet case study

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Abstract
With this research work, the aim is to structure an innovative modus operandi aimed at representing a territory with a multi-scalar approach, consistent with vector modelling, which allows to make analysis from an urban and architectural point of view in a synergistic way. The data at the base of this system are GIS type, therefore georeferenced, associated with geometric primitives. The intuition lies in the elaboration of three-dimensional vector models of even very large portions of territory, realized through a visual scripting digital tool (Grasshopper) and processed in a NURBS modeling software. At this stage of the research the attention is mainly focused on the faithful representation of the territory. The case study presented is Arischia, historical center of the province of L’Aquila, located at the foot of the Abruzzo Apennines. For the realization of the model we start from geotiff’s of the DTMs that are vectorized in order to get a three-dimensional grid of points that is used to create a NURBS surface that represents the orography of the territory, roads and buildings. The use of NURBS mathematical surfaces allows to lighten the computational burden, obtaining these results in a very short time. The criticality of this methodology is mainly inherent in the availability of accurate spatial data and in some manual operations to make the procedure work. Further development of this work will be the use of remote sensing for perceptive comparison between these two methods of representation.

Keywords: GIS, NURBS, parametric, landscape

1. Introduction
With this research work, the aim is to structure an innovative modus operandi aimed at representing a territory with a multi-scalar approach, consistent with vector modelling, which allows to make analysis from an urban and architectural point of view in a synergistic way. The data at the base of this system are GIS type, therefore georeferenced, associated with geometric primitives. The intuition lies in the elaboration of three-dimensional vector models of even very large portions of territory, realized through a visual scripting digital tool and processed in a NURBS modeling software. The work has been developed within Department of Architecture and Urban Studies (DAStU) of Politecnico di Milano, in collaboration with the Department of Civil, Building, Environmental Engineering and Architecture (DICEAA) of Università degli Studi di L’Aquila. In 2018 DASU has started a ministerial funded research project called “Territorial Fragilities” (http://www.eccellenza.dastu.polimi.it/) with the aim of studying and elaborating different declination of territorial fragilities. The present work defines a possible methodology to overcome the lack of building informations in areas on the wake of major earthquakes.
2. Methodology

The methodology applied with this work possesses several potential capabilities, thanks to the operational flexibility of the procedure, which remains unchanged, as input data varies. The process consists of the fusion of geometric and numerical data. The data that lead to the definition of terrain geometry are raster files derived from indirect surveys with overflights produced at different altitude, from the drone to the satellite. It is necessary to calibrate the accuracy of the result as the input data increases, by reducing the amount of generated points. It is therefore necessary to reparametrize the input data, for optimizing the output data flow in relation to machine times, by lowering the raster resolution in order to have a point matrix that can be effectively managed. From the point network it is possible to get the corresponding NURBS surface (Non Uniform Rational Basis-Spline) (Catmull, Clark, 1978). The entities belonging to this family have mainly been used for the sinergy with Rhinoceros software and computational tool Grasshopper (Gh) that find in the manipulation of this type of elements its point of strength. Additional vectorial data, as the perimeter of the building roofs can be added coherently with the Coordinate Reference System. It is possible to reconstruct the shape of the building with precision by combining the numerical value of the roof heights with their geometry inherited by the GIS database. This specific precision is of cardinal importance in the case of territories affected by the earthquake. In such territories the survey and delineation of the form, extent, and position of the buildings can be seriously jeopardized by a series of exogenous factors. These factors include the urgency to demolish a building for emergency or public safety reasons.

Figure 1. GIS-generated 3d Model of Arischia hamlet and its rural landscape

These evolutionary dynamics, typical of seriously quake-damaged areas, can generate needs that do not allow even the most basic geometric survey of buildings. These circumstances lead to demanding issues during the reconstruction phase because, especially in hamlets, where most of dwellings were built before the law that introduced the building permit in 1942 (Legge, 11). This law was the first to make the geometric definition of new buildings mandatory. Therefore - for buildings older than 1942, demolished before a proper survey - it is impossible to reconstruct with a certain degree of certainty even the most basic features, such as height above ground. Frequently the footprint area has been surveyed in the cadastral archives - although with the obvious limitations of the lack of evidence for legal purposes – but the height above ground is impossible to determine precisely. The case study, subject of this work, is the Arischia hamlet, belonging to the municipality of L’Aquila which, in 2009, was hit by a devastating earthquake that completely destroyed a considerable number of buildings and led to the demolition of even more artefacts. The choice of the Arischia was led by the experimentation applied on a territory where orography becomes a factor that cannot be neglected in the definition of the settlement. For all the buildings belonging to this territory it is necessary to reconstruct the administrative coherence even before the building, recovering all the documentation deposited at the offices in charge. When these documents are missing, it is necessary to employ historical memory, collecting photographic evidences of the buildings from unofficial or private sources. In case nothing of the support material is available, it is necessary to rely on the memory of the owners of the building for a reconstruction, albeit approximate. Authors experimentations have proved this method to have a very scarce degree of reliability. It has been therefore necessary to rely on other sources of
information to rebuild the geometric building configuration. In order to generate the three-dimensional model of the case-study area it is mandatory to verify the availability of the relevant georeferenced data. In this respect the cartographic database of the Abruzzo Region was used because of its availability of both vector and raster informations. Among those the digital terrain model (DTM) with a resolution of 10x10 meters and the 2007 Regional Technical Cartography (CTR) were used. The latter provides an “image” of the territory before the seismic event happened April 6th, 2009, which deeply damaged most of the building and monumental heritage in the areas near the epicentre. These data, contained in shapefiles, were processed with a GIS software and then in a three-dimensional NURBS modeler connected to a plugin that can manage the algorithm aided design side. The DTM represents the soil surface without considering the anthropic and vegetational elements. Since it is a three-dimensional raster file it is necessary to process in in a GIS environment in order to extract the points accompanied by their geometric coordinates which are readable in a 3D modeler. The procedure is performed using a GRASS algorithm in QGis. In this way a vector shapefile is generated representing a grid of equidistant points with a 10 meters pitch georeferenced according to the UTM-WGS84 coordinate system. In order to read this shapefile in Grasshopper (Gh) it was necessary using specifically designed tools that enable it to manage this type of file, usually belonging to the GIS software family. Once imported the points are read as an ordered list of two-dimensional elements. The data relative to the altimetric elevation are then extracted from the attributes table making it possible to place each point in its real position in the three-dimensional space. At this point of the procedure we obtained a cloud of georeferenced points that faithfully represents a part of the territory. It was chosen to use the mathematical model known as NURBS. In this sense we chose the component “Surface From Points” in Grasshopper but in order to work correctly it needs an additional parameter called “u” (Valenti, 2010).

Figure 2. GIS-generated 3d Model of Arischia hamlet. Green buildings are have been surveyed with traditional direct methods.

In order to calculate it in Gh, with reference to the point cloud described above, it is necessary to know the number of elements contained in one of the "n" lines of the ordered mesh. The problem is that the points are ordered in numerical lists (Tedeschi, 2014) where the indexes (and therefore the position of the points in the list) are only increasing (from 0 to “n” where “n” is the points total). It was therefore decided to subdivide the list into sublists containing only the points that have the same value as x and then calculate their number. Sublists now have the same number of items since they are sorted in a squared mesh. In order to do that the x-coordinates of each point are extracted then stored in separate lists using “Create Set” and finally their mutual equality is tested. In this way a Boolean exclusion pattern is defined by which data are sorted into sublists that meet the already explained rule. At this point it is possible to know the number of elements in each sublist, a parameter with which the “Surface From Points” component is fed as fundamental datum for the generation of the NURBS surface finally performed at this stage. It represents the portion of territory object of analysis scale 1:1.

The procedure used to achieve the three-dimensional algorithmic data related to buildings and roads is similar but has some peculiarities and difficulties, mainly related to the quality of the starting data, not completely solvable in an automated way that require some simplifications and operations to be performed manually at this stage of the research. Among the geometric informations about buildings
made available by the Abruzzo Region contained in the shapefile there is the one that express their height associated to their 2D geometry. At this point foot and eaves height of each of them is unknown. The procedure then implies importing polygons that describe the footprint on the ground, the extraction of their centroids and their consequent projection on the NURBS surface previously modeled. Polygons are now moved vertically to reach the height of the points projected and then extruded with their own height value stored in the attributes table. In this way it is possible to obtain closed polysurfaces that represent buildings. Roads requested a more complex procedure. It was necessary to process them in a Gis environment to extract the vertices of each curve representing the road trunks so generating a shapefile of points. In the attribute table points are described with values that identify curves they were related to before their extraction. They are eventually ordered with a raising index that informs the software about the order in which the points will be interpolated drawing three-dimensional NURBS curves. Each point holds its own geometric informations too enabling it to be positioned in the three-dimensional space at its own height. Now we have 3D closed NURBS curves representing road trunks. At this point Grasshopper generates additional and unnecessary curves that can only be removed manually in Rhinoceros once “baked” (The Grasshopper Primer, 2019). The now “cleaned” closed curves can now be used to generate triangular mesh surfaces in the NURBS modeler. This simplification will be subject of further experimentation, since the key objective is the total automation of the process using NURBS-type representations which require significantly less informations than mesh approximations. In this way the computational burden required for the execution of the algorithm would be lightened and its running time would be consequently very shortened.

3. Results
The volumetry is an essential parameter for the calculation of the silhouette allowed for the reconstruction as established both by the National Urban Planning Regulations and by the Technical Standards for the implementation of the General Regulatory Plan of the Municipality of L’Aquila. For the purposes of building legitimacy, the portions that can be reconstructed inside the historical centres are exclusively those present at the time of collapse/demolition. Therefore, the importance of the silhouette reconstruction of the pre-existence is paramount both from the administrative/legal point of view and from the point of view of the urban layout of the town.

Figure 3. A selection of the surveyed building. Comparison between ordinary surveyed buildings in wireframe and GIS generated volumes.

The generated geometries were compared with the buildings shown in Figure 3, which were surveyed using a traditional method before demolition. The comparison between these sample buildings and the resulting 3d models showed that the detection system has a variety of effects on the final return. It is however an additional source when ordinary sources of information about building volumetry are scarce or even absent.
Bibliographical References


[11] Legge Urbanistica, Legge n. 1150 del 17 agosto 1942