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MINISTERO DELL'AMBIENTE  
E DELLA TUTELA DEL TERRITORIO E DEL MARE



**Regione Umbria**

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**CIRIAF** - Centro Interuniversitario di Ricerca sull'Inquinamento e sull'Ambiente - "Mauro Felli"  
Università degli Studi di Perugia


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- 1) Energie rinnovabili e impianti sostenibili
- 2) Sostenibilità ambientale ed economico-sociale
- 3) Edilizia sostenibile e bioarchitettura
- 4) Modelli di economia circolare e filiere innovative integrate
- 5) Impatto del cambiamento climatico sugli ecosistemi naturali ed agrari
- 6) Pianificazione strategica del territorio

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- Methane recovery and carbon dioxide disposal in natural gas hydrate reservoirs
- Development and promotion of levulinic acid and carboxylate platforms by the formulation of novel and advanced PHA-based biomaterials and their exploitation for 3D printed green-electronics applications (VISION)

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# XX Congresso Nazionale CIRIAF

*Sviluppo Sostenibile Tutela dell'Ambiente e della Salute Umana*

## DTM to NURBS-A parametric approach to landscape modeling

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**Abstract:** The aim of this research work is the automated generation of a three-dimensional Nurbs model from a series of data on a territorial scale. The difficulty of working with this type of procedure is the sectorialisation of technical skills among the technicians who deal with design at the architectural scale and those who works at territorial scale. The undertaken methodology is to establish a workflow that can export data from a GIS tool and import it into a three-dimensional modeler. To do this you need an intermediate tool, a parametric software. The explained procedure aims to have maximum freedom of processing of model geometries; therefore, the geometry has been based on Nurbs mathematical models. The case study where the methodology of this research has been applied is the territory of Ortona, Italy, the Adriatic coast. Starting from the cartographic data of the Abruzzo Region, the three-dimensional model has been realized as in the forecast. This working methodology ensures efficient results with a low amount of human iteration to generate the final model. Some of the limitations of the procedure have been explained in detail, mainly due to the structure of the used components .

**Keywords:** Parametric; Modeling; GIS; Nurbs;

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### 1. Introduction

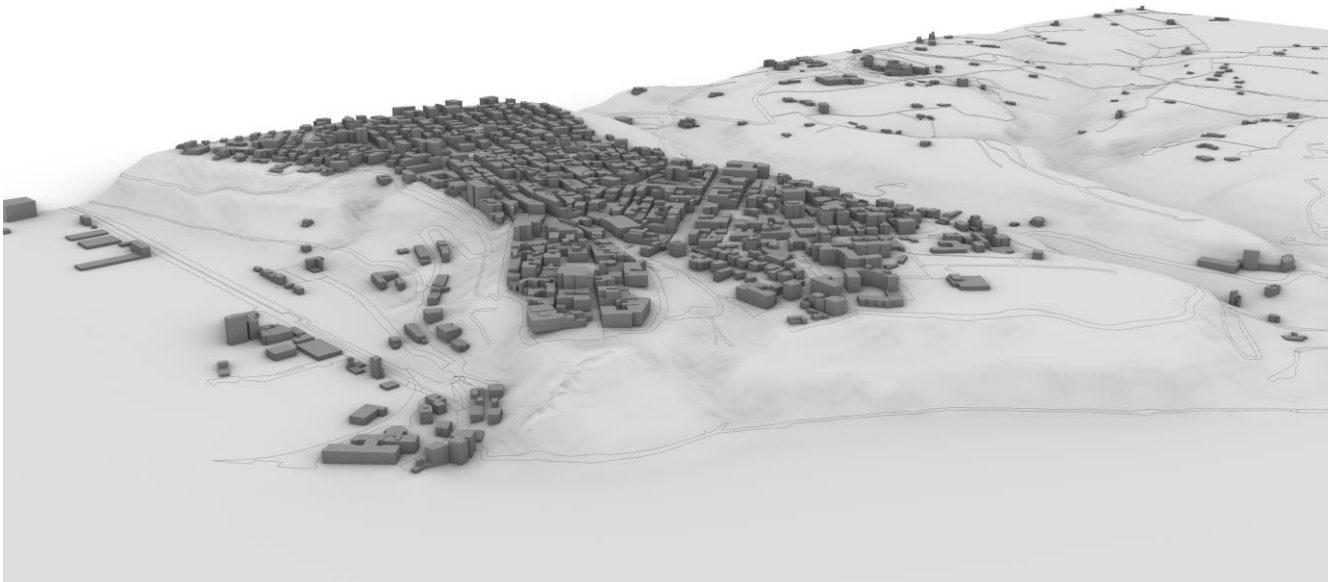
The of data processing explained in this work aims to facilitate the manipulation and analysis of specific areas, starting from territorial cartographic data to get a three-dimensional model. The work has been developed within the Department of Architecture and Urban Studies of Politecnico di Milano, in collaboration with the Department of Civil, Building, Environmental Engineering and Architecture of Università degli Studi di L'Aquila.

The scientific literature regarding the undertaken work is not yet consolidated; it illustrated methodologies, even if apparently similar to the one under discussion, presented substantial differences in result analysis. In particular, (Zhong, D. et al, 2008) focuses on the use of DTMs for the digital reconstruction of parts of the territory in order to perform hydroelectric engineering analysis. The methodology presented by the authors, in that case, reasons on a construction of a three-dimensional mesh model, starting from a DTM, using algorithms that exploit the Delunay triangulation. The contour lines are subsequently extracted at a certain interval and a NURBS surface is interpolated from them. The result suffers, however, from the lack of data excluded from interpolation due to the sampling performed for the extraction of contour lines.

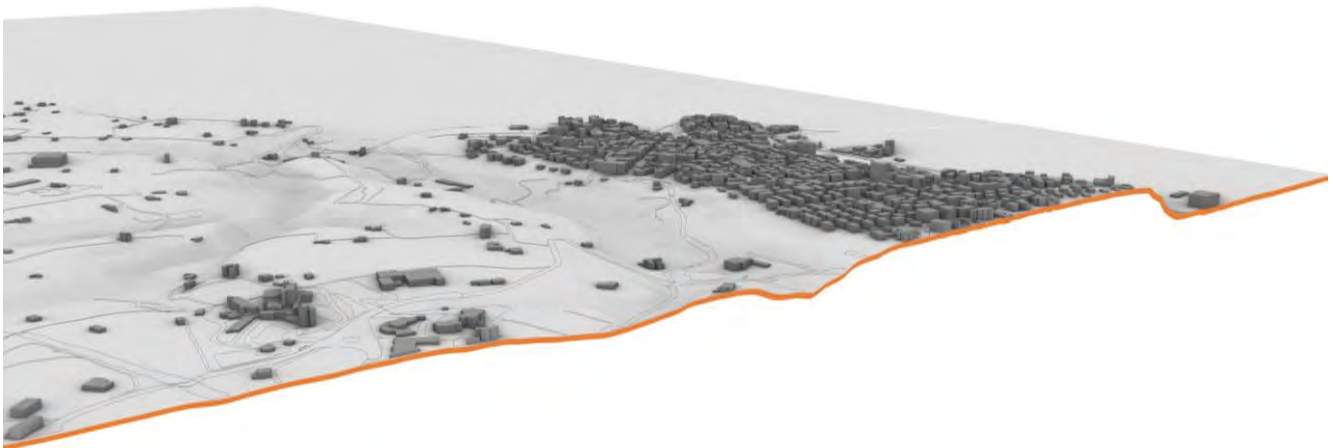
The methodology discussed in this paper makes use of tools belonging to the GIS family and those typical of generative parametric modelling have been used. The working methodology apply the elaboration of a territorial raster data - the Digital Terrain Model (DTM) - which is discretized into a two-dimensional grid of points, whose pitch corresponds to the precision of the DTM itself. Each coordinate of the DTM is associated with an elevation  $z$  that transforms the grid into a three-dimensional network of points. The final product of the methodology is a set of three-dimensional Nurbs vectors where different type of geometrical editing can be applied. The methodology described above has been applied on the city of Ortona, which was chosen as the study area.

## 2. Research

In order to create the parametric 3D model of the case-study area, data were found by selecting them in the Open Data cartographic database of the Abruzzo Region (<http://opendata.regione.abruzzo.it/>). In particular, the data relating to the raster DTM (Digital Terrain Model) were used. DTMs represent the trend of the surface of the soil cleaned of all anthropogenic and vegetational elements. Digital terrain models are used to represent the morphology of the territory; they are structured in grids where each point is determined by its interpolated height. The grid of the DTM used is square and each element measures 10 x 10 meters; this allowed to have sufficiently accurate data as a starting point. The processing of these data required a rather complex procedure; in fact, it was necessary to vectorize the geotiffs, in a GIS environment. Among different tools to transform raster into vectors it was used a GRASS script (`r.to.vect`) that made possible to translate them into a shapefile consisting of as many points as the number of angles of each element of the square mesh 10x10 from which they are composed. In this way it is possible to obtain a mesh of equidistant points on the plane. To add the information related to the altimetric altitudes above the sea level of each point it was necessary to modify the table of attributes of the shapefile obtained using another script in QGIS "`z(start_point($geometry))`": thanks to this tool you can enrich the information of the shapefile by creating a column in the attributes table that expresses the position  $z$  of each point by extracting the information from the so-called derived data. The other databases used were those of the D.B.T.R. (Regional Territorial Database) in 1:5000 scale, containing informations and geometries about: geodesy; technological networks; administrative limits; areas of relevance, hydrography, orography; vegetation. Those data are georeferenced with the reference system UTM-WGS84, aligned with the DTM.

**Figure 1.** NURBS model obtained from DTM raster.

The vectorial data have been imported into QGIS and suitably cut in order to frame the case-study area. In this way, all the initial datasets can be processed. To manage this amount of data in three dimensions, the use of Grasshopper, a Rhinoceros plugin designed for a visual scripting language, was paramount. It was used a Grasshopper plugin to manage the shapefiles, called @it, which provides the user with a set of tools that makes possible to generate geometries and features in Grasshopper starting from shapefiles. The geo-localized data contained in them are imported into Grasshopper and displayed in Rhinoceros as ordered points of a list. For the realization of the three-dimensional model of the territory, the data representing the altimetric heights of each point were extracted from the dataset. With the "move" component, it is possible to set an instruction within the algorithm that moves each point at once, in this case in the Z direction, and places it at its real height, previously associated in QGIS to each point. In this way, the procedure gets as an output, a cloud of georeferenced points in elevation that faithfully represents the portion of territory. For this purpose, it has been chosen the mathematical model commonly known as NURBS (Catmull, Clark, 1978). This procedure is able to generate a surface passing through each point of the three dimensional grid; this decision was due to the inner strength of a Nurbs modeler as Rhino, which base his strength and operational efficiency on the generation and manipulation of entities of mathematical type. The amount of information required for the NURBS representation of a geometric element is far less than the amount of information required to represent the same geometry by mesh approximations (L. Piegl, 1991). Furthermore, mesh approximation is made by polygonal shapes, which are not compatible with natural forms. The representation of landscape is more coherent with organic forms, mainly made of curved shapes. One of the examples of the flexibility of NURBS architecture is the possibility to extract curved contour lines from a landscape; while applying the same transformation to a mesh surface, the result will be polygonal.

**Figure 2.** Section of the NURBS model perpendicular to waterfront

It was chosen the use of component "Surface From Points", in Grasshopper, which allows to obtain a desirable result, although some input data are missing to complete the operation. The software requires, in fact, the value "u", as a coordinate of the relative cartesian system where surface points are located. To calculate it, a chain of components has been used, the operation of which is described below. In order to calculate "u" it is necessary to know the number of elements for each line of the generated grid of points in elevation; the problem is that the points are ordered in a numerical list in which the indexes are increasing (from 0 to n where n is equal to the total number of points). The idea is, therefore, to divide the list of points into sublists so that each of them contains only points with the same x-value and then calculate how many elements are present in each (the sublists will all be of equal length because the mesh of points is inscribed in a rectangle). The coding definition in Grasshopper is as follows: with the component "Deconstruct Point" the x-values of each point in the list are extracted, with the component "Create Set" a list of x-coordinates is generated and then with "Equality" component, the equality between the outputs of the two previous components is tested. In this way it is possible to get a list containing boolean variables (True / False) that describe an exclusion pattern that it is possible to use with the component "Cull Pattern". In this way a list of lists is obtained, each of which contains the same values of x. Since the indexes of each "point" element are the same as their respective x-coordinates, the points themselves will also be organized in the lists accordingly. At this point it is possible to apply a query to the list and get the number of elements contained in each sublist. This value can be used to generate the final surface, through which it is possible to get the NURBS surface. The procedures used for the representation of the other vectorial data (buildings, urban perimeters, railways, roads, sheep tracks, ski resorts) are similar to those described above. Some steps of this procedure have peculiar cues for further elaborations and researches. In particular, in the structuring of the algorithm aimed at displaying the buildings, after importing the points and creating first-degree interpolation lines between them, the problem encountered was obtaining vertical closed extrusions of a value equal to the exact height of the buildings. This request became indispensable because the case-study area was the subject of an energy analysis based on geometric data of individual buildings. In order to solve the first problem, the geometries' centroids were extracted by means of the Grasshopper component "Area" and projected onto the Nurb. Subsequently, the geometries were translated vertically along the vector that connects the centroids to their projections

and then extruded by a value equal to their real height from the data associated with each geometry (contained in the attribute table of the initial shapefile).

### 3. Issues and future development

There are some issues connected with this procedure, which is worth to examine. The first shrewdness is the check of system coordinate in GIS for the element to be imported into Grasshopper. Built into the Import component there is an universal converter into WGS84 Coordinate Reference Systems (SR), but different experimentations have proved this function to be not completely reliable. Therefore, a correct procedure is the verification that all of the imported element have the same SR. For the purpose of this work the export procedure from the GIS system was accomplished from a single file with a single SR to avoid any ambiguity.

The second issue is a limit of the chosen Grasshopper component, because the generation of the surfaces passing through points works only if these are in a rectangular or square array. If any points are beyond this limit the procedure doesn't work and therefore it is necessary to manually delete these elements. In the specific case of this experimentation, where surface represents portion of a terrain, the easiest solution is mending each Nurbs with the nearby. A future development in this workflow is the definition of a boundary curve, which include all the points that will be imported into the algorithm. Once this curve has been defined, a culling procedure should be activated, so that the outside points will be automatically deleted.

### 4. Conclusions

With the proposed methodology, the three-dimensional maps and models have been elaborated and they represent only one step which highlights the effectiveness of the procedure. A first simple step forward is the possibility to coordinate the three-dimensional model with a georeferenced texture of the territory, to get a photorealistic model of the landscape whose precision is limited only by the DTM mesh pitch. The explained procedure is provided with a certain degree of automation, because it only needs in input the raster shapefile of DTM to provide the three dimension terrain model. It is an important result because of the barrier which separates architectural and urban/territorial world. The application of this parametric design method to the territory could change its trajectory from a research tool that is difficult for non-experts to understand for software in common use by part of the actors of urban, territorial and regional transformations.

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