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Multi-technicalities approach to the preservation survey: modeling and reconstruction of Arquata del Tronto

In August of 2016, the town of Arquata del Tronto suffered an earthquake that produced significant damages to the village and the medieval Rocca's structure and integrity.
The earthquakes of 2016 and 2017 greatly damaged the structures added to the castle and the historical construction itself: the roof was perforated, the battlements fell, parts of the walls themselves crumbled. These events were understood as opportunities. The Rocca was still standing after the series of unfortunate events, thus holding a new symbolic function for Arquata.
This proposal aims to research a method to regenerate the place by following three scales of intervention unified in the landscape: territorial, urban and architectural. Based on the various reflections and analyses derived from the different survey models, we demonstrate that preservation actions depend on minor and necessary interventions in terms of connection and building restoration while keeping the cultural background and importance of the area intact. To do this, an accurate territorial and architectural survey is needed, based on mixed techniques between landscape and architecture. The aim of the process developed is the analysis of the site accessibility, creating a hinge between the survey, the restoration, and finally, an evaluation of the restoration project inserted in the territory itself.

Keywords:
Landscape; Photogrammetry; DTM; Parametric; Mapping; Representation

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*E non è forse superfluo ricordare a un'epoca che ha fatto del «digitale» il proprio perno centrale (ben al di là, con tutta evidenza, del solo ambito architettonico) che dietro il mondo dei numeri, dietro le cifre (*digits *in inglese, da cui il verbo* digitalize*, «convertire in una sequenza di cifre») c'è pur sempre il dito (*digitus*). E il dito, è la mano che conta, E ancora di più: e il digitus che dicit, che dice, che parla. Di ciò dovrebbe tener conto una cultura come quella progettuale attuale che, pur essendo prevalentemente digitale, ha ben poco a che fare con le dita, con le mani, con il corpo.* [1]

AIMS

In August of 2016, the town of Arquata del Tronto suffered an earthquake that produced significant damages to the village and the medieval Rocca's structure and integrity.
The earthquakes of 2016 and 2017 greatly damaged the structures added to the castle and the historical construction itself: the roof was perforated, the battlements fell, parts of the walls themselves crumbled. These events were understood as opportunities. The Rocca was still standing after the series of unfortunate events, thus holding a new symbolic function for Arquata.
This proposal aims to research a method to regenerate the place by following three scales of intervention unified in the landscape: territorial, urban and architectural.(Bianchi, 2020) Based on the various reflections and analyses derived from the different survey models, we demonstrate that preservation actions depend on minor and necessary interventions in terms of connection and building restoration (Carbonara, 2011) while keeping the cultural background and importance of the area intact. To do this, an accurate territorial and architectural survey is needed, based on mixed techniques between landscape and architecture. The aim of the process developed is the analysis of the site accessibility, creating a hinge between the survey, the restoration, and finally, an evaluation of the restoration project inserted in the territory itself.

BACKGROUND

Arquata del Tronto is a 93 square kilometers territory in the Marche region, in central Italy. From a geographical point of view, it is a typical West-East tripartite landscape, going from the Apennines and their mountainous landscape (Marchetti, 2017) to the small coastal front on the Adriatic Sea. The typical climate is a standard mountain area, with temperatures ranging from 25°C in summer to -15°C in winter. Precipitations are common, whether rain or snow.
The Stronghold of Arquata del Tronto originated from a need for defensive and control Infrastructure (Gemignani, 2013) along the popular commercial route that used to be via Salaria. It held a function that required specific spaces: the Torre Maestra, a lookout tower, the circular tower, artillery, the courtyard, a space for the military to rest and reside over short periods. It was later abandoned, eventually recovered during the 20th century, when the stronghold was approaching the level of the ruin. The following section of the research was born from the desire to develop a methodology of geometric analysis of the territory that, through a specially designed digital tool, allows quantitative assessments useful for several purposes where high precision and quality of data are needed. The difficulty in using this type of procedure lies in the sectorialization of technical skills between those who work on the design at the architectural scale and those who, instead, work at the territorial scale.
The digital tool created as a result of this research, based on parametric and algorithmic methods, (Catmull, 1978) has an analysis capacity that can be used in multiple scenarios and at different scales. The scientific literature on the NURBS-based (Piegl, 1991)) spatial analysis has not yet been consolidated because the illustrated methodologies, while seemingly similar to the one under discussion, have significant differences when analyzing the results.
The tools that make up the workflow created with this research work constitute a sort of hinge between the scale of architectural detail and the territorial scale, considering the system as a multiscalar and multidisciplinary unicum (Bianchi, 2020) that allows the integration of analysis and design needs of architects, restorers, and urban planners, thus uniting territory and architecture.
The spatial analysis investigates the possibility of improving terrain modeling accuracy using NURBS tools rather than traditional Mesh tools. This tool was chosen because Mesh entities distort the terrain because they are composed of polygonal meshes instead of NURBS objects, which approximate the terrain more accurately.
The use of NURBS entities instead of meshes is fundamental for the multiscalarity of the proposed analyses. At the widest scales, the efficiency of the mesh ecosystem is excellent, but the system goes into crisis as the level of detail increases. When one descends from the territorial scale to the urban scale, problems emerge. The first is in geometric terms because the polygonal geometry at the base of the mesh degrades the perception of the landscape, which passes from an organic form to an unattractive angular form. Furthermore, Nurbs geometry allows modification flexibility that mesh geometry does not, primarily when the built environment must interact with the landscape. In this case, the use of the mesh system becomes extremely more complex because digital tools operating at the urban, but above all architectural, scale work better with NURBS architectures both in terms of efficiency and flexibility.
The innovation within this methodology is using a digital ecosystem that embraces both the landscape and the built environment with the same characteristics. A traditional methodology assembles the geometric characteristics of the territory, commonly in mesh form, with those of the buildings, usually CAD/NURBS, very rarely mesh. Combining these two forms of digital representation leads to a whole series of problems in joining geometries. Representation systems generated with two different types - e.g., Mesh/NURBS, or MESH, CAD - need conversion operations to standardize the system with geometric entities belonging to the same family. This alteration leads in the first instance to a reduction in com-

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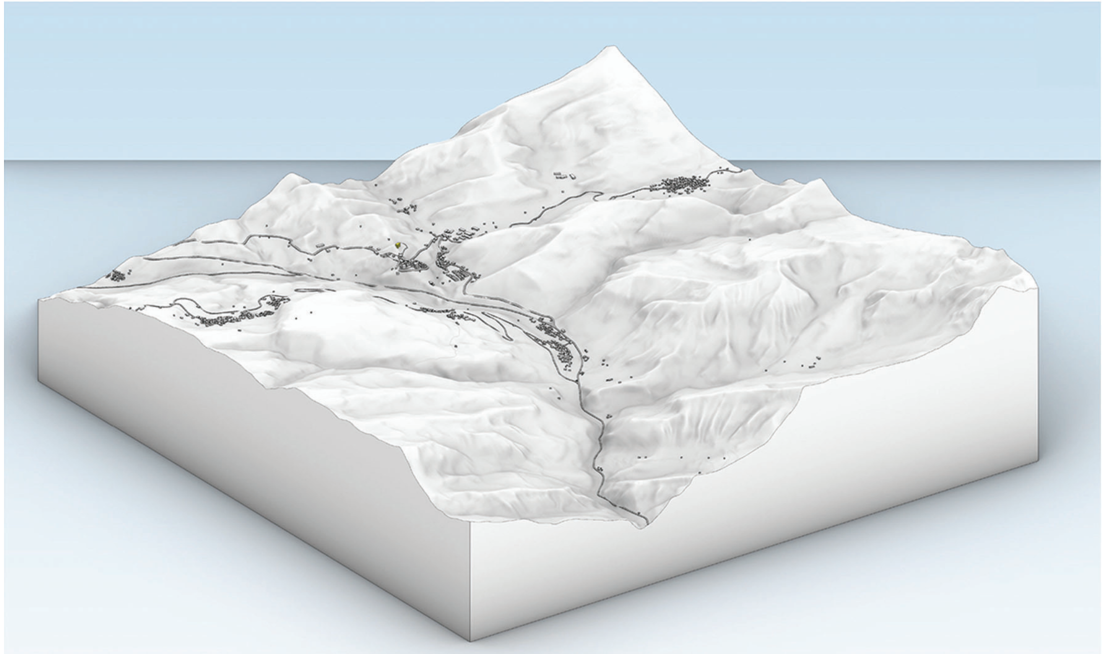

Fig. 1 - NURBS model obtained from DTM raster.

putational efficiency, which in landscape modeling is always a problem due to the multiplicity of data handled. Secondly, the accuracy of the geometry is thus compromised and degraded during conversion. Therefore, it is understandable why having an everyday basis for the geometric data used becomes a strength of this methodology.

METHODOLOGY

Data for the case-study area's parametric 3D model were found by selecting them from an Open Data cartographic database. Data from the raster DTM, in particular, were used. They are organized in grids, with each point determined by its interpolated height. The use of Grasshopper, (Belesky, 2018) a digital parametric tool designed for a visual scripting language, was critical for managing this amount of data in three dimensions. As a result, the procedure provides a cloud of georeferenced elevation points that faithfully represent the case-study territory. Instead of meshes, the mathematical structure known as NURBS was chosen for this purpose. This procedure can generate a surface that passes through each point of a three-dimensional grid; this decision was made due to a NURBS modeler's inner strength as Rhino, which bases his strength and operational efficiency on the generation and manipulation of mathematical entities.
For the development of facades of the fortress, the different images captured at various angles by drone-camera and hand-camera were used on Metashape and Photoshop to achieve the elevation of the four facades. The mixed techniques produced the photoplans and were strategically placed onto the 2D Autocad elevations to achieve a close to reality image for the façade. Then, the fortress was modeled individually using SketchUp, and the developed 2D photoplans were projected onto this basic model.

A PARAMETRIC APPROACH TO LANDSCAPE MODELING TOWARDS SUSTAINABLE DESIGN METHODS

The premise that gave rise to this research work is the clear division between landscape modeling at the architectural and territorial scales. Work-related to these two branches travels at different scales, with different tools, and is generally performed by different professionals. However, this methodology preconfigures a workflow that merges these two worlds and could provide synergistic benefits on both fronts. When these analyses are performed at a territorial scale, the third dimension is neglected, creating substantial gaps in the analysis and results. The digital tool developed with this research, based on parametric and algorithmic methods, can perform the mentioned operations in multiple scenarios and at different scales. This type of procedure also provides an innovative approach to the relationship between different scales of representation and design. With standard analysis tools, the design process begins at the large scale with a more conceptual approach that affects artifacts at smaller scales. Instead, the parametric approach allows the design at an intermediate scale that dialogues directly with the major scale, relating to the context, and with the minor scale, deepening aesthetic and tectonic issues. (Belesky, 2018) This dialogue occurs within a continuous flow of information exchange between the different scales and numerical control of the individual elements involved. The spatial analysis studies the possibility of increasing the accuracy and flexibility of land modeling with NURBS instead of traditional tools based on Mesh models. The choice of this tool is due to the polygonal aspect of Mesh entities that distort the representation of the terrain since they are composed of polygonal meshes.

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On the contrary, NURBS objects approximate the terrain using mathematical functions that, after multiple attempts, have revealed a reasonable degree of accuracy. A synergy between the territorial, urban and architectural scales is a direct consequence of using the same tools applied, in this way, in every context. The conducted analysis will be influenced by the accuracy of the data, proportional to the increase of the scale of representation. Therefore, the central part of the research was to create connections between the individual data to obtain a single system that provides results of acceptable accuracy at each level of investigation.
Based on these considerations and the data available on the individual territories, it was deemed appropriate, to begin with the acquisition of spatial data from which it was possible to deduce information subsequently integrated with data from the built environment.
The data processing methodology explained in this paper aims to facilitate the manipulation and analysis of specific areas, starting from spatial mapping data to obtain a three-dimensional model. The scientific literature related to this specific topic is not yet consolidated because the methodologies already investigated, although apparently similar to the one under discussion, present some differences that are, however, substantial in the analysis of the results. Among others, a research that places its analysis foundation on spatial modeling with Mesh technology (Zhong, D.; Liu, J.; Li, M.; Hao, C., 2008) focuses on the use of DTM for digital reconstruction of parts of the territory to perform a NURBS analysis for hydroelectric engineering. In this case, the authors' methodology offers reasons for constructing a three-dimensional mesh model from a DTM using algorithms that exploit Delaunay triangulation. Contour lines are subsequently extracted at a specific interval, and a NURBS surface is interpolated from them. However, the result suffers from a lack of data excluded from the interpolation due to the sampling performed of the contour extraction. Another example of a similar experience carried out on an Italian case study is the one that focused on the 3D reconstruction of the City of Amatrice (Calvano

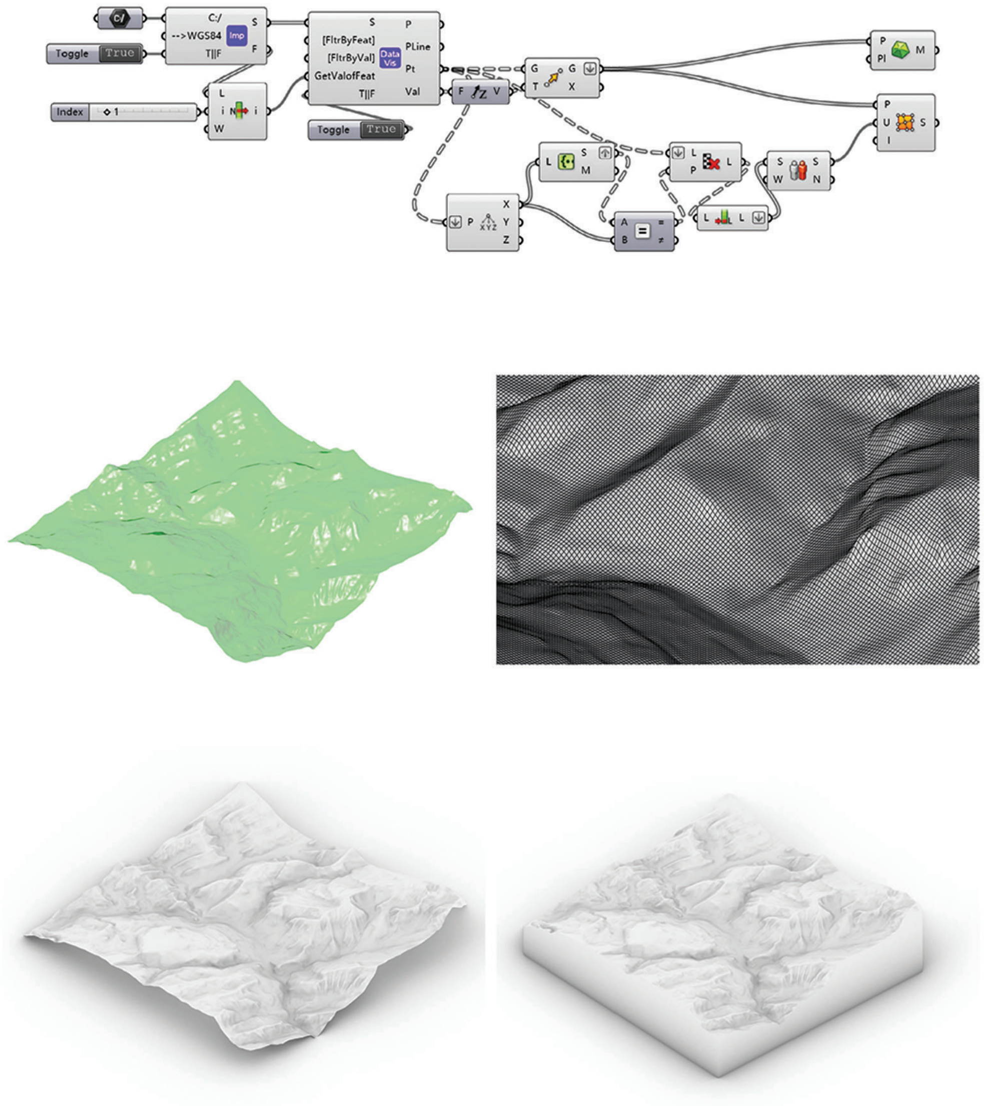

Fig. 2 - Landscape 3D model obtained from NURBS.

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& Guadagnoli,2016). The proposed methodology uses the same methodology as mentioned earlier (sampling contour lines from a DTM, extracting control points and finally creating a mesh with the Delaunay triangulation), making the same kind of approximations. Data used to model the buildings in 3D were moreover scraped from OpenStreetMap (www.openstreetmap.org), an open source geodatabase that allows users to modify and enrich themselves, making data not coming from official sources and therefore subject by their nature to interpretation.
The discussed methodology uses tools belonging to the GIS family and those typical of generative modeling (D'Uva, D., 2017). The working methodology applies the processing of spatial 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 point coordinate of the DTM is associated with a z-height that transforms the grid into a three-dimensional network of points. The methodology produces a set of three-dimensional NURBS vectors to which different types of geometric editing can be applied.

THE METHODOLOGY IN THE DETAIL

In order to generate the parametric 3D model of the case study area (Woodbury, R., 2010), data were retrieved by selecting them from a seamless digital terrain model (DTM) of the whole Italian territory, named TINITALY/01 (also known as the "TINITALY" DTM, in short), presented in 2007 (Tarquini et al. 2007*). This DTM was obtained starting from separate DTMs of single administrative regions of Italy. The DTM is freely available as a 10 m-cell size grid (in GeoTIFF format) in the UTM WGS 84 zone 32 projection system. DTMs represent the trend of the soil surface cleared of all anthropogenic and vegetation elements. Digital terrain models are used to describe the morphology of the territory; they are structured in grids in which the georeferenced spatial position interpolated during the survey determines each point. The DTM grid used is square, and each element has a 10m x 10m pitch; this allows for sufficiently accurate data as a starting point. The processing of this data required a rather complex procedure. In order to manage this amount of data in three dimensions, the use of Grasshopper (Tedeschi, A., 2014) - a parametric digital tool designed for a visual scripting programming language - was fundamental. Since it is a three-dimensional raster, it is necessary to process the DTM in a GIS environment to extract the points accompanied by their geometric coordinates readable in a 3D modeler. The procedure is performed using a GRASS algorithm in QGis that generates a vector shapefile representing a grid of equidistant points with a step of 10 meters georeferenced according to the UTM-WGS84 coordinate system. It was necessary to use tools specifically designed to handle this type of file in Grasshopper because these usually belong to the GIS software family. Once imported, the points are read as an ordered list of two-dimensional elements. The elevation data are then extracted from the attribute table, making it possible to place each point in its real position in the three-dimensional space. At this point in the procedure, we have obtained a cloud of georeferenced points that faithfully represents a part of the territory. It was chosen, as already mentioned, to use the mathematical model known as NURBS. In this sense, a Gh component was chosen to interpolate a surface from a point cloud. The latter, to work properly, needs an additional parameter called "u" (Valenti, 2010) that represents the intrinsic coordinates of each point laying on the surface that will be generated. To calculate it in Gh, with reference to the cloud of points described above, it is necessary to know the number of elements contained in one of the "n" rows of the ordered mesh (considering the points that make up the mesh ordered in rows and columns all of the same steps of 10m). The problem encountered is that by default, the points are ordered in numerical lists (Tedeschi, 2014) in which the indices (and therefore the position of the points in the list) are only increasing (from 0 to "n" where "n" is the total number of points). It was then decided to divide the list into sublists containing only the points with the same value of x and then calculate their number (thus calculating the number of columns that make up the mesh). The sublists now have the same number of elements since they are ordered in a square mesh. To do this, the x-coordinates of each point are extracted, then stored in separate lists and finally, their mutual equality is tested. In this way, a Boolean exclusion pattern is generated by which data are sorted into sublists that satisfy the rule already explained. At this point, it is possible to know the number of elements in each sublist, so the scripting component in Gh is fed with fundamental data for the final generation of the NURBS surface. It then represents the portion of the territory under analysis at a scale of 1:1. This decision is due to the internal strength of a NURBS modeler like Rhino, within which Gh works, which bases its strength and operational efficiency on the generation and manipulation of mathematical entities. Moreover, the amount of information required for a NURBS representation of a geometric element is much less than the amount of information required to represent the same geometry with mesh approximations (Mazure, 2016) (D'Uva, 2021). An example of the flexibility of the NURBS model is the ability to extract contour lines from a spatial model easily; applying the same operation to a mesh surface, however, will result in a polygon. However, NURBS are not always the best choice for this type of operation. Mesh models can lighten the computational load for large portions of territory and speed up the algorithm by using Delaunay triangulation, skipping the calculations of all the parameters needed to create the mathematical surface. In this case, NURBS is overkill because the mesh can achieve a similar result with less computation. A mesh representation would strongly impact landscape definition with a less precise quantity (and quality) of data, so a NURBS representation is desirable. The procedures used to represent the other vector data (buildings, urban perimeters, railways, roads) are similar to those described above. Some steps of this procedure offer particular cues for further elaboration and research. In particular, in the use of the algorithm

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Fig. 3 - Rendered 3D model of the Medieval Stronghold, its surroundings, and the village of Arquata del Tronto.

aimed at the visualization of buildings, after having imported the points and programmed first-degree interpolation lines between them, the problem encountered was obtaining closed vertical extrusions with a value equal to the exact height of the buildings. To solve the first problem, the centroids were extracted from the geometries and projected onto the main NURBS surface. Next, the geometries were vertically translated along the vector connecting the centroids to their projections and then extruded by a value equal to their actual height associated with each geometry (contained in the attribute table of the initial shapefile).

INNOVATIVE ASPECTS AND FUTURE DEVELOPMENT

This type of methodology innovation lies in the multiscalarity and synergy between the three-dimensional precision modeling and the perceptual coherence of the photogrammetric approach. The modeling developed through NURBS provides flexibility in the accuracy of processing both at the spatial scale and the architectural scale. Photogrammetry is essential to complete the analysis. Future developments in this type of research are in the direction of greater integration between the tools already described. The use of this digital ecosystem will allow the analysis and quantitative control of the elements that are present on-site and the possibilities of the preservation and new design actions.
The integrating modeling, among multiscalarity and different approaches to the software procedures, may become a way to a tangible or intangible generative process of the representation of the territory and architecture, from an interactive representation of the landscape to a dynamic museum of the cultural heritage itself. These are the future developments for the multi-technicalities approach to the preservation survey, where even a disaster like the earthquake (Earthquake August, 2016) in Arquata del Tronto can suggest us a completely different scenario of thinking, managed not only in a traditional approach of hard restoration but also in the virtual procedure of digital communication of what is not convenient even impossible rebuild without forget the sense of our actions.

RESULTS AND CONCLUSIONS

The survey is a result of different software and techniques, the main concern before modeling the area was to get the accurate overlay, but the positioning of the river simplified the process as they

Fig. 4 - Photogrammetric restitution of the four facades of the stronghold at the current state and at the design state. The project hypotheses developed by the students were made possible by the studies undertaken using the described methodology.

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followed the valley bed. The use of NURBS technology allows flexibility that the traditional workflow from GIS to Mesh does not allow, especially in the modification of geometric elements inherited at the architectural scale from the territorial one. The result of this analysis faces a contemporary issue related to preservation activities, where the obstacles at the survey (vegetation, strong slope, stones, and other elements) became a strategy to invent a mixed methodology to achieve a good and believable basis for the project. We are looking for a new process handbook suitable for the contemporary management of the restoration science, where 3d modeling and digital procedures can help professionals in their decisions in a sort of continuous interactivity between survey and design, going on and going back, along the pathway of the project. So, for example, the decision of rebuilding a preexisting - and destroyed by the time - tower of the castle can depend on a number of data collected by the overlapped analysis, historical, structural, new necessities, aesthetics.

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NOTE

[1] And it is perhaps not superfluous to remind an era that has made the "digital" its central pivot (well beyond, with all evidence, the architectural sphere alone) that behind the world of numbers, behind digits (hence the verb digitalize, "to convert into a sequence of digits") there is still the finger (digitus). And the finger, it is the hand that counts, and even more: it is the digitus that dicit, that says, that speaks. This should be taken into account by a culture such as the current design culture, which, although predominantly digital, has very little to do with fingers, hands or the body (p.129).
Translation by the authors.

REFERENCES

Belesky, P. , 2018 , The Green Grasshopper: Approaches to Teaching Computational Design Methods in Landscape Architecture. *Journal of Digital Landscape Architecture*, 3-2018, pp. 406-413.

Bianchi, A., D'Uva, D., & Rolando, A. (2020). AN INNOVATIONAL DIGITAL TOOL IN GIS PROCEDURE: MAPPING ADRIATIC COAST IN ABRUZZO REGION TO SUPPORT DESIGN OF SLOW MOBILITY ROUTES. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLIII-B4-2020, 533–537 https://doi.org/10.5194/isprs-archives-xliii-b4-2020-533-2020

Bianchi, A., D'Uva, D., Rolando, A., & Scandiffio, A. (2020). A view from the track: Measuring spatial quality of slow mobility routes. Possible integration of GIS and machine learning based methods. In *CONNETTERE - UN DISEGNO PER ANNODARE E TESSERE · CONNECTING - DRAWING FOR WEAVING RELATIONSHIPS*. FrancoAngeli srl. http://dx.doi.org/10.3280/oa-548.163

Calvano, M, & Guadagnoli, F. (2016). Ricostruzione 3D della città di Amatrice. Una operazione di 'instant modeling. *DisegnareCon*, 17/2016, ISSN 1828-5961.

Biraghi, M. (2021). *Questa è architettura. Il progetto come filosofia della prassi*. Einaudi.

Carbonara, G. (2011). *Architettura d'oggi e restauro. Un confronto antico-nuovo*. Utet.

Catmull, E., & Clark, J. (1978). Recursively generated B-spline surfaces on arbitrary topological meshes. *Computer-Aided Design*, 10(6), 350–355. https://doi.org/10.1016/0010-4485(78)90110-0

Earthquake August 2016, info available at: http://www.protezionecivile.gov.it/attivita-rischi/rischio-sismico/emergenze/centro-italia-2016 (Accessed 18 March 2021).

D'Uva, D., & Eugeni, F. (2021). DTM to NURBS—A parametric approach to landscape modeling for an environmentally-conscious design. *Sustainability*, 13(4), 2379. https://doi.org/10.3390/su13042379

Gemignani. (2013). *L'occhio sul paesaggio. Archivi fotografici locali e patrimonio rurale della montagna appenninica: Archivi fotografici locali e patrimonio rurale della montagna appenninica*. FrancoAngeli.

Marchetti, M., Panunzi, S., & Pazzagli, R. (a cura di). (2017). *Aree interne. Per una rinascita dei territori rurali e montani*. Rubettino.

Mazure, M.-L. (2016). NURBS or not NURBS? *Comptes Rendus Mathematique*, 354(7), 747–750. https://doi.org/10.1016/j.crma.2016.01.027

Piegl, L. (1991). On NURBS: A survey. *IEEE Computer Graphics and Applications*, 11(1), 55–71. https://doi.org/10.1109/38.67702

Tarquini, S., Isola, I., Favalli, M., Mazzarini, F., Bisson, M., Pareschi, M. T., & Boschi, E. (2009). TINITALY/01: A new Triangular Irregular Network of Italy. *Annals of Geophysics*, 50(3). https://doi.org/10.4401/ag-4424

Tedeschi, A. (2014). *AAD algorithms-aided design. Parametric strategies using Grasshopper*. Le Penseur Publisher.

Valenti, G.M. (2010). *De.form.are*. Roma Design Più Editore.

DOI: https://doi.org/10.20365/disegnarecon.27.2021.15