LOCATION MAPPING AND SPATIAL ANALYSIS TO MITIGATE THE RISK OF EXTINCTION OF A PAST ARTEFACT. (GYPSUM CEILINGS IN PIEDMONT)

A. Spanò
[a] DINSE, II Facoltà di Architettura, viale Mattioli 39 – 10125 – Torino - antonia.spano@polito.it

KEY WORDS: location mapping, spatial analyses, GIS.orthoimages, LIDAR models, CH vulnerability.

ABSTRACT

In Piedmont a widespread handmade artefact has grown for several centuries starting from the 16th century AD. They are the so called gypsum ceilings, i.e. a simple and ingenious building system that replaces the wooden planking lean on beam warping with a gypsum jetty. The success of such building technique in the countryside, produced with poor material, is due to the large availability of raw materials and to the possibility of obtaining ornate ceilings, which hearken back to the richer carved and painted coffers, typically used in higher quality building. Geometrical, flowery and many other kinds of decorations have been obtained through the simple means of carved wooden patterns.

Avoiding the extinction of such heritage, which is being methodically replaced, has the role of rebuilding the history and the identity of the territory, and this can be obtained by sharing awareness of them.

One of the most important aspects concerning the gypsum ceilings, constituted by load bearing panels, is their geographical distribution. The sighting of repeated decoration typologies and the identification of contemporary ones, gives the opportunity to use ornate gypsum panels as dating elements addressing the issue of settlement growth. [E. Fiandra, 2000]

Many geomatic applications have been employed to aid in the spreading of their knowledge and to provide useful information to several studies interested this kind of cultural heritage: starting from historical investigations, to artistic and stylistic studies, from anthropological to social and economic implications connected to the circulation of skilled workers.

The organization of a geographic information system, targeted specifically to thematic mapping for the representation of territorial distribution of a phenomenon, has been carried out. Furthermore suitable GIS analyses, based on spatial and statistical parameters, have been implemented in order to express renewed hypotheses regarding the development of the ceilings. After all we confide that such approach can be applied to investigate and analyze other similar example of non-monumental heritage.

The metric survey, performed by LIDAR and photogrammetric acquisitions, and the following 3D processing applied to obtain surface models with ortho-proiected textures of some selected samples of gypsum panels, can allow for an increased consciousness, even through the web, to integrate the educational purposes of current expositions in regional museums.

1. INTRODUCTION

The gypsum ceilings are a very interesting phenomenon that testify how the past traditions and know-how in the field of building have generated a peculiar constructive solution for farmhouses and houses in small villages of the Piedmont countryside. Such ceilings have static features which have astonished experts in structures and in building technologies.

Gypsum ornate ceilings have been built from the late ‘500 till the end of the XIX sec. (at least this in temporal frame corresponding to what we know is the currently known period of diffusion, documented by recorded models).

The main features of ceilings are as follows[1]:

- They constitute an evolution from the more simple wooden plank floors.
- They are a daring solution from a static point of view because they function as floors supported by reinforced concrete beams.
  (the laying was realized upon a wooden grid of oak beams and joists, spaced in such a way as to be able to position a carved wooden mould, measuring about 45x 180cm. At the moment of the cast of the gypsum mixture, small chestnut, or hazel branches or reeds were thrown in, serving the same function as the iron bars drowned in concrete. The first cast was made of superfine gypsum because it had to reproduce the ornamental drawing in the negative carved mold; the subsequent castings were coarser).
- The diffusion of these kind of ceilings is based on the exploitation of the available raw material. The gypsum can be widely found as gypsum lens located in the in the geological clay layers of the Messianic, largely present in the Monferrato areas.
- The success of decorated ceilings is also due to the serial production of panels, coming from wooden moulds used several times, in different houses and sometimes in different villages.
- The variety of drawings and ornamental elements of these panels makes this practice a meaningful artistic expression of rural culture.

In this paper we are going to present how such historical research can benefit from various methodologies of data collection and organization typical of Geomatics. The research featured by detailed and widespread investigation on the

[1] The CIRAAS (International center of archaeological, anthropological and historical researches), directed by E. Fiandra has endorsed the study and the census of decorated ceilings. (the publication of the “Catalogue of decorated gypsum ceilings” by CIRAAS is forthcoming). During the years the center has availed itself of the collaboration of many researchers (Dr. G. Mangiapane, Dr. M. Capellina, Dr. D. Mondo, Arch. C. Corradino, Arch. G. Chiaramenllo, Arch. I. Vigna, Arch. L. Spriano, Dr. N. Savio, Dr. P. Ostino). The CIRAAS, in cooperation with central and local administration offices and with regional eco-museums, has promoted the establishment of permanent museum collections.
http://www.comune.maglianoalfieri.cn.it/compaginagt.asp?id=1288&S=6861&C=5
http://www.comune.moncucco.asti.it/castello/museogesso/
http://www.romaspqr.it/roma/Musei/Museo_arti_e_tradizioni_popolari.htm
http://www.lacabalesta.it/testi/percorsi/percorsigesso.html

territory, collecting a huge amount of documentary material, especially photographs; (experts have located and catalogued 236 different typologies of ceilings, located in four different districts of Piedmont: Asti, Alessandria, Cuneo, Torino). An organization of a geographical information system with consequent location mapping and close range survey applications performed by digital photogrammetry and LIDAR techniques have been carried out to support the general research. (Fig. 1)

2. RESEARCH AIMS

In this report we propose to highlight how the development by means of computer resources of this study was performed according to three main objectives:

A. Organization of a geographical information system, with relative drafting of more than 140 digital maps, representing and furthering the investigation concerning the territorial propagation and distribution of different typologies of ceiling decorative elements. CIRAAS researchers have recognized 120 different ornamental typologies, grouping them in 10 classes called “type of ceilings” and assigning them capital letters: raceme decoration (A), religious symbols (B), mixed elements such as flowers, stars and birds (C), imitation of wooden frameworks (D), imitation of carved doors or windows (E), single drawing covering the whole panel surface (F), original drawing(G), anthropological element (H), pastoral scenes (I), geometrical ornamental drawing (L). (Fig. 2)

B. Accomplishment of close range metric surveys, realized as educational activities for the courses of Architectural survey and Digital Photogrammetry at the II faculty of Architecture (Politecnico di Torino). Some decorated panels and a whole gypsum ceiling have been surveyed by photogrammetric and LIDAR methodologies; a high scale digital map, managed in a 3d-GIS environment, has been derived by the fusion of a technical regional map, a cadastral map and the integration of terrain surveys, prevalently oriented to obtaining rendered buildings by ortho-controlled images.

C. The third objective is aimed to achieve spatial analyses pertaining the investigation of the territorial distribution of decorative typologies of ceilings; the point is to verify if the exploitation of such an analysis tool is suitable for suggesting renewed hypotheses relatively to its development on the territory. This portion of the research could seek to answer questions like, for example, why some areas have been a higher vocation to introduce some ornamental drawings rather than others.

The spatial statistic includes tools that enable to analyze by means of specific statistic parameters, a spatial distribution of geographical elements; the establishment of logical grouping of territorial elements based on their location and on other similar features can improve the comprehension of the dynamics driving settlement and diffusion.

3. ORGANIZING THE DATABASE AND GIS REPRESENTATION TOOLS

The spatial representation of ceiling typology distribution has been accomplished thanks tpthe the use of the basic 1:100000 scale datasets made avilable to users by the Piedmont Regional mapping office through the regional cartographic web server; only some selected data, basicly altimetric data for the terrain spatial model representation, have been processed from higher scale data.

Even though every catalogued ceiling is paired with the village or town it was found in, we decided to represent their presence and typologies connecting this information to polygons representing administrative boundaries of municipalities.

The database organization is based upon a table containing the identification code and the name of each of the 120 typologies discovered and upon the dataset of municipal boundaries of Piedmont. The representation of typology distribution, based on GIS tools, has employed a RGB code as ordering element: every ceiling typology is connected to a specific rgb code, which is selected from a nuance identifying the ceiling type.

1. The simple relation between boundaries and the presence of typologies has allowed to carry out 120 spatial location maps (Fig. 3).

2. A large set of selection queries has enabled to assign the differently combined presence of typologies to each boundary. This kind of data selection and representation enables to clarify if typologies appear in a detached mode or if they aggregate among typologies of the same kind. The representation of different combinations of presence has been established by e new set of rgb codes, again connected to the grouping nuance. Since a very large number of rgb codes have been used, a joined legend has been essential to understand how many and which typologies are attested in every municipal boundary. The number of maps representing ceiling type distribution is obviously 10.

Each map shows how many typologies are in each group, how many boundaries are involved in the distribution of each type, how many combination of typologies are present in the territory. (Fig. 4)

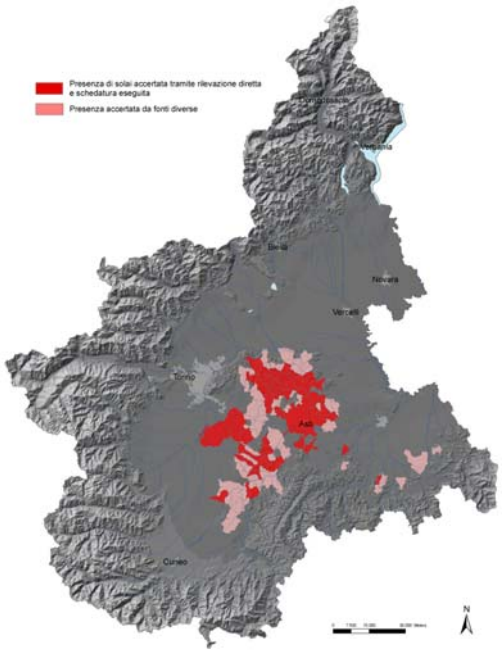
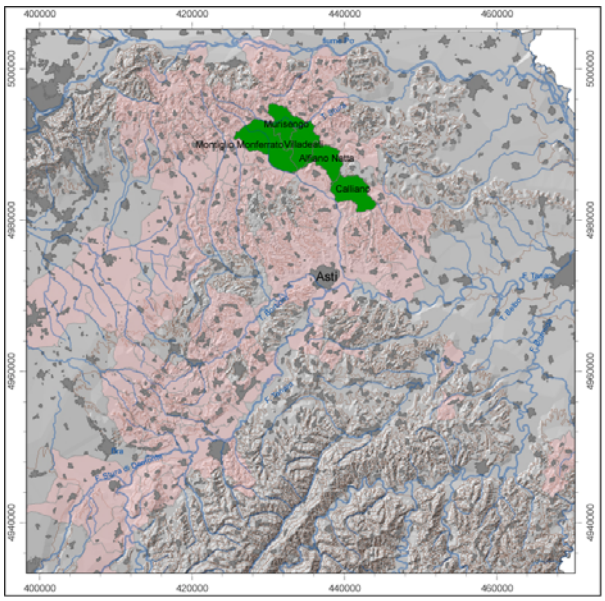


Figure 1. Propagation of decorated gypsum ceilings in the Piedmont territory. Dark red shows areas where floors have been catalogued, while light red means that the presence has been noted but not surveyed. The phenomenon interest the 8.8% of Piedmont municipalities.

Figure 2 – Some examples of decorated gypsum ceilings selected from several groups (CIRAAS Archive).



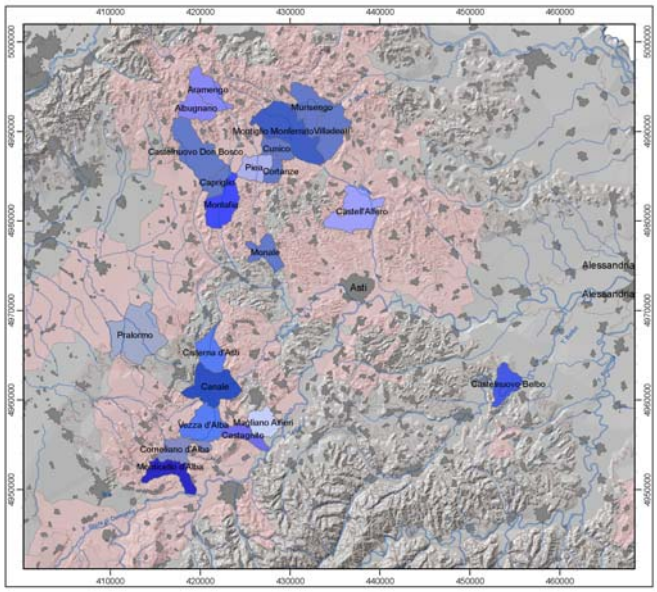


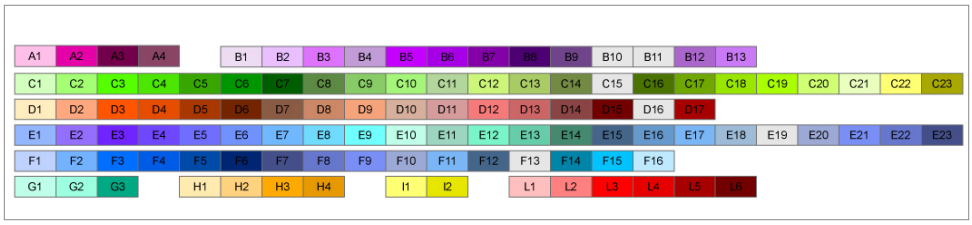
Figure 3 – An example of first set map (registered presence of C6 typologies of ceilings). One rgb code points out boundaries of municipalities where ceilings have been observed and registered. (original scale 1:600000)

Figure 4 – An example of second set map (extension of territorial distribution of ceiling type F). Rgb codes indicate combination of typologies rather than typologies.

Distribuzione territoriale delle diverse tipologie di solaio del tipo F.

N

- tipologia F1: Aramengo, Albugnano
- tipologia F2: Montiglio Monferrato
- tipologia F3: Capriglio, Castelnuovo Don Bosco, Cortanze, Cunico, Monale, Murisengo, Villadeati
- tipologia F4: Piea
- tipologie F3, F5: Montafia
- tipologia F6: Castell'Alfero
- tipologia F7: Cisterna d'Asti, Vezza d'Alba
- tipologia F8: Pralormo
- tipologie F8, F16: Castagnito
- tipologie F8, F9, F10: Canale
- tipologia F11: Monticello d'Alba
- tipologia F12: Magliano Alfieri
- tipologia F13: Castelnuovo Belbo
- tipologie F14, F15: Corneliano d'Alba



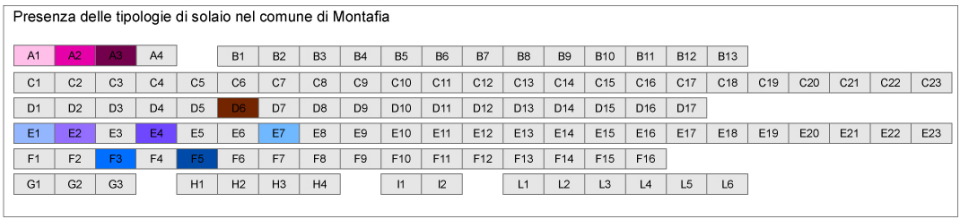


Figure 5 – (a) The abacus symbolized by every rgb code of typologies. (the relationship between rgb code and typology id codes allows to apply the same symbols to maps and to abacus frames.

(b) an example of symbolized abacus; it shows the result derived from associating entity frame and the selection query aimed to group the ceiling typologies existing in Montafia d'Asti.

3. Since the first two set of location maps do not allow to represent the combination in each municipality of typologies belonging to different types (typologies grouping), another form of representation has been introduced.
An abacus made of 120 elementary geometric entities has been created; each cell of the abacus has been joined to the id-code of typologies so as to establish a relation with a set of queries selecting every typology documented in each municipality.
The number of symbolized abacus-frames are equal to the number of municipalities where a decorated gypsum ceiling is attested (56). These last frames have to be read in relation to the first set of location maps, in order to connect the information of a single typology presence with all the possible spatial combinations and with other typologies, selected from the total set of ornamental drawings. (Fig. 5).

4 . CLOSE RANGE SURVEYS – EDUCATIONAL ACTIVITIES

In the II Faculty of Architecture (Politecnico di Torino) educational curricula include Topography and Photogrammetry courses focusing on Architectural and Urban Survey; the special aim of these courses is to tech the basic concepts concerning acquisition, processing and representation of metric data, in compliance with the rigouros approaches of those disciplines which nowadays go under the term Geomatics.
Its operative nature can be found in its vocation which distinguishes the educational contents of the teachings intended for students in Architecture; often the choise of study cases allows the pursuing of investigations in the fields of History of Architecture, Restoration, technological aspects of Architecture, planning and design which are concerned with landscape identity issues.
The chance of suggesting the gypsum ceilings subject, besides allowing us to address a study which deals with

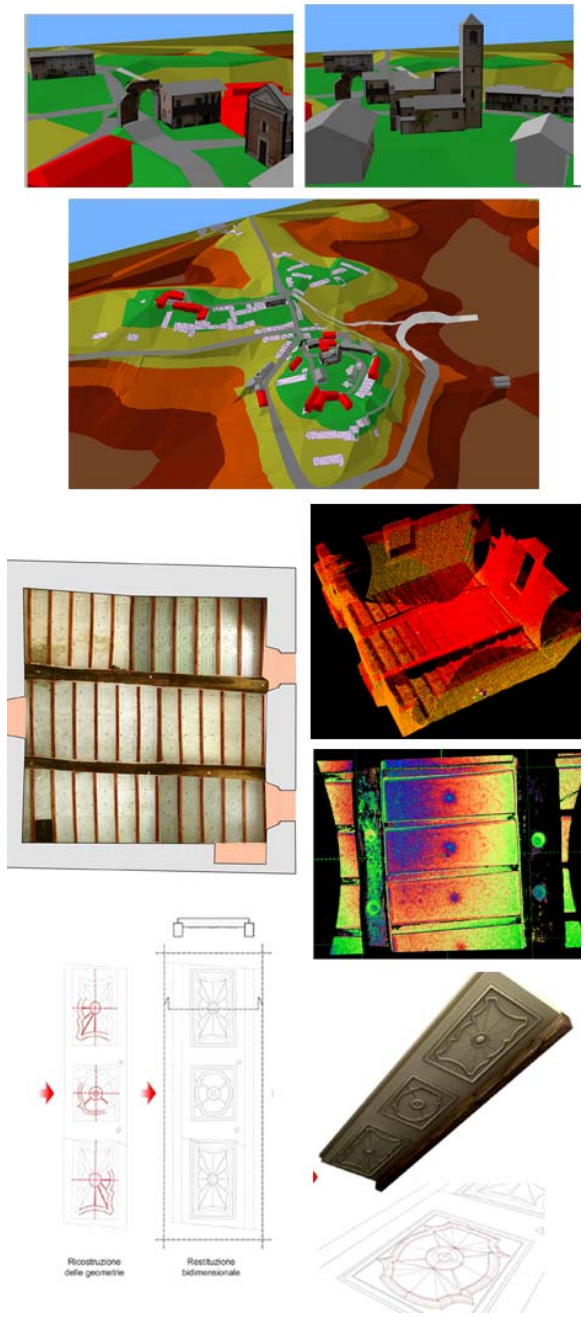


Figure 6 – (a, b, c) Close and bird flight views of 3D map. (d) plan, from bottom to top, of a whole ceiling, yielded by photogrammetric orthoprojection. (e, f) processing phases of points clouds registration and altimetric definition of dense dtm (DDEM) for the drawing reading. (g) production of a continuous 3D model after triangulation and analyses of geometric features of drawing.

different scales, from the rural landscape to the ornate details, also allowed us to deal with the spatial data management issues, aimed at obtaining a 3D map managed in a tridimensional GIS environment; moreover the close range surveys of ceiling panels have been carried out through Lidar and digital photogrammetry techniques. (Fig 6)

In this paper we can report only few details pertaining the training activities, but we can assert that the objective of carrying out a tridimensional map concerning a small town in the Monferrato area, at a higher scale than the Regional technical map, has been achieved by integrating the cadastral map, conveying more detailed planimetric information. In the raster-vector conversion careful attention has been paid to the arrangement of geometric entities in compliance with rules of topographical databases. The altimetric information has been integrated with on site data collection by means of cinematic GPS method; thank to the enhancement of altimetric information a new more detailed digital elevation model (DEM) has been used to locate roads and buildings.

The buildings facades have been surveyed and processed using the images plane projection technique, and they have been metrically referred to correspondent planes of 3D geometric entities.

The gypsum ceilings survey has been performed by integrating laser scanning and photogrammetric techniques; a photogrammetric projection produced the orthophoto of the whole ceiling, while smaller gridded points clouds have been exploited to deepen the analysis of decorative drawing.

5. SPATIAL ANALYSES

Creating location maps has highlighted how the distribution of different ceiling typologies has grown with extremely variable dynamics. Some ceiling type (the groups of typologies) have largely developed in areas with extensions similar to global diffusion, while others are grouped in smaller areas; some of them are present in neighbouring municipalities, while others seem to be located randomly. Moreover, observing the distribution of single typologies, we can notice that some of them are registered in a single municipality, or that the presence in more towns is extremely infrequent, while others are attested in several municipalities, even far away from each other.

Since the ceiling development is probably based on skilled workers moving to places where their skills were needed, one of the first objectives was to achieve a more summary representation of the general phenomenon. Figure 7 shows the total extension of distribution with the ramp colour pointing out the typologies variety assessed in each municipality. The visual analysis of the map seems to underline the presence of two fulcra (blue in the map), one in the Monferrato and one in the Roero[2].

The second summary representation is carried out by the typology abacus; it shows the total of discovered examples, classified according to typologies. (fig 8).

Some tests comprising the typical tools of spatial statistic have been performed: the first is the *Spatial autocorrelation* algorithm (Moran's I), while the second is the *Average nearest neighbour* algorithm. Both of them are aimed to provide a measure of the spatial distribution features and they are able to point out logical trend.

The spatial statistic works as the statistic inference which allows to predict distribution behaviours, comparing the results with a predefined hypothesis; the starting assumption is that a behaviour is totally stochastic (this it's called null hypothesis), and the purpose of the analysis is to refute it. Therefore, analyses results have to be accompanied by significance level indexes (likelihood index and Z-score)

The *Spatial autocorrelation* algorithm (Moran's I) searches a probable similarity among near elements, on the basis of their position and one attribute. The test has been performed for every sufficiently numerous ceiling type; the test has considered the position of centroids of municipalities boundaries and it has been weighted by the variety of ceiling typologies in each municipality.

The Moran's index denotes a clustered distribution if it's closer to +1, or a dispersed distribution if it's closer to -1.

The *Average Nearest Neighbour* algorithm computes the distances between each observed element and its nearest, afterwards it computes the average distances. It measures how the observed average distance is similar to one yielded by a hypothetical random distribution. (Only distances are considered and not other numeric attributes)

The results (Tab1) show an absence of clusters in the autocorrelation test and a substantial dispersed distribution in the second one (there is a single value for *Average Nearest Neighbour* index which is barely close to a clustered result, but the z-score value is high)

The results seem to point out an absence of cluster distribution, but it's necessary to observe that the introducing of the typologies variety in the first test surely meant introducing a very stochastic factor.

A last statistical analysis tool has also been employed: it's the *central feature* detection. This algorithm is based on the computing of the smallest distance among observations; even in this case the variety of typologies has been inserted as a weighting factor (here it plays a more significant role). Test results are shown in figure 9: two municipalities, Montafia in Monferrato and Guarene in Roero, have emerged as central for two types of ceilings, respectively Montafia for Band F and Guarene for H and L types.

6. CONCLUSIONS

Conclusions no-doubt differ for three proposed objectives. Concerning the firsts two, i.e. organizing the database, and generating location maps and the close range surveys and models, we can state that they achieve the purpose to enhance the ceilings study and they aid in augmenting the consciousness of their artistic and historical value.

Regarding the spatial analyses, we can say that the little information they have been able to add can be due to the nature of the raw data we have at our disposal. We can't forget that the ceilings census is almost able to comply with the diffusion phenomenon, but it also denotes the destruction and the methodical replacement; the ceilings loss has surely a stochastic behaviour!

[2] The Monferrato and the Roero are two areas of south Piedmont featuring a different identity, a different landscape, devoted to different economic activities, mostly related to the wine-making.

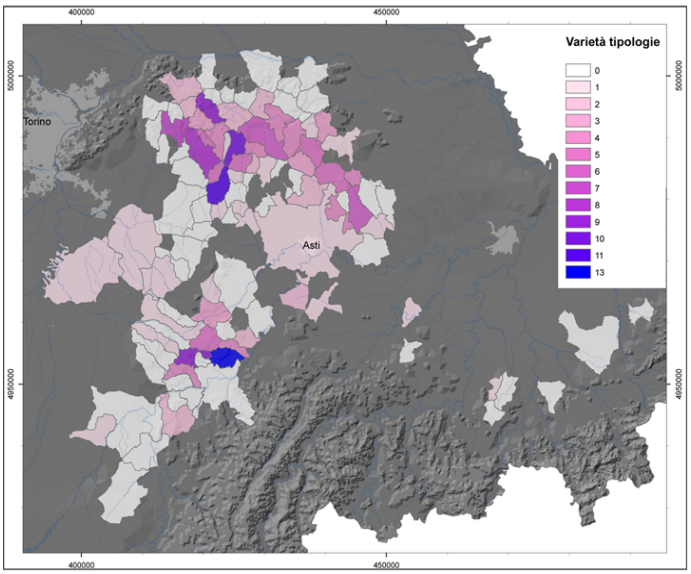


Figure 7 - the total extension of distribution with the ramp colour pointing out the typologies variety assessed in each municipality. The visual analysis of the map seems to underline the presence of two fulcra (blue in the map) one in the Monferrato and one in the Roero.

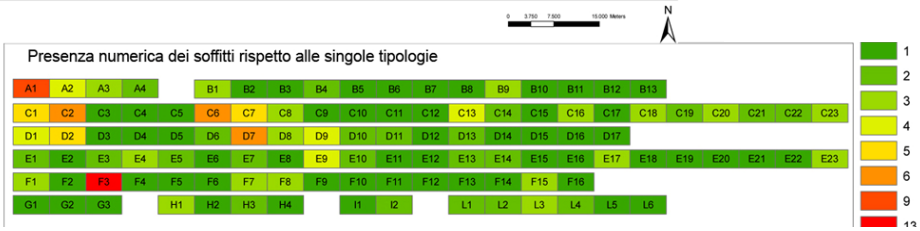


Figure 8 – A summary representation generated by the typology abacus; it shows the total of discovered examples classified according to typologies.

	SPATIAL AUTOCORRELATION				AVERAGE NEAREST NEIGHBOR	
	Morans index	Z score	variance	expected index	Ann Index	z-score
tipologia A	-0,0321	0,764 SD	0,02	-0,142	0,084	3,3 SD
tipologia B	-0,0219	0,789 SD	0,007	-0,0909	1,38	2,53 SD
tipologia C	-0,0257	0,355 SD	0,001	-0,04	1,12	1,21 SD
tipologia D	-0,03	0,36 SD	0,002	-0,045	1,36	3,3 SD
tipologia E	-0,09		0,004	-0,055	1,15	1,21 SD
Tipologia F	0,005	0,87 SD	0,003	-0,045	1,07	0,61 SD
Tipologia G	(troppo poco numerosa)					
Tipologia I	(presente in un unico comune)					
Tipologia L	(troppo poco numerosa)					

Table 1 - *Spatial autocorrelation* and *Average Nearest Neighbour* results. The test has been performed for every sufficiently numerous ceiling type. The results show an absence of clusters in the autocorrelation test and a substantial dispersed distribution in the second one.

It's important to notice that the calculation of the central elements has confirmed an information that appeared to be identifiable already from the visual analyses of the maps.
In the light of the results we can suggest historic experts to verify the hypothesis concerning the existence of two skilled workers schools, the first with a likely origin in Montafia or neighbouring villages, and a second one coming from Guarene or its surroundings.

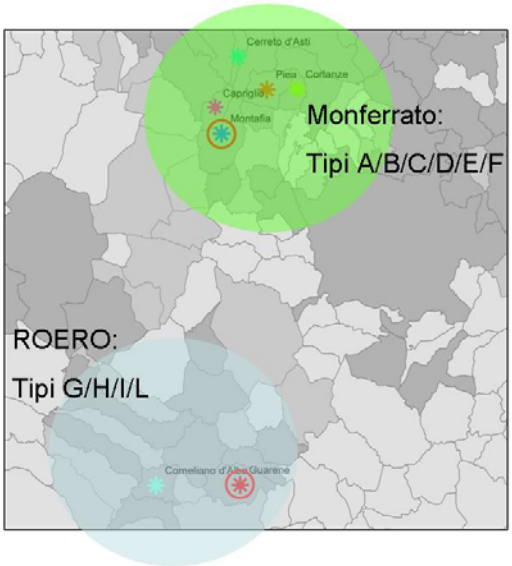


Figure 9 - Test results of *central feature* detection: two municipalities, Montafia in Monferrato and Guarene in Roero, have emerged as central for two types of ceilings, respectively Montafia for Band F and Guarene for H and L types. Ceiling types A,B, C, D, E, F are preferably located in Monferrato, while types G,H, L in Roero area.

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ACKNOWLEDGEMENTS

I would like to thank some students involved in training experiences, especially C. Alfero, P. Abellone, E. Ottino, C. Vizzini and E. Costamagna (Phd student).