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HOW TO RECONSTRUCT THE HUMAN MOBILITY IN MOUNTAINOUS AREA. A CASE FROM NORTH-EASTERN ITALY

1. Introduction

Today, the reconstruction of mobility network is becoming a more and more important line of research, in particular in flat areas. Nevertheless, some scholars had already developed methods to study viability and mobility in mountain (Llobera 2000; De Silva, Pizziolo 2001; Fàbrega Alvarez 2006; Fàbrega Alvarez, Parcero Oubiňa 2007; Murrieta-Flores 2012). The majority of these ones had produced algorithms to draw Least Cost Paths, which represent the fastest and less costly path between two points. At the contrary, the intent of this research is to elaborate a methodology in order to obtain a mobility network, which consists in one or more nets of paths which run from a common point in all directions around it, describing a possible mobility grid that involves all the analysed territory.

In fact, the particular objective of this approach is to understand how many contemporary routes in an area follow ancient mobility halls and how much antique they are. The method adopted (Mascarello 2021) is based on the modification and compenetration of two other theories. The first one developed by C. Citter (2019), using algorithms for hydrographical analysis, the second one by P. Murrieta-Flores (2012), which adopted the Line Density Analysis to identify the level of accessibility of an area. The work presented had been developed in a small region in the Northeast of Italy, named Feltrino (BL), in a time frame that runs from the Bronze Age to the Contemporary. The goal was the identification of continuities and breaks in human mobility strategies between five different periods: Bronze Age, Late Roman (IV-VI centuries), Middle Age (XII-XIII centuries), Modern Age (XV-XVII centuries) and Contemporary.

2. Methodology

We first step with collecting all the historical and archaeological information about the analysed territory, selecting the better represented historical periods and creating maps of settlements and archaeological areas for each one using a GIS (Geographic Information System). Then, we select and map the natural features which could have better influenced human mobility: for example morphology (outlined through the algorithm TPI-Topographic Position Index), hydrography, slope, passes. In case of important changes along time, we could produce more maps for one feature. It is important to underline that the parameters need to be chosen every time, in relation with the characteristics of the region. The next passage consists in the creation of friction surfaces by reclassifying maps with the allocation of a series of weights. These run from 0 (no difficulty) to 70 (maximum difficulty). We do not use the score 100, because we really do not know the abilities of ancient people in moving through mountainous environment and what they perceive as unaccessible. Different strategies were applied to weigh maps according to their peculiarity.

For example, in a map showing dots, such as attractive points or passes, the application of Multi Ring Buffer (MRB) was useful to suggest the algorithm to attract or discourage the crossing. A different weight is attributed to each ring in order to encourage the crossing. On the contrary, in hydrography, rivers have the highest weight, while the rest of the environment has the smallest one, in order to underline the impossibility to go through the water without bridges. If the presence of some bridges is testified, they become part of the environmental base and assume its weight. Finally, in the TPI, weights are related to the geomorphological characteristics of the area while for slope their amount increase in relation with the rising of percentage of slope. When all maps are made, a weighted sum for every period considered need to be made, in order to create the cost surfaces, simply using the raster calculator.

These resulted maps are the bases to elaborate the cumulative cost surfaces. This method provides the application of the algorithm r.walk.points, in which we use as starting points the vector maps of settlements and arriving points are not considered. In this way, it would be possible to estimate the potential movement in every direction around each settlement. The cumulative cost surfaces represent the environment in which the potential paths networks run. They are generated by the application of another algorithm, Channels network and drainage basins, and start from selected points, that could be settlements or passes or some other types of sites. At the end, a map with some moving networks is obtained for every historical period analysed.

At this point, based on the works of M. Llobera (2000) and P. Murrieta-Flores (2012), we realised a Line Density Analysis through the application of the tool Line Density (available in QGIS from the version 3.16), in order to generate more general moving halls that could be easier to match, but also more likely to represent the human ability to move in their territory. The halls created represent the density of paths that are included in their width, which could be defined in relation with geomorphological characteristics. In our opinion, in relation with mountainous areas, it is better to use short range buffers because of the rapid variation of altimetry and geomorphological features. A map for each period has been produced.

Finally, we compare the Line Density maps created through both the sums of couples of them of consecutive periods and the sum of all of them, so that the common corridors are more visible. The first solution underlines continuity and breaks between two consecutive periods, the second one the continuity in the *longue durée*.

3. CASE STUDY

3.1 *Location*

The area of application and development of this method is a 215 square km region, named Feltrino (BL), in the Northeast of Italy (Fig. 1). Its territory is partially enclosed in the National Park of the Dolomiti Bellunesi and thanks to the variety of its landscape, it is resulted an ideal place. In fact, its morphology run from valley bottom to middle hight plateaus, on which were and are today located the majority of settlements, to upper glacial circles and mountainous peaks. The glacial circles, also named "buse", are basins produced by the erosion of the incoming of glaciers during the last Wurm Ice Age, between 75.000 and 12.000 years BP. The mountain range of Vette Feltrine, which characterised this area, have ever been a transit hall because of their location along the boundary between reigns, duchy, and today regions. And we have information about changes that occur in its environment along time, both from archaeological findings and historical sources and from geomorphological and hydrological researches. All the specificities indicated before became fundamental in the choice of this place for the application of this method.

3.2 *Application of the methodology*

Both historical and archaeological data, hydrological and geomorphological information about the Feltrino region had been collected and all had been mapped on a GIS platform. The platform selected was the open source

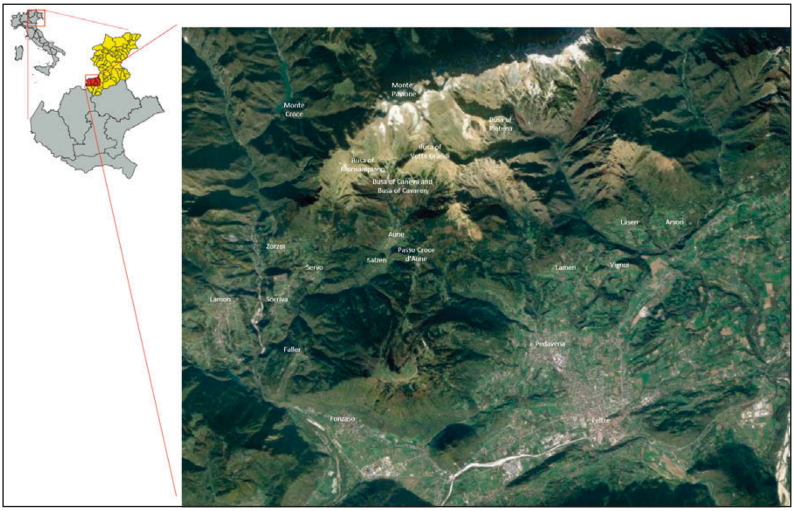

Fig. 1 – General view of the area of Feltrino (by C. Mascarello).

QGIS, in particular two versions: the 2.18 with GRASS 7.4.1 and SAGA 2.3.2, for the simplest elaborations, and the 3.16 implemented by GRASS 7.8.5 and SAGA 2.3.2 for the most particular ones. Some historical periods had been selected, due to the amount of information collected: Bronze Age, late Roman (IV-VI centuries), Middle Age (XII-XIII centuries) and Modern Age (XV-XVII centuries). We produced two maps for each one representing settlements and archaeological areas. Moreover, some selected natural characteristics were mapped: slope, hydrography, mountainous passes and morphology. All the maps were based on the CTR (Carta Tecnica Regionale, scale 1:10.000) and the DTM (Digital Terrain Model, scale 1:5000) available on the Geoportale of Veneto (https://idt2.regione.veneto.it/geoportal).

One of the main characteristics of this research is that it was developed on three different scales of work: the littlest one strictly involves the mountainous area of Vette Feltrine, the middle one is referred to the boundaries of the municipality of Sovramonte, the biggest includes all the Feltrino region. Based on the variable mapped, we built the cost surfaces. Firstly, the elements of every map were weighed, giving a score from 0 to 70 in order to indicate where the human movement could be easier or more difficult. Different methodologies were used: a score had been given directly to the element and another, usually of opposite amount, to the rest of the environment, for example for hydrology. In this case, rivers had the highest weight, while the rest of the territory, included bridges, had the lowest. In the maps with dots, for example archaeological areas or passes, we applied a multi ring buffer (MRB) to every element represented, in order to encourage the crossing, but not oblige it. Increasing scores were given to the rings starting from the central one, the closest to the point, whose weight was 0. This same rating was assigned to the base representing the rest of the territory. The third method, used for slope and TPI, consisted in assigning different weights where changings occur, for example, with the rising of the percentage of slope or with changing in geomorphological characteristics.

When all maps were created, a weighted sums of them for every period need to be evaluated, in order to create a cost surface. It could be done in the raster calculator, as exemplified:

TPI * 0.2 + mountain passes * 0.2 + hydrography * 0.2 + slope * 0.2 + sporadic findings * 0.2

These cost surfaces were the bases for the construction of the cumulative cost surfaces. This method provides the application of the algorithm r.walk. points of GRASS, where the maps of settlements were considered as starting points. Arriving points were not considered and the DEM (Digital Elevation Model) was the referring map for elevation. For all other parameters, the default data were maintained. On the cumulative cost surfaces, we applied the algorithm of SAGA Channels network and drainage basins. A map with some path networks was created for every period. We decided for a threshold of 6 and settlements resulted as starting points. The last step consisted in the application of the Line Density Analysis. For every analysed period, we created a map of networks of movement halls with 100 m of radius. As said before, the use of a short range buffer is due to the rapid change of altimetry and geomorphological features that occur in mountain. Finally, we compared the results obtained through both the sum of couples of maps of consecutive periods and the sum of all of them, to understand continuities and breaks in the hypothetical human mobility network in the Feltrino region along time.

3.3 *The change of the parameters in the function of r.walk*

A collateral test had been attempted during the elaboration of the cumulative cost surfaces. Some parameters of the function of the tool r.walk were modified, in order to try out a more reliable terrain model. It was also useful to understand if some changes occurred in channel networks compared with those obtained using standard parameters. In particular, the parameter b (additional walking time in seconds, per meter of elevation gain on uphill slopes, corresponding to +6 s/m; Langmuir 1984; Minetti 1995) were changed. We deduced the necessary steps from an article of the physiopathologist A. Minetti (1995), starting from the walking time in seconds and the elevation gain in meters, as in the example:

1. Speed calculation in m/s.
2. Changing from m/s to s/m.
3. Subtraction of the time that occur for walking 1 m in plan (0.72 s).

The data were acquired both from field survey and from some trekking sites about Vette Feltrine area.

3.4 *The field surveys*

Some field surveys had been organised in the upland of Vette Feltrine. They occurred in three days and allowed us to better understand the morphology of this area. Moreover, we explored and traced with a GPS some paths both already in use and abandoned, in order to compare these traces with the hall networks obtained. For the first day, we climbed to the Vette Feltrine through a 3320 m path with 1200 m of elevation gain, climbed in 2 hour and 50 minutes. The second day, we explored the "buse": we walked about 20 km in 6 hours, without important elevation changes. The last day we came down through a different path. We hiked for about 19 km downhill and in the plain for 4 hours and a half.

During these surveys, every human trace had been documented through some photographs. A little percentage of paths resulted from the creation of maps of channel networks had been verified. And some of the enregistered data were used to calibrate the parameters applied in the different elaborations described above.

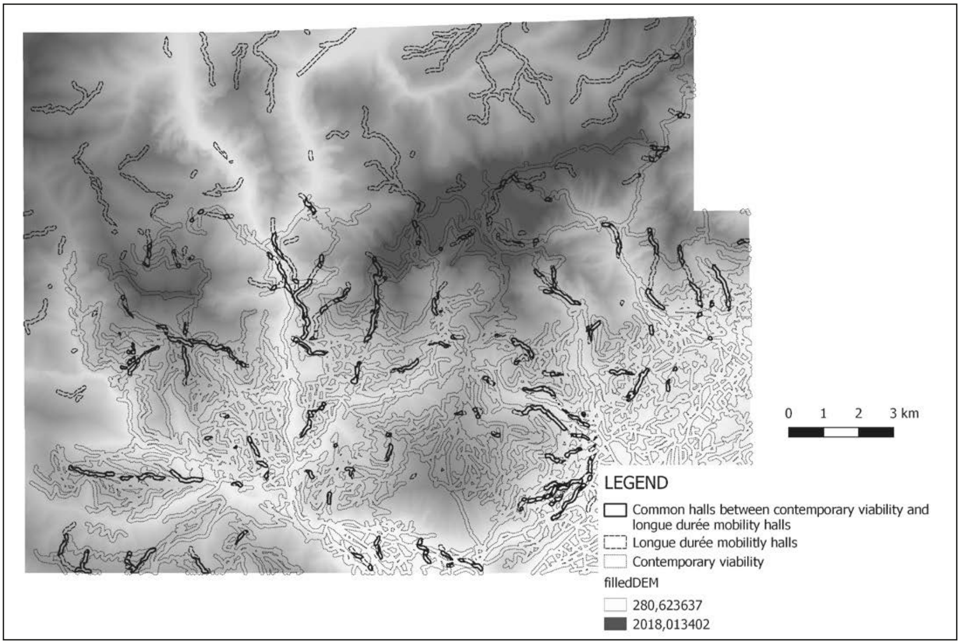

Fig. 2 – Contemporary routes in relation with the results of GIS elaborations. Dots lines correspond to contemporary viability, dashed lines represent the *longue durée* mobility corridors. Continuous lines draw paths resulted from the intersection between contemporary routes and the *longue durée* mobility (by C. Mascarello).

4. Conclusions and discussion

We compared the Line Density maps through both the sums of couples of them of consecutive periods and the sum of all of them, so that the common corridors are more visible. The second elaboration represents the *longue durée* and reveals a probable continuity along millennia of some of the mobility halls identified. They both climb from settlements to "buse" and passes and run between villages in the Feltrino valleys. Moreover, an overlay between this one and the contemporary street map shows several overlaps and a possible antiquity of some of the today's routes (Fig. 2). It is partially confirmed by the comparison with the Modern Age cartography, in particular the *Dissegno del Territorio di Feltre qual per comando dell'Illustrissimo et Eccellentissimo signor C.O.: Lodovico Flagini* of F. Grandis, dated to 1713 (Fig. 3) and the information from historical and archaeological sources.

About the changing of parameter b in the r.walk function, the most evident difference was a general upstream stretch of the paths: the higher the parameter b, the longer the channels. This phenomenon is due to the increase

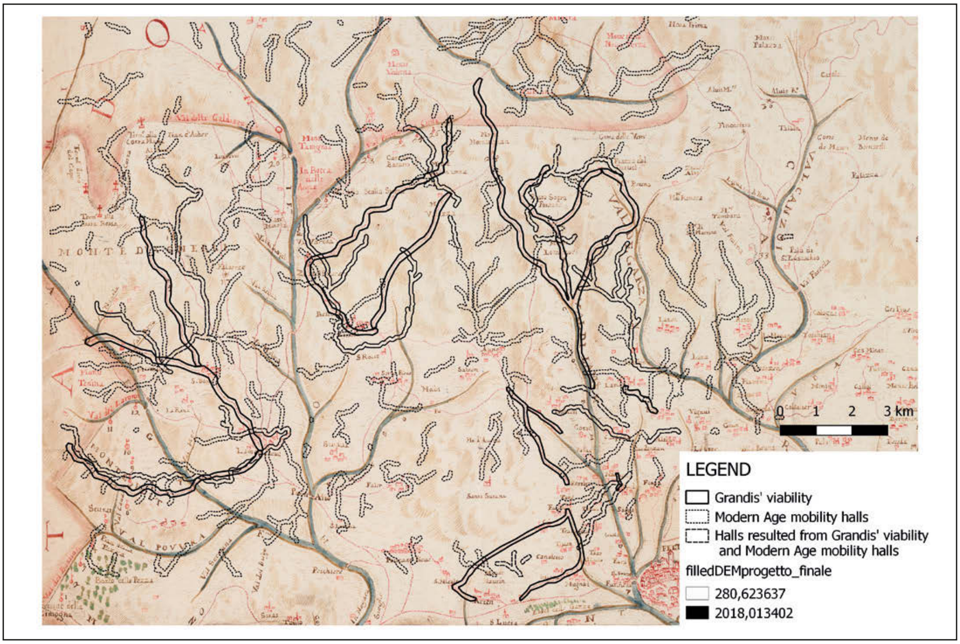

Fig. 3 – Continuous lines represent some tracks on the Francesco Grandis' map that could be compared with the Modern Age mobility corridors, indicated by dots lines. Dashed lines draw the mobility halls resulted by the comparison between Modern Age elaboration and Francesco Grandis' map (by C. Mascarello).

of areas with a less difficult transit, linked to a cheaper travel in term of physical costs due to the decrease of the speed during the hiking. Moreover, new paths resulted, in some cases with important correspondences with the viability on the CTR. No substantial shifts occurred in moving directions. All these results show that the morphology of mountainous environment strongly limits the corridors of transit and that the choice of a path is not influenced by the time, but by the necessity to gain the destination.

Obviously, we need to test the outcomes of these evaluations. We partially did it in the Vette Feltrine, though we still need to extend the survey. The main goal is now to re-trace the connectivity network, according to the evaluations and to check the intersections of the halls to test their archaeological potential. This approach can be applied to every mountainous environment, though the parameters should be calibrated.

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ABSTRACT

The aim of this research is to define a new methodology in order to reconstruct the historical human mobility network in mountain areas in a perspective of *longue durée*. Through the match of different types of data, in particular historical and archaeological sources, the analysis of environmental features and the application of a series of algorithms on a GIS platform, we produced a series of maps of possible mobility networks. The comparison between them and with the historical cartography emphasizes both continuities and breaks over time and outlines the reliability of the elaborations obtained. Our focus is a small region in the North-Eastern Italy, called Feltrino (BL), on a time frame from the Bronze Age to the modern times.