ACCURACY OF DIFFERENT GEOREFERENCING STRATEGIES ON HISTORICAL MAPS OF ROME

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Abstract

The map of the city of Rome 1:5000 scale of 1908 and the map of " Roma e l'agro Romano" that represents a wider area, realized in 1912 have been studied in earlier papers were parameters useful to perform the transformation of the used geodetic system in more modern systems were estimated. Here we want to evaluate the effect of different georeferencing strategies on these maps evaluating separately precision of the model and accuracy obtainable from the maps. The geodetic system used the ellipsoid of Bessel oriented locally in the geodetic observatory in Genoa, while for the projection was used conformal Flamsteed one. To be able to exclude that the deformations are mainly due to the different projection in comparison to the transverse of Mercatore used both for the UTM and for the national system used after 1940, called Gauss-Boaga and based on the Datum Roma40, we decided to study a transformation able to re-project the coordinates of the points with known coordinates as the vertexes of the cartographic elements. The reprojection of the maps need use of package with more complex algorithms of those available on the most diffused software to resample the raster images. After the geroreferencing step, the residual errors must be studied to assess the partial or complete remove of systematic errors. The map georeferenced using the cartographic reprojection can furnish a valid tool to detect variations as the geomorphologic variations due to natural and human causes within one century. The studied cartographies are one of the only existing documents that uniformly represents this whole territory and realized according to modern cartographic methodologies.

Key Words: *City of Rome, map, georeferencing strategies, cartographic reprojection.*

INTRODUCTION

The goal of this work is to find a method to accurate georeferencing of 1:5000 1908-13 maps of Rome and its surroundings. The importance of this study is due to the fact that different research fields dealing with diachronic territorial analysis need georeferenced historical maps. The areal extent of Rome has undergone different phases of evolution during its history. The city reached its largest extension during the Imperial period (100–200 A.D.) when the number of inhabitants exceeded one million. In the early Middle Age the hills encircled by the Aurelian walls were already abandoned; so the population had dropped down to 10 000 inhabitants, and the urban area was mostly restricted to the meander of the Tiber river. The urban development restarted after the return of the Pope from Avignon and had a boost during the Renaissance. The urban area we call today "the historical city" was completed and reached its highest. Since historical maps remain the only sources to understanding the urban aspect before expansion, it is important to accurately georeference them. (*Baiocchi et al., 2010*) In particular to gereferencing this historic maps it was necessary to study the geodetic datum transformation between ancient and modern one and also test the different georefencing algorithm to find the most efficient.

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The new features of QGIS environment make possible to separately estimate the accuracy and precision obtainable in in georeferencing raster maps and this characteristics can be of a particular interest for historic maps were usually deformations are bigger.

2. DATA

The map used in this work was produced by the "Military Geographic Institute" (IGM) as requested by the "Comune di Roma" that needed a topographic base for the city Regulatory Plan. The IGM produced a cartography in scale 1:5000 composed of six elements of extension 1'47" 'in latitude for 3'30" in longitude each, disposed on two columns and three lines, covering the whole territory of the city (**Fig. 1**) The survey and the editing of the maps finished in 1908. In 1912 a new updated version in 12 sheets, covering also some surrounding rural area, was produced. In both the maps the representation of buildings and the morphology of the ground has all the characteristics of a modern 1:5 000 scale map.

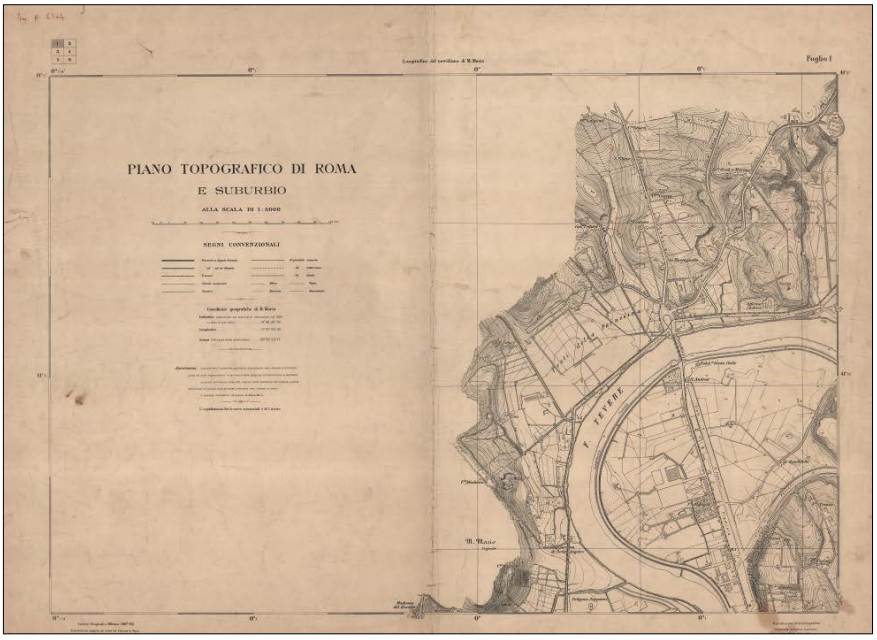

Fig. 1. The first of six elements of the historic maps.

In order to find the possible causes of map deformation and correctly georeference these maps, it was decided, in previous works, to investigate the geodetic system of reference.

In literature the IGM maps produced before 1940 generally are reported as referred to the ellipsoid of Bessel oriented to Genoa; this can be true for cartographies produced in the northern part of Italy but, a map produced by the IGM in 1908 for the city of Rome had to be referred to the ellipsoid of Bessel oriented to Monte Mario. It was concluded that the rotation between the two systems was very small so only a Latitude shift is needed, since the Longitude conventionally is considered equal to zero in both systems. The rotation, that cannot be readily determined because the orientation of the two datums has been referred to

different points (Monte Cavo for Bessel-Roma and Monte Soratte for Roma40), can be estimated to be as approximately 5" and lead to translations of less than one meter (which should be the graphic error of the cartography in study) for distances up to fifty kilometers (that go far beyond the extension of the study area).

3. RESULTS

In photogrammetry it's well known that precision of the orientation of the images can be estimated considering residuals on Ground Control Points (GCPs) while accuracy can be evaluated considering residuals on Check Points (CPs), points independent from parameter estimation. Exactly the same consiuderation can be made for the georeferencing of raster maps in a GIS environment; using QGIS software for georeferencing these historical maps, it was possible to extimate both precision and accuracy, while most of the other GIS software don't allow to use Check Points so actually they estimate only the precison but don't estimate the accuracy obtainable for the single map.

In addiction to this, QGIS offers the possibility to use more algorithms than most diffused commercial software, infact it’s possible to choose between:

- Linear
- Helmert
- Proiective
- Polinomial first to third order
- Thin Plate Spline

Moreover, QGIS offer the possibility to choose the resampling algorithm such as Nearest neighbour, Linear, Cubic, Cubic Spline etc... but in our tests we always use the first one that is the most conservative and for this reason it’s the most suitable for historic cartography.

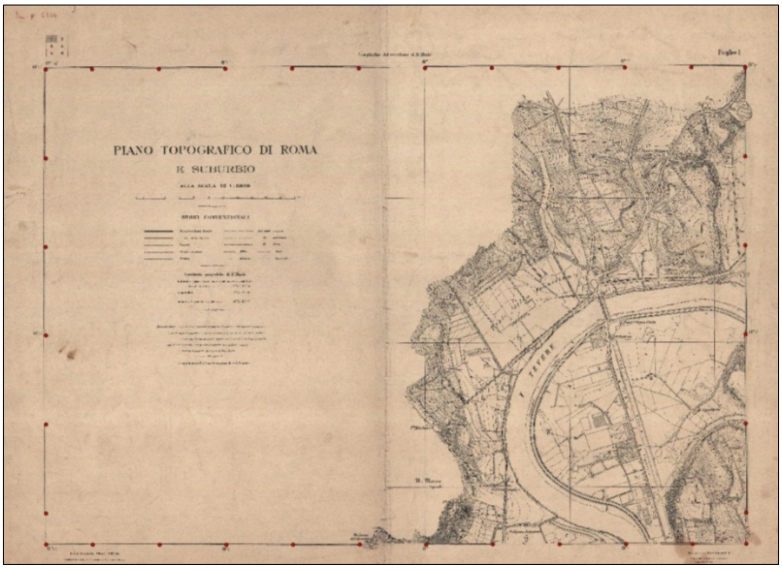

Fig. 2. Distribution of GCPs on the map.

Different series of georeferenciation tests were performed increasing number of GCPs used and observing the correspondent residuals on GCPs and CPs. All the results are here omitted for space reasons but we'll show the most representative results. We started whith the minimal number of GCPs required for each algorithm and then increasing two points at time. In this way we tried to find an homogeneous and symmetric distribution of GCPs in each test (**Fig. 2**).

As already remarked, on this paper we'll report only the results for second (**Fig. 3**) and third order polynomials cause we think they are the most suitable for this maps but we repeated the georeferencing for each map with all algorithms implemented in QGIS software. When trend of residuals seemed not realistic, different tests changing order of GCPs used where performed.

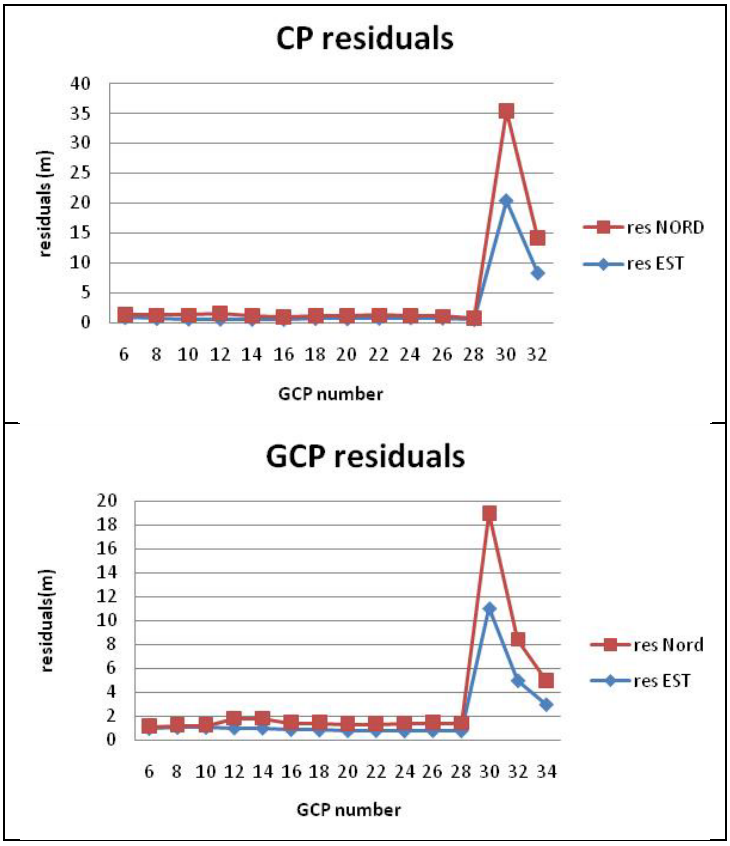

Fig. 3. Graphs of precision and accuracy obtained with second order polynomial function.

We observed a peak that we can't explain and so we investigated if there was an error on that specific points. We checked cartography coordinates and collimation on the image but we can't find anything of wrong. So we repeat the test changing the order of GCPs but we obtained the same result, as it is shown in **Fig. 4**.

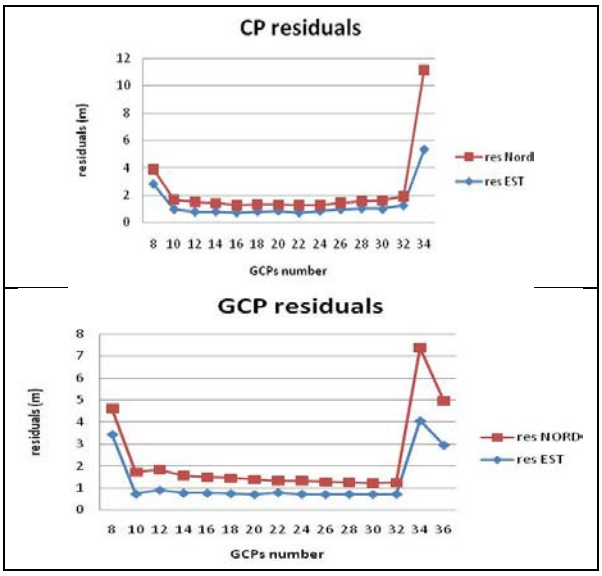

Fig. 4. Graphs of precision and accuracy obtained with second order polynomial function second test.

We can notice the presence of a peak but also in this case, we can't find an error in GCPs. Thinking that it was due to a problem of the software with this specific algorithm we repated the test with third order polynomial function (**Fig. 5**)

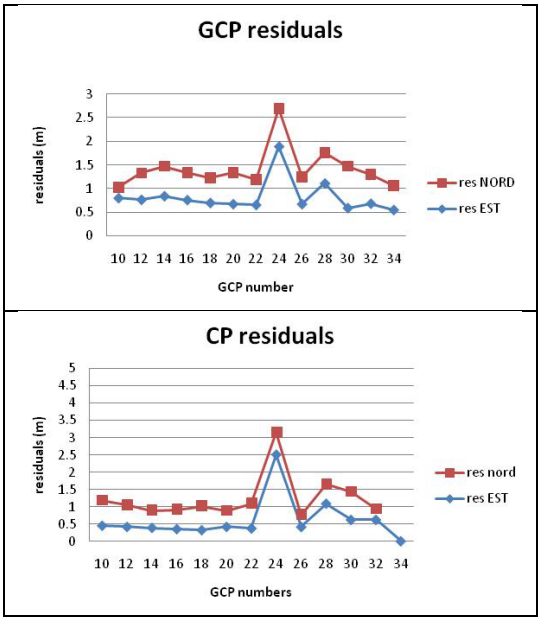

Fig. 5. Graphs of precision and accuracy obtained with third order polynomial function.

Using the third order polynomial function for georeferncing these maps we obtained a strange trend of residual on GCPs and CPs; there is again a peak even if it is after the minimum number of point required for the algorithm.

After this tests we tried to repeat them in ArcGIS 9.3, to evaluate if the cause of this problem is due to the software or to the data. The result obtained, in term of GCPs and CPs residual, were different from wich reported before.

So we suspect the reported the problem is to due to a "bug" in Q- GIS and for this reason we reported it on the Q-GIS development web site asking for an answer.

Table no. 1. Comparison between the results obtained with Arc GIS and QGIS.

RMSE of residuals (m)	***Arc GIS 9.3***	***QGIS 1.8***
Second order	1.05	3.66
Third order	0.55	0.88

This comparison seems to confirm our hypothesis about a bug in the software QGIS.

Although the strange trend obtained, we georeferenced our historic maps and we can observe (**Fig. 6**) a good correspondence between gereferenced historic map and a modern 1:2000 map of the same area (*Baiocchi et al., 2010*).

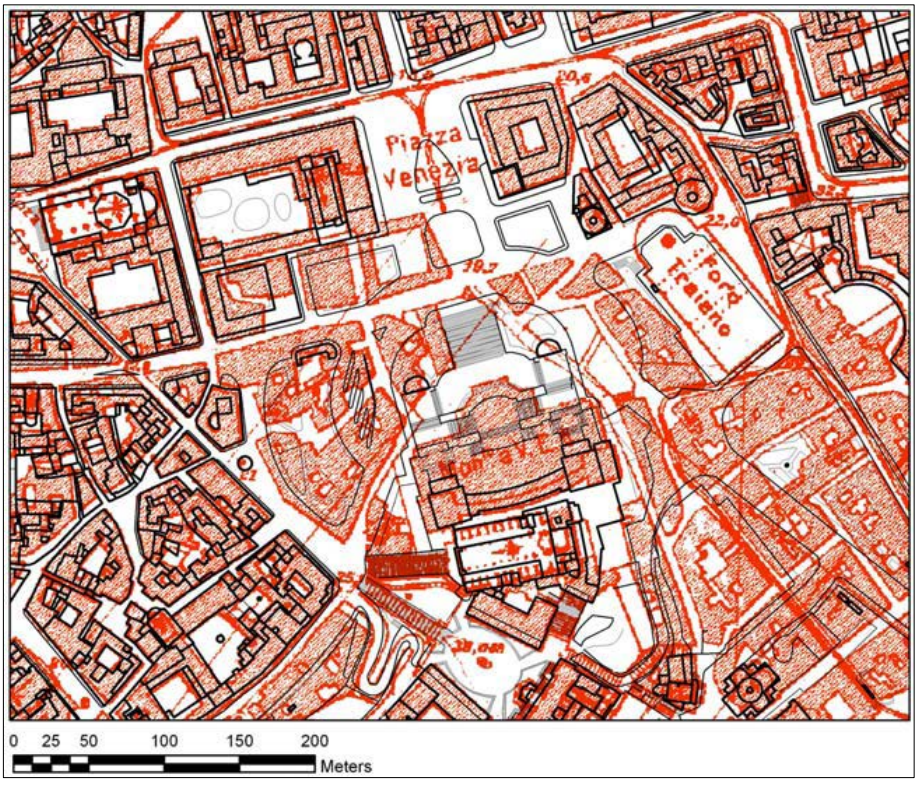

Fig. 6. 1908 1:5 000 map (red) compared with 2003 1:2 000 map of the same area.

4. CONCLUSIONS

QGIS implemented an impressive module for georeference-rectify raster files, very useful for historic maps but, at the end of this study we can conclude that more deep investigation has to be made on QGIS behavior to solve the probable bug of the software.

Maybe the developing of an external module for least square fit estimation is needed and after these steps and the assessment of the correct implementation of the transformations in QGIS the final correct georeferenciation of al the 1:5000 scale maps of Rome will be performed.

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