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Geomatic and Archival Sciences Applied to the Gregorian Cadastre of Bologna (Italy) for Analysis and Representation of the XIX Century Urban Arrangement

Keywords: Gregorian Cadastre; Bologna; floor maps; 3D digital modeling; urban arrangement

Summary: The research focuses on the first establishment urban map of the nineteenth century Gregorian Cadastre of Bologna, kept today at the State Archives of the city. In this cadastral cartography the city is divided into some sectors; for each sector – unique case in the Gregorian Cadastre of the ancient Papal State – there are ground floor maps and maps for the floors above and below. The present study aims to analyse this peculiar cadastre using digital tools deriving from the integration of geomatic and archival skills. For some test-areas, a careful comparative consultation of the graphical information stored in the georeferenced maps and the written one in the related cadastral registers is performed; this allows 3D digital reconstructions of the horizontal and vertical extent of the cadastral proprieties, and also thematic visualizations (e.g. according to owners, designed use, rent, etc.). This modern kind of representation allows a deep analysis of the complex nineteenth century arrangement of Bologna – still preserved in the ancient Gregorian Cadastre of the city –, highlighting some interesting aspects which otherwise would remain invisible. Thus, it turns to be a powerful tool of analysis for historians and city planners.

Introduction

The study is one of the results of a research project, finished in 2014, which aimed at studying the ancient arrangement and appearance of three main Italian cities (Bologna, Milan, Rome), by means of some examples of historical cartography, with specific interest for the cadastral one. The main aim of the research project was the realization, for each of the three cities, of a Geographical Information System accessible on-line, to collect interesting examples of historical cartography, and link them with other cartographic or textual documents. The research, funded by Fondazione Cariplo, was carried out for the main part by the pertinent Universities and National Archives (Iarossi 2014).

One of the analysed documents for the city of Bologna was the urban map of the Gregorian Cadastre, made at the beginning of the nineteenth century, composed by three surveys (1811-1831, 1873 and 1890-1901) (Fig. 1). The present study focuses on the first one, characterised by a very peculiar multi-storey structure, and it aims to prosecute other studies belonging to the present research project (Arioti et al. 2013, and also Bitelli and Gatta 2011a, Bitelli et al. 2012). Aim of the present study is to understand the realization modalities of this very rare cadastral system, and give a modern and innovative tool for the study of the ancient city by means of the same Gregori-
an Cadastre. Thanks to an accurate cross-consultation of maps and registers, selected information on storeys recorded in the cadastre has been expressed as three-dimensional digital models, capable to display the ancient urban arrangement in an intuitive and expressive way.

**Study subject**

**The maps of the Gregorian Cadastre of Bologna**

Documentation on preservation of the Gregorian Cadastre of the territory of Bologna, composed by both maps and registers, today can be consulted in the local National Archives. The maps, like all the maps from the Gregorian Cadastre used by the peripheral cadastral offices of the ancient Papal State (*Cancellerie del Censo*), are copies of original documents formerly preserved in the *Presidenza del Censo*, a central unit responsible for cadastre, and later transferred to the National Archives of Rome (Buonora 2009, Vita Spagnuolo 1995). Contrary to the original maps, which are of large format, the maps copied for the *Cancellerie del Censo*, notwithstanding at the same scale, were divided in rectangular sheets, to make them more usable, with an index map at the beginning.

In particular, the urban map of Bologna consists in one copy, probably updated to shortly before 1831, of the original document surveyed in the late Napoleonic period (1812-1814), during the realization of the *Regno d’Italia* (Italian kingdom) general cadastre, and then regained into the first cadastral establishment map of the Gregorian Cadastre. This copy was divided into 14 sectors, and the modifications occurred in the urban fabric from 1812 to 1831 – due to property divisions, new buildings or demolitions, road rectifications and similar cases – were reported on the pertinent rectangular sheets with a red pencil (Fig. 1).

![Figure 1. Scheme of the updates of the maps of the Gregorian Cadastre of Bologna.](image)

As already stated by Capoferro Cencetti (1981), the peculiarity of the primary map of Bologna, in respect to the maps of all the other urban centers of the Papal State, Rome included, is that, in 1831, the representation was split in floors: the ground floor (*primo piano*), the floor below (*secondo piano sottoposto*), and up to 5 floors above (*secondo, terzo, quarto, quinto and sesto piano*) (Fig. 2). In the course of the studies conducted as part of this research project, it has been ascertained that the sheets of the so-called *primo piano* are not belonging to the first level underground,
as preliminary supposed (Arioti et al. 2013), but they are re-drawings of the ground-floor sheets, made in 1831, where only the updates on the copy of the ante-1831 original map in loose sheets were reported; moreover, a subdivision in isole (block of lots) was made, on the base of which the lots were listed in the Brogliardi urbani (see below). Therefore, for each sector into which the city was divided, 1 to 7 sheets exist, one for each floor which the lots belonging to the specific sector were drawn in (Fig. 3). It is to emphasize that, in the sheets of each specific floor, the only drawn and numbered lots were those of interest for cadastral purposes (Arioti et al. 2013, Tura 2004).

This very rare cadastral system seems to anticipate, with uncertain outcomes given the complexity of the required activities, the following land register recording based on the concept of real estate unit. The extreme complexity of the graphic representation and the connected records probably advised against continuing the experiment, which therefore remained an isolate attempt, without sequel for the other cities of the Papal State.

Cadastral registers equipping the maps

The maps of the Bologna Gregorian Cadastre represent the city inside the third wall perimeter, i.e. the part of the city today framed by the boulevards. The drawing consists of cadastral lots identifying the single proprieties, marked with a progressive number (or an alphabet letter for the public properties). The primary map is equipped with two series of cadastral registers: Sommarioni (3 volumes compiled in 1812-14, and a fourth volume reporting the 1873 updates) and Brogliardi Urbani (8 volumes, compiled in 1831). In the first series of volumes the lot numbers are listed in progressive order, whilst in the second series they are grouped according to a territory criterion, the membership isola (block of lots). The Sommarioni report, for each lot, some information: identifying number or letter, possible subdivision, owner’s name, location, designed use. In addition, the Brogliardi report some extra information (e.g. civic number, number of rooms per floor, surveyed area) and the results of the estimate operations, i.e. current or available rent and the evaluation (equal to the eight per cent of the rent).

From the maps to a digital 3D environment

In order to elaborate these maps in a digital environment, and to realize the final WebGIS (providing a database linking the lots drawn in map to the description contained in the two series of cadastral registers) according to the aim of the research project, the original documents (maps and registers) were acquired by means of high resolution scanning, according to parameters of common use in cartography (Sgambati et al. 2006).

As widely discussed in Bitelli and Gatta (2011a), the sheets of the ante-1831 update were individually georeferenced in the UTM-ED50 cartographic system, therefore they were digitally joined basing only on the georeferencing information, and a digital mosaic was obtained. Basing on the mosaic, the storey-maps of the 1831 update were georeferenced, therefore a digital mosaic for each mapped floor was achieved.

Afterwards, on the digital mosaic of the ante-1831 sheets, a virtual restoration (Federzoni, 2008) was performed. This allowed providing complete graphic data where geometry and/or identifying number of the lots were lacking or unreadable because of wear and tear of the analogical support, due to frequent use during time. The virtual restoration was made by means of a digital copy of the original Napoleonic map (1812-14) kept at the National Archives of Rome (better preserved
than the 1831 rectangular sheets), which the incomplete areas of the ante-1831 mosaic were digitally “filled” with (Fig. 4).

Figure 2. Left: representation of a central portion of the city in the ante-1831 Gregorian Cadastre of Bologna. Right: the same portion of the city split in floors in the 1831 update.
Figure 3. A page of a Brogliardo (1831) and an excerpt that highlights the kind of data reported in the registers (circled in red that ones used for the aim of the present study).

Figure 4. The ante-1831 digital mosaic restored with the original 1812-14 Napoleonic map (in yellow).
Three-dimensional visualization

Geomatic techniques applied to historical cartography appear very useful for exploring cartography from different viewpoints, e.g. a rigorous 3D modelling of urban scenographic maps for the representation of the ancient cities (Bitelli and Gatta 2011b). Studying the Bologna Gregorian Cadastre, the digital environment resulted very useful to a deep understanding of its extremely peculiar multi-storey arrangement. In spite of what was stated by Capoferro Cencetti (1981), the first researcher to recognize the extreme importance of such documents, information deduced from the mere consultation of the maps does not appear to give a realistic elevation image of the ancient city. In particular, it seems strange that only few cadastral lots are represented on the last floors, whereas Bologna is composed by historical buildings usually high. Therefore, it was decided to exploit the digital environment to represent data resulting from the whole amount of cadastral entries in an easier and more intuitive way, by means of a three-dimensional visualization. To achieve the aim, for some selected study areas, a precise comparison of the cadastral registers (in particular the Brogliardi, which are exactly corresponding to the 1831 maps) and the floor maps was carried out. In such a way, on the one hand the registers allowed us not only to recognize the features of interest (e.g. owners and designed use) of the lots (Figure 3), but also to identify possible extensions to the upper floors or to the lower one of the same cadastral lots (also when the lots were not mapped on the floor maps); on the other hand, the floor maps allowed us to highlight lot perimeter variations between the ground floor and the floors above and below, and to identify different properties on the same ground floor lot. Information derived from this analysis was exploited to produce, in a specific digital environment, georeferenced three-dimensional models of the examined portion of the city. To the aim, each lot was extruded according to the specific height assigned to each floor; the created three-dimensional lots were coloured according to the different selected themes. Below the results of some tests conducted on three areas of the city – different in terms of social and urban features – are reported. These areas are composed by real buildings whose elevation cannot be ambiguous, because it has appeared consolidated since the XIX century, contrary to other areas of the city, invested by demolition and subsequent reconstruction during the XIX and XX centuries. Each area is an interesting case for a peculiar topic of the XIX century arrangement of Bologna recorded in the Gregorian Cadastre: social stratification, rent, changes of designed use.

The social stratification topic: the piazza Maggiore case

In Arioti et al. (2013), Figure 9, the results of a first test performed on a building adjacent to the principal square of Bologna (piazza Maggiore) – and whose lots have a graphical representation on all floor maps – are shown (Fig. 5). In this first test, it was hypothesized that the so-called primo piano (first floor) was the first level underground; therefore, the 3D model turned out to be composed by two underground floors. By subsequent researches, it was ascertained that the floor was instead the update on the ante-1831 ground-floor map; the update was made in 1831, together with the split of the map drawing in floors. The 3D digital model was corrected by means of the results of this research: by adding the modifications reported on the 1831 primo piano sheets to the ante-1831 ground floor, and replacing the first floor underground with the secondo piano sottoposto, the model shown in Figure 6 was ob-
tained. The model was coloured according to two themes: the homeowner and the designed use. As assessed by Arioti et al. (2013), an urban fabric extremely split arises; it is characterized by a variety of lots and homeowners on the same piece of land of only 300 m² in area. It is similar to a modern condominium, composed not only by houses and cellars, but also – usually under the arch of the arcades and in the underground level – by commercial spaces (stores and warehouses).

Figure 5. The studied area of the first test, on the ante-1831 Gregorian Cadastre (upper left), and on current panoramic aerial images (*Bing Maps 3D* environment) (lower right).

Figure 6. Updated version of the 3D model of the portion of building highlighted in Arioti et al. (2013), Figure 9, coloured according to the homeowner (a) or the designed use (b).

*The rent topic: the via Mirasole case*
In order to analyse the peculiar multi-storey arrangement of the Bologna Gregorian Cadastre from a different viewpoint – the rent – a second test-area was identified, correspondent to the blocks of lots of the present via Mirasole street, once called via Mirasol di Mezzo, to the south of Bologna, near San Mamolo gate. As done in the previous test, a preliminary investigation was made to check the buildings of this area had not been subject to significant variations since the XIX century.

The rione dei Mirasoli district originally consisted of three streets: via Mirasol di Mezzo (now via Mirasole), via Mirasol di Sopra (now via del Falcone) and via Mirasol Grande (now via Solferino), so called because very sunny (Fig. 7). After the year 1000, a heterogeneous population of dispossessed and artisans resettled in the district; in the subsequent centuries, the district became a social microcosm where the mob – whose slang has influenced the current spoken – was spreading easily. When the Gregorian Cadastre began to be in force, the district was characterized by a low level of social stratigraphy. In the area, there were also many religious buildings, which were property of San Procolo, a church of unknown origin, but mentioned for the first time in 1075 (Bocchi et al. 1998). On the one hand the urban fabric remained practically unchanged over time, however, on the other hand, the population totally changed, and rapidly decreased during the last century: the inhabitants were about 9000 in 1920, today only 2720 still remain (Vianelli 2006).

Figure 7. The studied area of the second test, on the ante-1831 Gregorian Cadastre (upper left), and on current panoramic aerial images (Bing Maps 3D environment) (lower right).

To the aim of the present study, for the lots of the selected area, written information reported in the Brogliardi was examined: both data inherent the number of rooms per floor and data inherent the rent (Fig. 3). These data were related to graphic information that can be extracted from the floor maps, and the results from the comparison were used to derive, in a specific digital environment, a georeferenced three-dimensional model of the examined portion of the city. To achieve the aim, each lot was extruded according to the specific height assigned to each floor (3 m, ex-
cluding the attic, whose height has been set equal to 2.5 m, and the secondo piano sottoposto, which was considered a basement 2.5 m in height and 50 cm above the ground level). In order to make the model more realistic, some decorative elements – such as roofs, doors and windows for the buildings, columns for the city arcades, vegetation for the courtyards – were included. Finally, the created three-dimensional lots were coloured according to the designed use; in particular, three different colours were used to distinguish between houses of own property, houses for rent and houses for unspecified use. The latter are houses whose part of own property cannot be distinguished from the part for rent, basing on the Brogliardi: probably, these are houses where the homeowner lived in only one floor and he rented the rooms of the other floors (Fig. 8).

The creation of a georeferenced three-dimensional model representing the data inherent the designed residential use allows qualitative and numerical analysis on the social stratification in the middle of the XIX century, for the selected portion of the city. For instance, from calculation of the number and the area of the different kinds of houses, it is possible to assess that the total area from buildings for rent was about 1/3 of the area from houses of own property, even though they (21 in total) were triple the houses which the owner lived in (7 in total). The result is a great difference in the average area per house: 273 m² for the buildings for rent, 524 m² for the houses of own property (Fig. 9). Moreover, the model highlights a social differentiation between the two street fronts, with predominance of houses of own property on the north front. Therefore, it can be assessed that the two blocks of lots that face via Mirasol di Mezzo street had a different social background: a well-to-do class lived in the north side, and a poorer one lived in the south side, characterized by many more and much more fractioned lots, many of them property of San Procolo church.
The topic of the changes of designed use: the case of a central block of lots

Another theme that has been investigated for the aim of the present study concerns the differences in the urban arrangement for some areas, found comparing Sommarioni (1812-14) and Brogliardi (1831). In particular, concerning the differences in the designed use, the case of a central block of lots between via Parigi, via Galliera, via San Giorgio, and the current via Nazario Sauro street resulted particularly interesting (Fig. 10). At the beginning of the Nineteenth century, via Nazario Sauro was named “Strada detta Poggiale” (in the Sommarioni), or “via Poggiale” (in the Brogliardi); it acquired the current name in 1919. Via Galliera (name still existing) is one of the most significant historical streets of the city; it served as main link between the city centre and the North area – where today is the railway station – until 1890, when via Indipendenza was realized (Fanti 2000).

The analyzed block of lots appears to be an interesting case of study, because, when the Gregorian Cadastre was activated, it was composed by different kind of buildings. In fact, in the block of lots there were: the sixteenth Zucchini Palace (at the beginning the Torfanini family and afterwards
also the Estensi family lived in), the notable San Colombano monastic complex (the monastery, founded around 616 A.D. and afterwards enriched with the Madonna dell’Orazione chapel and the Oratory, remained open for worship until 1798), living houses, stores, orphanages, hospitals (which were places for not only cure and rehabilitation, but also social assistance and “shelter” for the poor) (Bocchi et al. 1998).

In the Gregorian Cadastre, the block of lots under examination, composed by 23 land lots, is drawn only on two floor maps: the ante-1831 ground floor map and the map of the floor above (secondo piano). Moreover, the only two land lots drawn in the second floor are those inherent the complex of San Colombano; they are the only two that have a subdivision in sub-lots in the Brogliardi. Therefore, in this case, the cadastral registers appeared indispensable for deriving the exact number of floors occupied by each land lot, by means of reading of the column reporting the number of rooms per floor and the column inherent the designed use. As done in the previous tests, basing on this information and the geometry of the land lots, a georeferenced three-dimensional model of the block of lots was derived in a specific digital environment.

Comparing the two subsequent series of cadastral registers for this block of lots, a general change of designed use between 1812-14 (as can be deduced from the Sommarioni) and 1831 (as can be deduced from the Brogliardi) arose. Therefore, the three-dimensional model was used to highlight this fact, by means of a more intuitive representation of the data. The model was texturized according to the theme of the designed use in 1812-14 and 1831.

By consulting the cadastral registers 5 kinds of designed use were recognized: palace, house, house with store, house with barn, church. Therefore, the land lots were assigned to each of them, in both 1812-14 and 1831 models. In this way, the three-dimensional models shown in Figure 11 were produced; by comparing them it is possible to immediately recognize the land lots which have been subject to variations in designed use during the two analyzed decades. An important change that was recognized is the passage from “house” to “palace” for 4 land lots (all of them owned by Giuseppe Zucchini), or from “house with barn” to “house” for other land lots. Basing on this fact, it is possible to state that between the years 1812-14 and 1831 the block of lots, that housed a wealthy social class, composed by upper-middle class and members of the clergy, in addition to traders and ordinary citizens (partly in rent and partly owners), has undergone a development of many locals, probably due to a general enrichment of the social class. Having at our disposal georeferenced data allowed us to quantify the analysis, whose results was summarized in diagrams (Fig. 12).
Figure 11. 3D model of the portion of the city highlighted in Figure 10 in 1812-14 (above) and 1831 (below); the colours reflect the designed use, as deduced from Sommarioni and Brogliardi respectively.

Figure 12. Percentages of area occupied by land lots with different designed use, for the two cases showed in Figure 11.
Conclusions

The present study aimed to acquire a deep understanding of the particular multi-storey structure of the Bologna Gregorian Cadastre of the XIX century, and to show possible innovative tools for the study of the ancient city by means of the same cadastre. Some experiments on three areas of the city – with different social and urban features – were performed. By means of the graphic information stored in the georeferenced maps, coupled with the written one in the related cadastral registers, a reconstruction of the horizontal and vertical extent of the cadastral properties for each area was possible, and the results were displayed by means of three-dimensional digital models, coloured according to different themes.

The examined examples highlight the extreme complexity of the multi-storey structure of the Gregorian Cadastre of Bologna, clearly confirming that such a system was not intended to describe the vertical extent of the buildings, but rather to realize the most precise and reliable possible tool of fiscal levies, in some ways anticipating the subsequent cadastral system in real estate units.

The experimentation shows that the geomatic techniques, coupled with a punctual knowledge of the archival sources, can furnish innovative tools for not only a deep study of the Gregorian Cadastre of Bologna and the historical cadastres in general, but also researches of urban or architectural kind, e.g. analysis and representation of the XIX century urban structure by means of the same Gregorian Cadastre. In other word, these techniques enlarge the research opportunities in a rich and modern multidisciplinary context. Therefore, from this viewpoint, the digital environment results in a very precious tool for not only preservation, but also recognition of the historical cartographic heritage and its use in a modern way.

Acknowledgements

The research was realized in the framework of the project “Ritratti di città in un interno. Consolidare la memoria collettiva della città attraverso l’informatizzazione e la divulgazione della cartografia storica” (2010-2014), funded by Fondazione Cariplo.

We would like to thank Giulia Casamenti and Margherita Bianchi for the elaborations made in their high degree thesis.
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