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Analysis in a digital environment of the multi-storey arrangement of the Gregorian Cadastre of Bologna (Italy) - XIX century

Keywords: Gregorian Cadastre; Bologna; floor maps; 3D digital modelling

Summary: The presented research focusses on the first establishment urban map of the nineteenth century Gregorian Cadastre of Bologna, kept today at the National Archive of the city. In this cadastral cartography the city is divided into some sectors; for each sector – unique case in the Gregorian Cadastre – there are ground floor maps and maps for the floors above (5 floors) and below (2 floors).

The present study aims to acquire a deep understanding of this rare multi-storey arrangement of the cadastral maps, focusing on a little but special group of cadastral lots in the centre of the city. By means of the graphical information stored in the georeferenced maps, coupled with the written one in the cadastral registers, a reconstruction of the horizontal and vertical extent of the cadastral properties which overlap each other on the little group of lots was possible, and the result was displayed by means of a three-dimensional digital model. By comparing the latter to the appearance of the city given by both previous scenographic maps and the reality of today, it is possible to state that the multi-storey structure of the Gregorian Cadastre of Bologna was not intended to describe the vertical extent of the buildings, but to experiment with a tool for raising taxes on urban buildings in a more precise way, by means of criteria which seem to anticipate the subsequent land register recording by real estate units. Unfortunately, the sophistication of such a system probably advised against its extension to other realities of the Papal State, making the Bologna experiment an isolate – even if for this reason more interesting – attempt.

Introduction

The study belongs to a research project which aims to investigate 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 is the realisation, for each of the three cities, of a Geographical Information System accessible on-line, which collects interesting examples of historical cartography, and links them with other cartographic or textual documents. The research, funded by Fondazione Cariplo, is carried out for the main part by the pertinent Universities and National Archives.

One of the analysed documents for the city of Bologna is the Gregorian Cadastre, made at the beginning of the nineteenth century, composed by three surveys (1811-1831, 1873 and 1890-1901). The first one, already examined in some studies belonging to the present research project (Bitelli and Gatta 2011a, Bitelli et al. 2012), is here analysed for its particular feature of a multi-storey structure, in order to understand the modalities of this very rare cadastral system, which seems to anticipate, with uncertain outcomes given the complexity of the required activities, the following

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land register recording based on the concept of real estate unit. Thanks to an accurate cross-consultation of maps and registers, a rendering of the multi-storey structure in a digital environment was possible, by means of a three-dimensional visualization, capable of displaying the ancient urban arrangement in an intuitive and expressive way.

Study subject

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 Archive. 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 Archive of Rome (Buonora, 2009). 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 of one copy, updated in 1831, of the original document surveyed in the later 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 that 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 in red pencil drawing.

Structure and peculiarity of the primary map of the Bologna Gregorian Cadastre

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 proprietries, 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). 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, 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).

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 the 1827-1831 updates, not only the survey of the ground floor, but also the survey of the other floors, above (up to 5) and below (up to 2), was carried out and drawn in map (Fig. 1) (Capoferro Cencetti, 1981). Therefore, for each sector into which the city was divided, 1 to 8 sheets exist, one for each floor which the lots belonging to the specific sector were drawn in. In each sheet the only drawn and numbered lots are those of interest for the specific floor; moreover, in the first floor underground map a subdivision in *isole* was made, on the base of which the lots were listed in the *Brogliardi* (Fig. 2) (Tura, 2004).

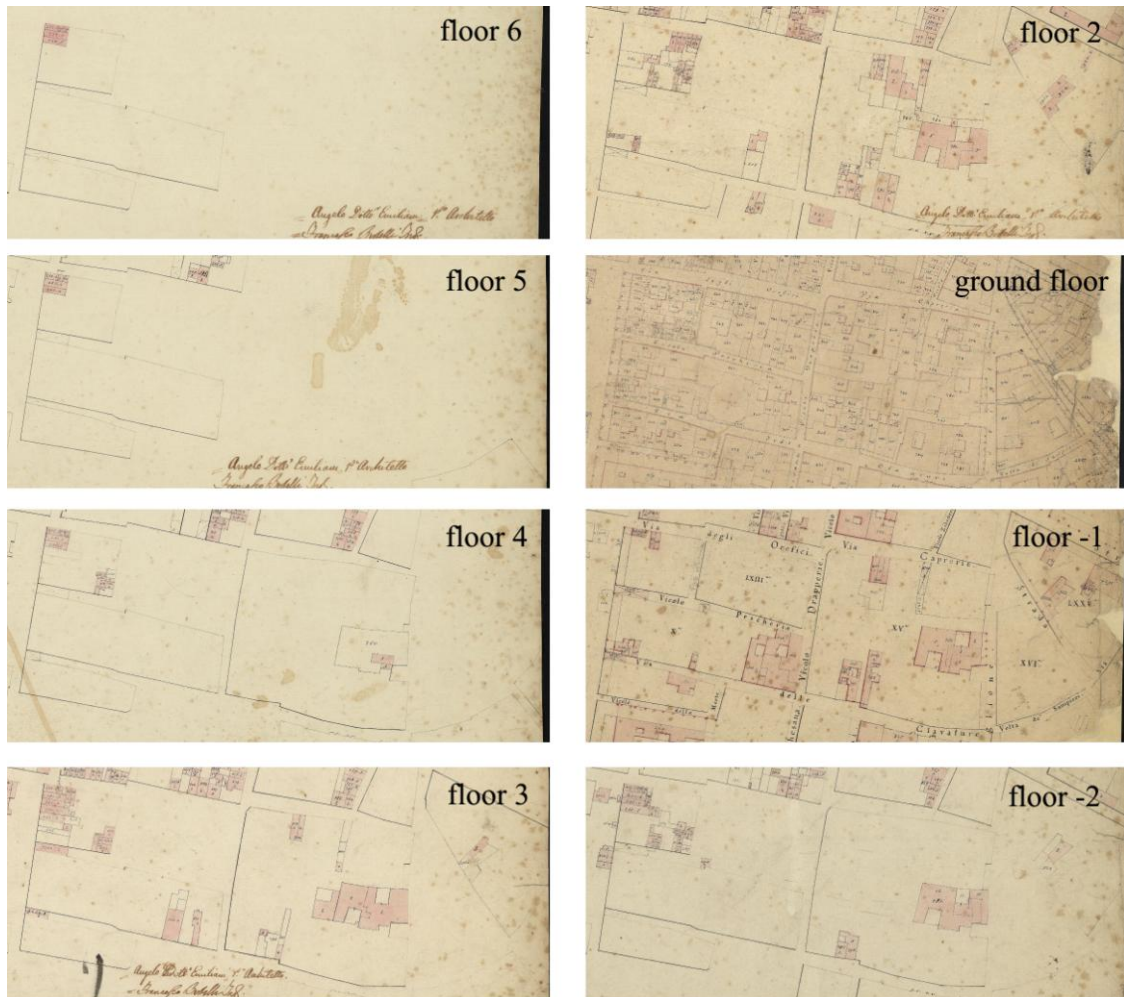


Figure 1: A portion of the first establishment Gregorian Cadastre of Bologna (1811-1831): the ground floor map and the maps of the floors above and below.

LEGAZIONE di		COMUNE di									
NUMERO del foglio di mappa	USAZIONE e FONDI	DATA del foglio del catasto	COGNOME E NOME e QUALITA' DEL PROPRIETARIO	NUMERO del foglio di mappa del catasto	TOTALE DELLA PAGLIA	PERIZIONE DELLA PAGLIA	ESTIMO DELLA PAGLIA (per ogni moggio)	ESTIMO DELLA PAGLIA (per ogni moggio)	ESTIMO DELLA PAGLIA (per ogni moggio)	ESTIMO DELLA PAGLIA (per ogni moggio)	ESTIMO DELLA PAGLIA (per ogni moggio)
107	Industria	1811	Industria	107	107	107	107	107	107	107	107
108	Industria	1811	Industria	108	108	108	108	108	108	108	108
109	Industria	1811	Industria	109	109	109	109	109	109	109	109
110	Industria	1811	Industria	110	110	110	110	110	110	110	110
111	Industria	1811	Industria	111	111	111	111	111	111	111	111
112	Industria	1811	Industria	112	112	112	112	112	112	112	112
113	Industria	1811	Industria	113	113	113	113	113	113	113	113
114	Industria	1811	Industria	114	114	114	114	114	114	114	114
115	Industria	1811	Industria	115	115	115	115	115	115	115	115
116	Industria	1811	Industria	116	116	116	116	116	116	116	116
117	Industria	1811	Industria	117	117	117	117	117	117	117	117
118	Industria	1811	Industria	118	118	118	118	118	118	118	118
119	Industria	1811	Industria	119	119	119	119	119	119	119	119
120	Industria	1811	Industria	120	120	120	120	120	120	120	120

Figure 2: Excerpt from a page of a Brogliardo (1831), where some lots comprehended in the portion of Figure 1 are listed.

Digital elaboration of the maps

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). The main steps of digital elaboration, widely discussed in Bitelli and Gatta (2011a), are here summarized.

Georeferencing and mosaicking

The ground floor maps were individually georeferenced in the UTM-ED50 cartographic system, by means of Ground Control Points (GCPs) belonging to Bologna buildings which had not been subject to important variations during time, as resulting from a careful consultation of graphic and descriptive historical documentation (Bocchi et al. 1998); the coordinates were deduced from the current large-scale numerical map of the Bologna Municipality (CTC). Therefore, the maps were digitally joined basing only on the georeferencing information, and a digital mosaic was obtained. The maps of the floors above and below were georeferenced based on the previous mosaic, due to two factors: the need to best fit the map of each floor with the corresponding map of the ground floor, and the possibility of recognizing a higher number of GCPs. Digital mosaics, each one coming from the assemblage of the georeferenced maps belonging to a single floor, were achieved.

Virtual restoration

Secondly, a virtual restoration (Federzoni, 2008) was carried out on the Bologna copy of the ground floor cadastral sheets, since their analogical supports have been partially subject to wear and tear, due to frequent use during time. This was made only on the ground floor mosaic, in order to provide mapping information (*i.e.* geometry and identifying number of the lots) where data were lacking because of wear and tear of the analogical support. To reach the aim, the original Napoleonic map (1812-14) kept at the National Archive of Rome (better preserved than the 1831 rectangular sheets, due to the fact that the maps stored in the *Presidenza del Censo* were not used to achieve administrative aims) was used: a digital copy of the map (provided by the Rome National Archive) was referenced on the basis of the 1831 ground floor mosaic, and coloured using a different colour tone; therefore, all areas lacking data in the 1831 mosaic were vectorized and given a transparency, in order to overlay the product on the Napoleonic map and make the latter visible through the 1831 mosaic (Fig. 3).

The resulting product makes available a historical cartographic base for the final WebGIS, and allows to establish links between cadastral lots drawn in map and digital images of the corresponding registers, even for those lots no longer visible on the 1831 documents. Moreover, the product results useful for historical studies, and for comparing drawing style and representation details of the original with the copy.

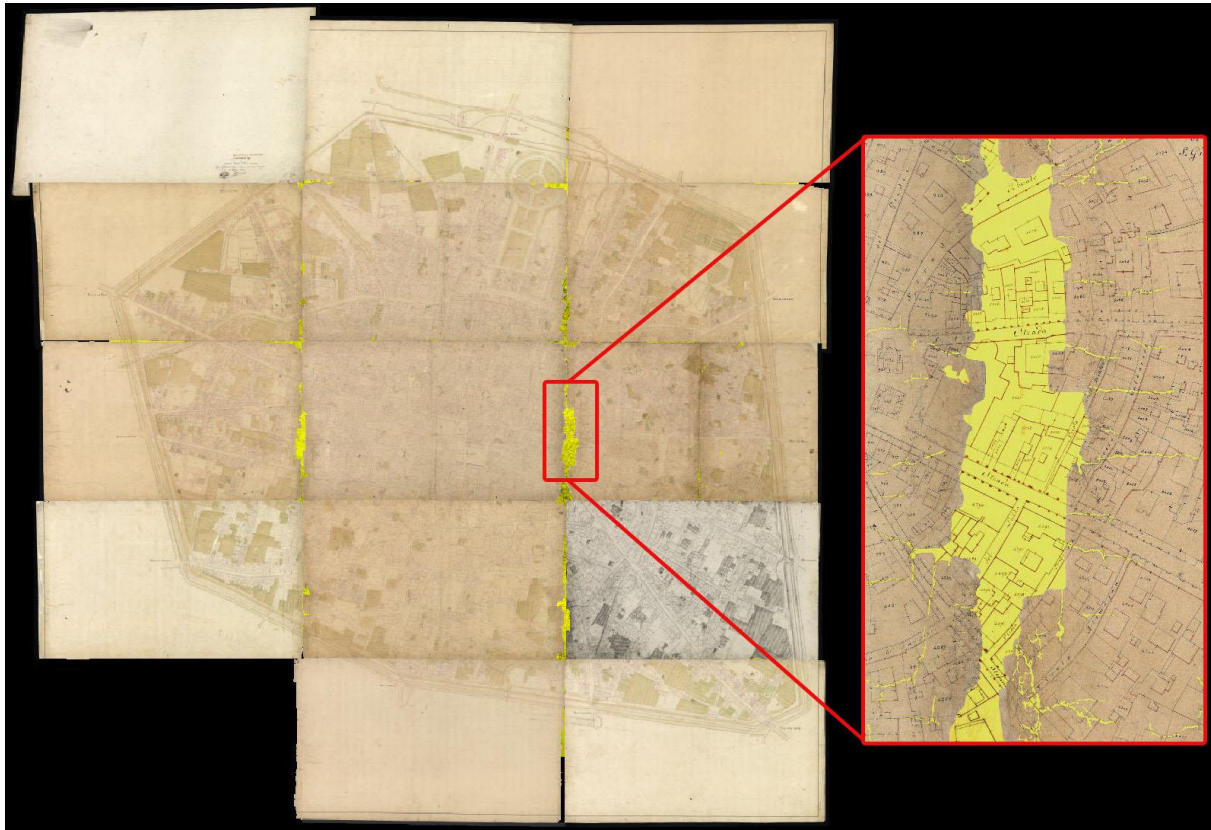


Figure 3: The 1831 digital mosaic restored with the original 1812-14 Napoleonic map (in yellow); in the box, a detail of an area of junction between adjacent sheets, particularly worn, is shown.

Three-dimensional visualization

Since the Bologna Gregorian Cadastre has the peculiarity of a multi-storey arrangement, that we want to deeply understand, the digital environment was exploited to represent data resulting from the whole amount of cadastral entries in an easier and more intuitive way, by means of a three-dimensional visualisation. In fact, information deduced from the mere consultation of the maps did not appear to give a realistic elevation image of the ancient city, in spite of what was stated by Capoferro Cencetti (1981), though it must be highlighted that she has been the first researcher to recognize the extreme importance of such documents: in particular, it seems strange that few cadastral lots were represented on the last floors, whereas Bologna is composed by historical buildings usually high. An area adjacent to the principal square of Bologna was selected in order to perform the virtual visualisation experience; in this area lots with a graphical representation on all floor maps (the ground floor, 5 floors above and 2 floors below) exist, and for some of them the real building elevation could not be ambiguous, due to the fact that it had remained unchanged since the construction of those buildings (contrary to other areas of the city, which were invested by demolition and subsequent reconstruction during the XIX and XX centuries). As it can be seen in Figure 3, the availability of a restored digital mosaic appears useful to recognize lot perimeters even for buildings laying on areas on the margin of the sheets, which look worn in the 1831 Bologna maps.



Figure 4: The test area for the 3D modelling, vectorized in black on the restored digital mosaic.

Modelling based on maps only

The first modelling was run using only the ground floor maps and the maps of the floors above and below. For each floor map the lots lying in the study area (Fig. 4) were vectorized, and were given a ground altitude equal to zero and an eaves altitude corresponding to the higher floor in which each lot appeared (considering each floor 3 or 4 m in height). The resulting numerical files were displayed simultaneously, on the georeferenced digital mosaic (Figure 5) and in a three-dimensional viewer (Fig. 6), giving each floor a different colour, according to a predefined scale. In order to test the reliability of the result, the 3D model was compared with a previous scenographic map (*Ichnoscenografia* by Filippo de' Gnudi, 1702) and the present map, that one used for georeferencing (CTC, numerical large scale map realized by the Bologna Municipality). In the first case (comparison with the XVIII century reality), the texturized three-dimensional model obtained by Bitelli and Gatta (2011b) from the *Ichnoscenografia* was used, whereas in the second case (comparison with the present day reality) the CTC was visualized in three dimensions, classifying the eaves altitude values of each building according to the scale defined for the Gregorian Cadastre. In Figure 7, especially in the comparison with the CTC, it can be seen that the 3D model of the Gregorian Cadastre based on information deriving from the maps only does not reproduce the city elevation appearance. In fact, the majority of buildings appears too low and frequently composed only by the ground floor, whereas in such area of Bologna all buildings reach at least the third floor (as it can be seen from the three-dimensional displaying of the CTC), and they have not been subject to significant variations, especially in height, during time (as it can be seen from the comparison with the *Ichnoscenografia*, made one century before). Moreover, in the 3D model of the Gregorian Cadastre some buildings present clear gaps, since some floors result lacking.

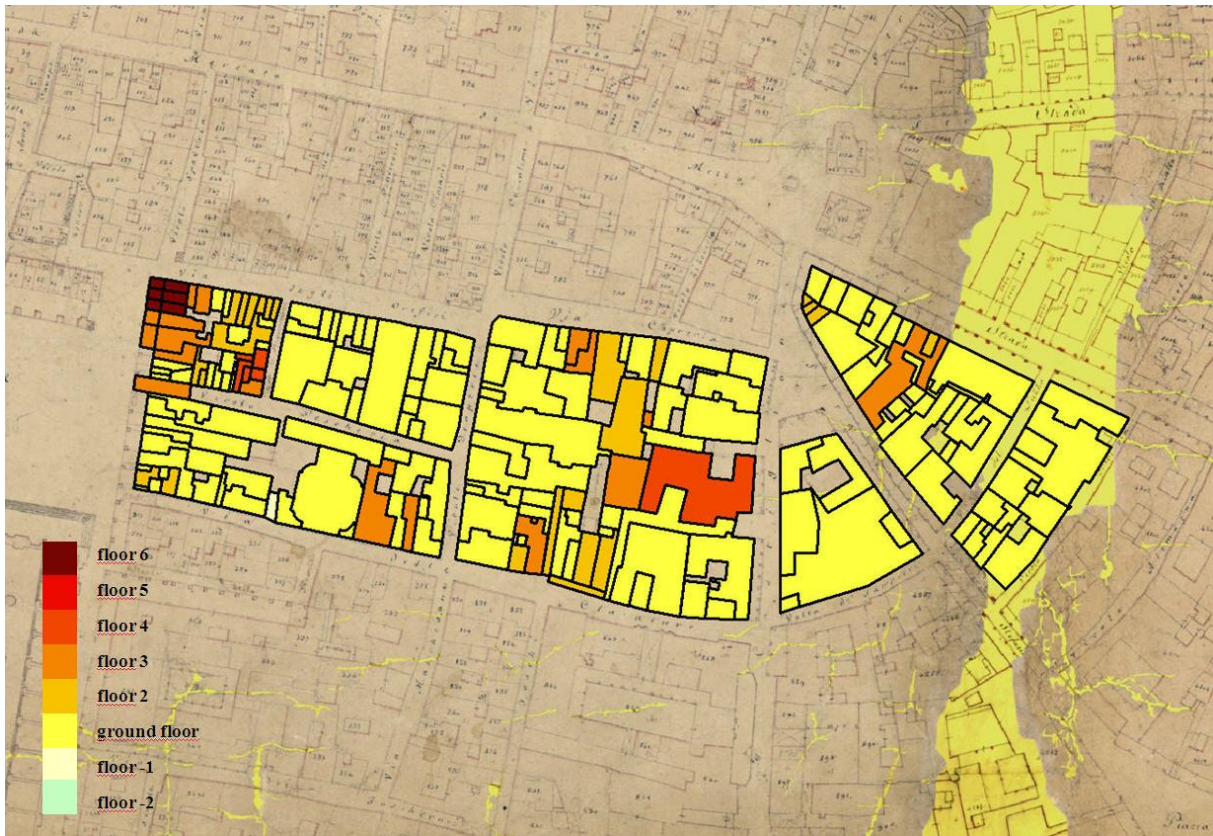


Figure 5: 2D visualisation of the vectorized lots, coloured on the base of the highest floor they show in map, according to a predefined scale.

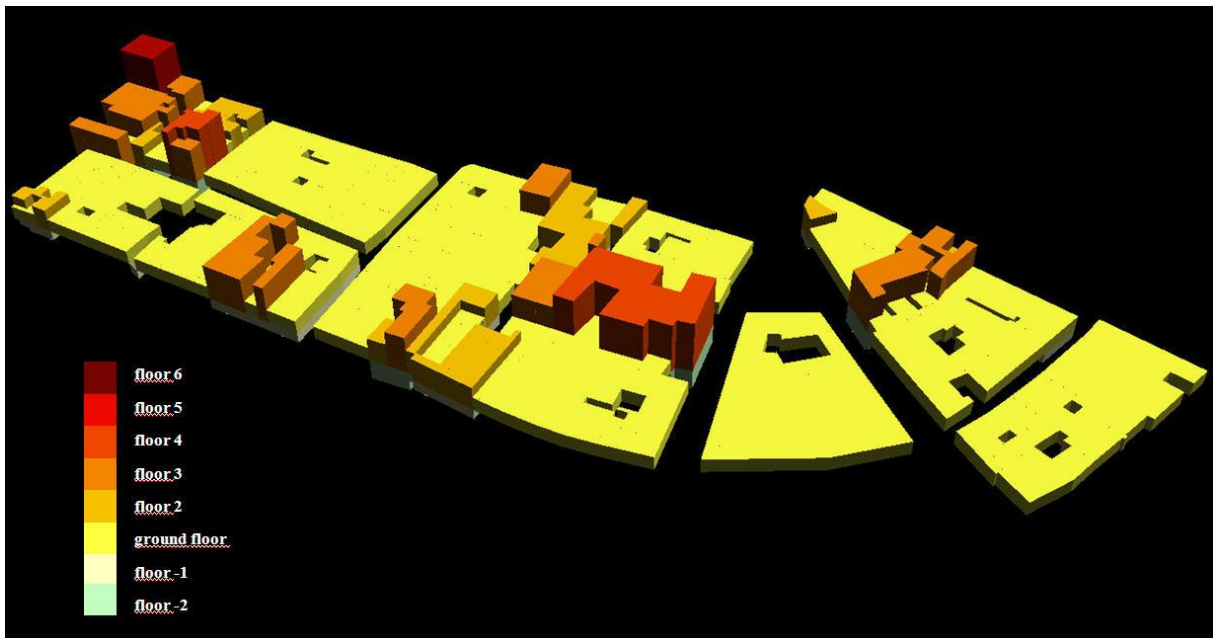


Figure 6: 3D visualisation (obtained assigning to each floor a fixed height) of the vectorized lots, coloured on the base of the highest floor they show in map.

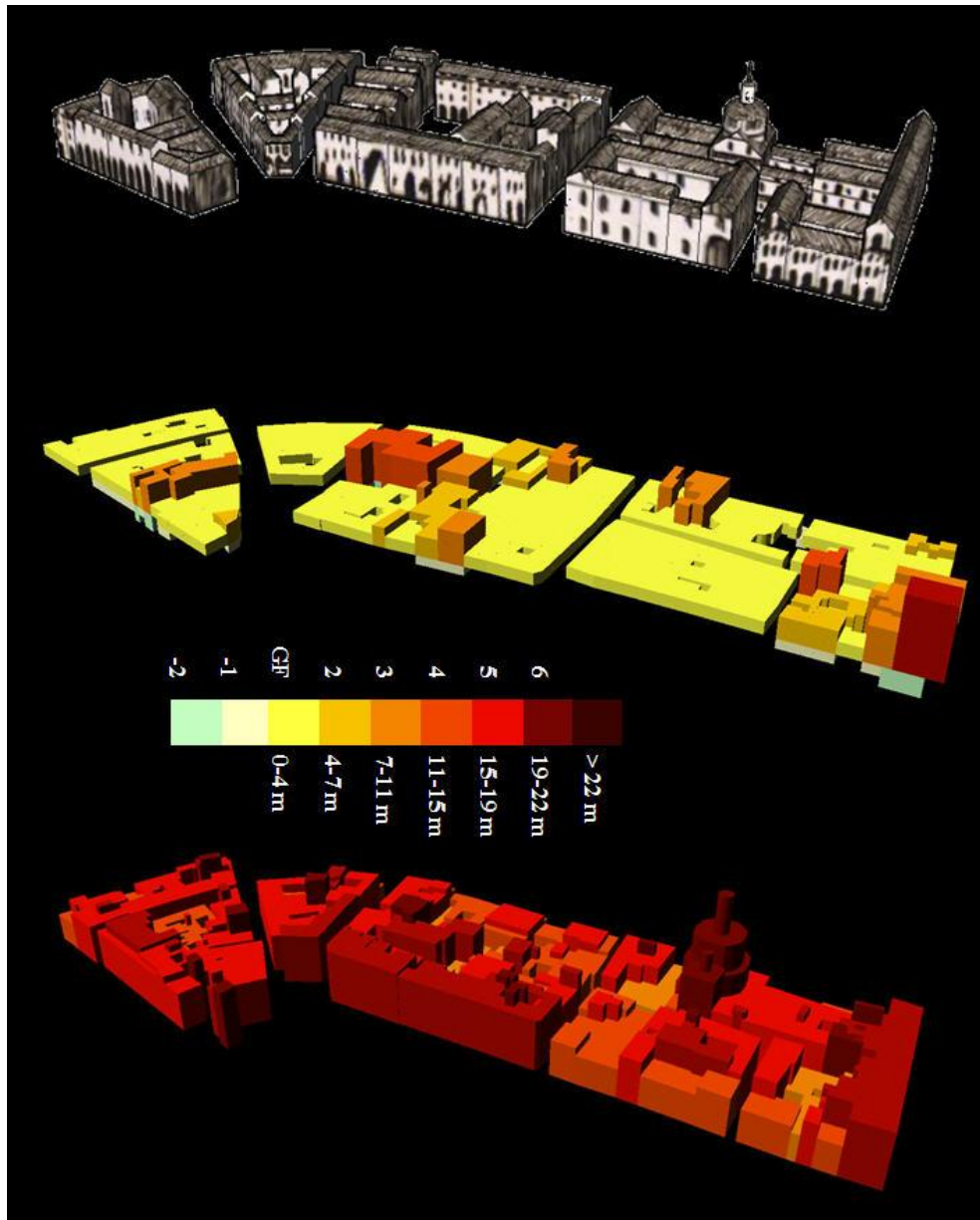


Figure 7: Comparison of the 3D model of the Gregorian Cadastre (in the middle) with the 3D model of the 1702 *Ichnoscenografia* (up), and the 3D visualisation of the present CTC (down) according to the same colour scale used for the Cadastre.

Modelling based on maps and cadastral registers

What is previously stated confirms the hypothesis that mapping the floors in the Bologna Gregorian cartography was not for the purpose of giving a complete and self-contained elevation representation of the city buildings, but was rather a tool for the right interpretation of property data. Therefore, the second test tried was intended to further substantiate this hypothesis: for a little part of the studied area, a precise comparison of the cadastral registers (the *Brogliardi*, which are exactly corresponding to the 1831 maps) and the floor maps was carried out (Fig. 8). In such a way, on the one hand the registers allowed us not only to recognize owners and designed use of the lots, but also to identify possible extensions to the upper floors or to the lower ones of the same cadastral lots (for this reason, in the previous test, the lots which were not mapped on the floor maps caused an incomplete structure of the buildings); 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 were exploited to produce, in a specific digital environment, a georeferenced three-dimensional model of the examined portion of the building. To achieve the aim, each lot was extruded according to the specific height assigned to each floor; the created three-dimensional lots were coloured according to two themes: the homeowner and the designed use (Fig. 9).

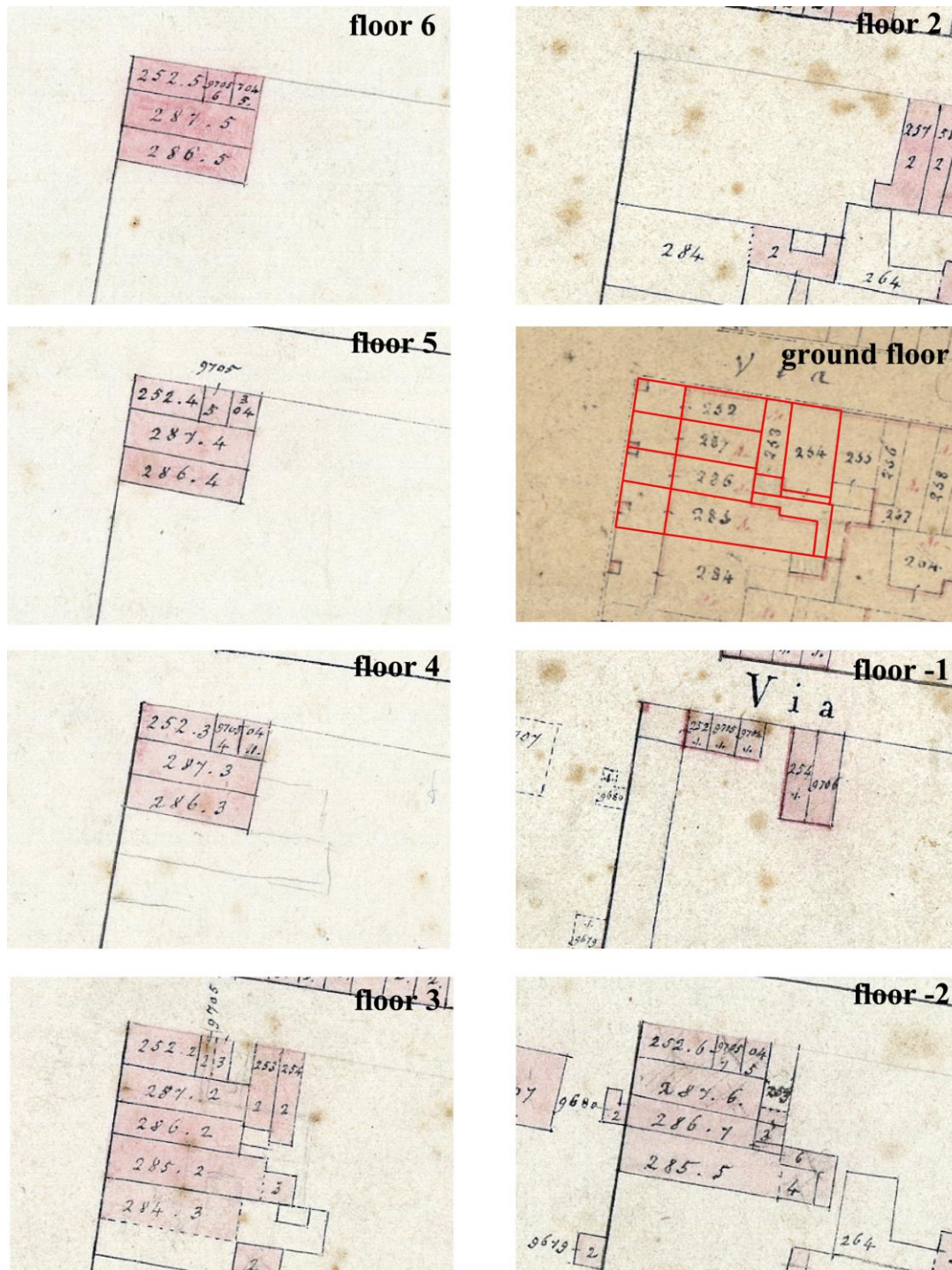


Figure 8: The analysed area of the second test on the different floors of the Gregorian Cadastre. (vectorized in red on the ground floor map).

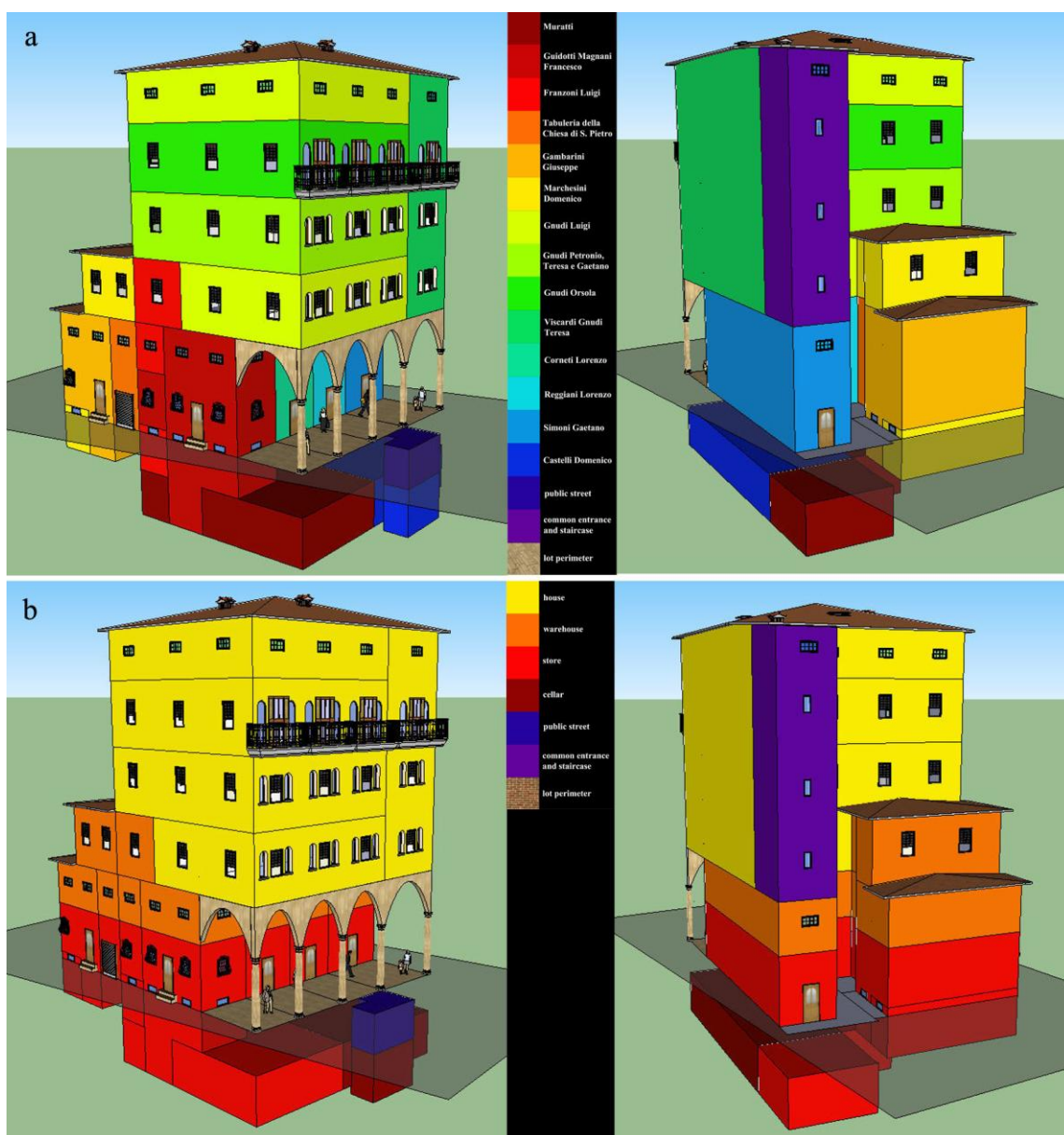


Figure 9: 3D model of the portion of building highlighted in Figure 8, coloured according to the homeowner (a) or the designed use (b).

The result shows an extreme diversified situation of lots and homeowners on the same piece of land, with a vertical extension both in elevation and in depth: 14 different homeowners and 6 different designed uses (house, warehouse, store, cellar, public street, common entrance and staircase) on a piece of land of only 300 m² in area. In other words, the urban fabric results extremely split, characterized by real “condominiums” where the civil houses overlap the commercial spaces – consisting of stores (some of which totally in the underground) and warehouses, usually under the arch of the arcades (typical of this and many other areas of the city) – only from the third floor (that one immediately above the arcades) up. It becomes evident that the mere use of the map drawing of the ground floor lots could not make possible an analytical recognition of the homeowners of the apartments of the upper and lower storeys, in such a way allowing largely inequalities of calculation of the evaluation and tax evasion.

In order to test the reliability of the model and provide it with a more expressive representation, a direct comparison with historical photographs (late XIX – early XX century) (Romagnoli, 2006)

was performed; this was made possible by texturization of the 3D model with the photographs on the only two sides of the building overhanging the street (Fig. 10).

The analysed example confirms that the complex multi-storey arrangement tested during the construction of the urban Gregorian Cadastre of Bologna was not intended to describe the vertical extent of the buildings, but to realize the most precise and reliable possible tool of fiscal levies, in some ways anticipating the succeeding land register recording by real estate units. It can be hypothesized that the peculiarity of such a map representation could derive from a property asset too complex to be managed only with the graphical aid of the ground floor maps and the written aid of the cadastral registers, in such a way suggesting the recourse to an auxiliary graphical representation; further, it can be hypothesized that the Bologna cadastre was a test to extend a possible multi-storey mapping to all other cities of the Papal State. Unfortunately, up to now searches conducted at the *Presidenza del Censo* (since the administrative correspondence of the *Cancellaria del Censo* of Bologna dispersed) have failed, and the interpretation of the order of the floor maps does not appear fully satisfactory, due to the fact that now the floor named “first” cannot be positioned with any certainty in respect to the ground floor. Notwithstanding this, the model – a sort of *ante-litteram* 3D GIS – did not have a sequel, neither in the following updates of the Bologna urban cadastre, nor in the cadastres of the other cities of the Papal State, probably because it revealed itself extremely complex to be constantly updated.

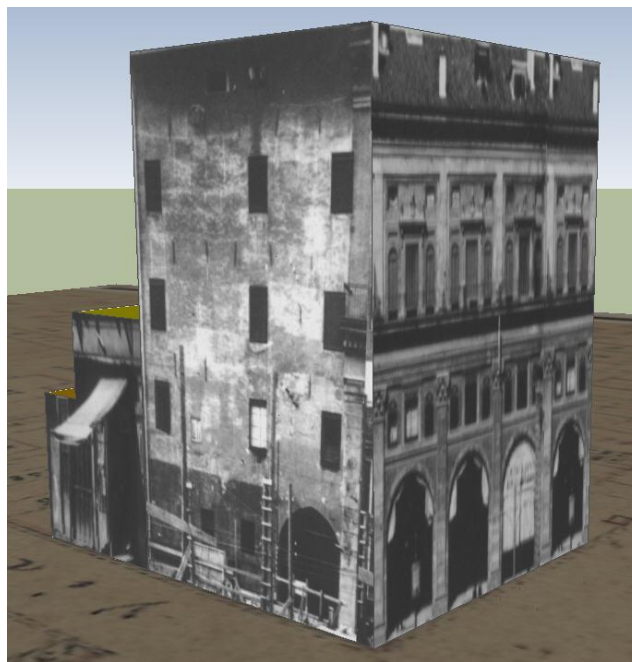


Figure 10: 3D model of Figure 9 texturized with historical photographs (late XIX – early XX century).

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, focusing on a small but special group of cadastral lots in the most central area of the city. By means of the graphical information stored in the georeferenced maps, coupled with the written one in the cadastral registers, a reconstruction of the horizontal and vertical extent of the cadastral proprieties of the group of lots was possible, and the result was displayed by means of a three-dimensional digital model. If the modelling was based

on information deriving from the maps only (*i.e.* without use of the registers), an unreal visualization of the ancient city would be reached, where buildings would appear too low – or would present clear gaps – with respect to the appearance of the city given by both previous scenographic maps and the today reality.

On the contrary, the examined example clearly confirms the fact that the multi-storey structure of the Gregorian Cadastre of Bologna was not intended to describe the vertical extent of the buildings, but to realize the most precise and reliable possible tool of fiscal levies, in some ways anticipating the subsequent cadastral system. The extreme complexity of the graphical 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.

Therefore, the result of this first experiment highlighted the extreme complexity of the storey-mapping system of the Bologna Gregorian Cadastre; other tests will be necessary to confirm or not the hypothesised relation between the “first” floor and the ground floor, and other searches will be aimed to acquire a full comprehension of the reason that entailed performing such a kind of map representation only in Bologna.

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