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Modern Geomatical Applications for Cadastral Reform: The Italian Case

Gabriele GARNERO[1] and Flavio Celestino FERRANTE[2]

[1]University and Polytechnic of Turin - DIST (Interuniversity Department of Regional and Urban Studies and Planning) Torino, Italy
[2]Revenue Agency- Central Directorate for Cadastre and Cartography, Roma, Italy

Correspondence should be addressed to Gabriele GARNERO, gabriele.garnero@unito.it

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Abstract The recent introduction of the IMU (Municipal Property Tax) in Italy has highlighted the vexed question of inequality existing in cadastral appraisal systems. This article outlines the methods and activities, in the field of mapping, supporting of the important process of renewal of the entire cadastral system. It describes the technology and spatial data currently available that can assist in setting up complex issues of reforming appraisal system and, more generally, in the processes against tax evasion in real estate. This paper aims to offer a contribution to the documentation and comprehension of geo-referenced data of the real estate in Italy and processing and analysis tools. The contribution is related to both the hypothesis of a reform of the cadastral appraisal system and, more generally, to the fight against tax evasion in real estate, and to the regular institutional Agency's (*Agenzia del Territorio* – AdT) activities recently incorporated in the "Agenzia delle Entrate". We will discuss AdT data and the technologies of the Agency; then the data and technologies outside the domain of the Agency, but closely related to and interoperable with the first one.
Keywords *Cadastral Surveying, Land Management, Oblique Images, Cadastral GIS*

1. Introduction

In support of the important process of renewal of the entire cadastral Italian system, the principles and criteria relevant for this paper are listed below:

- territorial and functional segmentation of the real estate market;
- use of statistical functions expressing the relationship between the market value, location and positional features and building assets for each destination cadaster and for each geographical area;
- use of "per square meter" as a measurement of urban real estate.

As can be seen from the principles and the above operational criteria, the data concerning the geo-localization of properties in relation to the urban context and to the characteristics of manufactured building play a fundamental role in the revision process, for the correct determination of cadastral appraisal systems and for the time and resources needed for their acquisition. To effectively address these challenges, we need a precise, complete and qualified knowledge of Italian real estate. The AdT manages, on behalf of the State, the real estate information system in Italy, in terms of identification, description of the technical characteristics and economic evaluation and registration of rights. The geo-localizing of real estates is based on the cadastral mapping system.

Since 1960, the Cadaster, as an official cartographic body of the State, is responsible for the management of cadastral maps and especially its continuous updating. The mapping system of the Cadaster is now complete and relatively uniform, throughout the country; it is based on large-scale mapping and entirely managed in vector format, and it is connected to the administrative and census archives through a unique identifier for the entire national territory, consisting of the number of parcel.

The system is now integrated with high-resolution digital ortho imagery and road graphs, but the real strength is its updating system. The inextricable link between the technical component of the map and the legal and administrative-census component, represented by the register identifier (parcel number), must be constantly updated and aligned in both archives throughout all stages of preservation, in order to make effective land registry information in all tax, civil and land governance proceedings [20].

In the more general framework, for the exchange of information with other local authorities where the Cadastral database is characterized by a great potential, in order to meet the needs of territorial knowledge, punctual and prompt updating of archives by automated and standardized procedures is essential to ensure the constant updating and synchronization of information provided by the various cadastral archives [12, 13].

To cope with the amount of more than 600,000 updating acts presented every year at the provincial offices of the Cadaster handling an average of 1,500,000 parcels, in order to eliminate any possible subjectivity in technical examination of documents, the updating system of maps and census data of Land cadaster (*Catasto dei Terreni*) has been fully automated by a computer procedure called *"Pregeo10"* [6, 8]. The new updating system, developed by the Agency with the active participation of concerned National Boards of Professional Associations, is entered into force throughout the country on October 15, 2009. This important goal qualifies the Italian Cadaster as Public Administration type 2.0 [18, 19].

2. The Ortho Imagery Produced by Agea & Identification of Unknown Buildings in the Cadaster

In the context of spatial information available throughout the Country, the ortho imageries produced by *Agea* (*Agenzia per le Erogazioni in Agricoltura*) certainly occupy an important position in the context of the checks provided by the Community regulations for the management of the contributions granted under the CAP (Common Agricultural Policy).

Agea is responsible, according to Decree no. 99/2004, of the coordination and management of the SIAN - National Agricultural Information System, where a full aero-photogrammetric coverage is provided every three years throughout the entire national territory and the production of the cultivation themes based on cadastral maps, in regard of agricultural land.

The Decree 82/2005 (Digital Administration Code) establishes the principle of the "reuse" of the data generated by each Public Administration and their accessibility, through appropriate agreements, by other administrations concerned.

Since 2010, in order to optimize its aspects related to the reuse of ortho imageries, the planning of survey programs has changed. It now becomes on a regional basis rather than provincial, and opens the possibility for the concerned administrations, to acquire jointly to *Agea* ortho imagery with the ground pixel resolution 20 cm instead of 50 cm institutionally provided: this increase in resolution, in case it would be implemented, will start from the next three years 2014-2016 and will lead to a real improvement in the possibilities of using the ortho maps produced within the SIAN for real estate updating.

The ortho images with ground pixel resolution of 20 cm would allow to determine with greater accuracy the positional and close range parameters properties and, consequently, to refine the appraisal of urban housing units, considerably limiting the direct intervention on the ground.

In the broader context of the fight against tax evasion, the AdT has undertaken a long series of actions aimed to identify potential evasion in real estate projects with high technological contents. In the recent past, according to the provisions of the Finance Act of 2007, the AdT has undertaken a significant project to "identify the buildings unknown by the Cadaster".

The project, characterized by an advanced technology, was prepared in collaboration with AdT, *Agea* and *Sogei* (*Società Generale di Informatica*) and is an example of cooperation and integration between information systems of Public Administrations. Thanks to a special agreement signed in May 2007, the agencies have identified the common ground where their skills might find useful synergies for the government and citizens, in the general interest of the State.

In order to achieve this goal, a general survey of the whole country has been carried out, with the exception of the Autonomous Provinces of Trento and Bolzano. The local survey was carried out through the integration of cadastral maps in vector format with digital high-definition color ortho imagery, the Digital Terrain Model (DTM), the Digital Surface Model (DSM) and near-infrared images [11]. The first step, carried out on the basis of the DTM and DSM, has involved the automatic identification of existing land features; these were then classified, first in relation to the height and then with the aid of near infrared images: it was possible to discriminate the vegetation from other artifacts, thus identifying buildings in automatic mode.

The spatial intersection, between polygons related to objects on the ground identified and the polygons of the buildings, present in the cadastral maps allowed to highlight the parcels on which buildings were found which are not present in the cadastral maps.

The results obtained were then subjected to systematic quality control, performed through the conventional photo-interpretation on the same digital high resolution ortho photos (pixels 50 cm), in order to eliminate errors that an automated process at industrial level inevitably entails, especially in relation of the "quality" of the used data.

The final product of the activity, carried out in synergy with *Agea,* consists of a list of the parcels on which buildings were found which are not present in the maps of the Cadaster; the list of the parcels was then intersected with the data of the various cadastral archives. This operation has eliminated, from the initial parcels, the ones known in the Land cadaster, as in other internal records.

The project, which began in mid-2007, was concluded in the early 2010 and has identified over 2,000,000 parcels on which there are unknown buildings. Among the positive effects of this project, the full availability for the Cadaster, of the high-definition ortho imageries immediately integrated with the cadastral maps in their systems must be highlighted, for the development of important projects, not least for the reform of the Cadaster.

According to the current provisions of law (Decree Law 78/2010, Art. 19, Paragraph 12), from 1 January 2011, the AdT, on the basis of new information related to technical and administrative checks, remote sensing and ground surveys must provide to start the constant monitoring of the territory by identifying, in collaboration with municipalities, other buildings not declared in the Land Cadaster. In order to achieve these statutory provisions and to make a more effective investigation, the AdT is considering the possibility of making use of advanced technological solutions such as aerial images acquired by oblique sensors, as explained in the following paragraphs.

3. Applications Relating to the Use of Google Earth and Microsoft Virtual Earth

The diffusion of shared *web* tools providing completely free of charge repertoires of dynamic aerial and satellite imagery on a global scale is now well established: the basics of *Google Earth* and *Microsoft Virtual Earth.* We all quickly learned to know and use for no professional applications are becoming real integrated tools proposed as a *repository* of spatial information not limited to data entered in network by the managers of the system, but as instruments in which it is possible to integrate and share information in different ways [3, 7].

Recently, this potential has been extended to the world of geographic information systems, with the opportunity to integrate local databases with remote *databases* of images: the instrument is of great interest for the study of territorial and landscape issues, given the integration of GIS tools already widely used in the field, and good image quality and potentially continuously updated, allowing a careful reading of the territory and its modifications [5]. Its implementation in the GIS also allows an active participation in the process of spatial analysis, with the option to extract data interpreted from the images in vector and/or alphanumeric geographic databases. There have already been numerous studies [2, 14, 17] on the possibilities of use of these innovative supports in the processes of territorial and landscape analysis, in order to identify the scale threshold beyond which the basics in subject no longer constitute a support geometrically reliable.

Virtual Earth and *Google Earth* are using a reference system that, at least in Italy, is not employed in other applications: the system *3785 - Web Mercator WGS84,* as codified in *EPSG Geodetic Parameter Dataset.* EPSG (*European Petroleum Survey Group*), an agency currently included in *OGP Surveying and Positioning Committee*, body of the *International Association of Oil & Gas Producers* (OGP) which provides to maintain and to issue a worldwide database of cartographic and geodetic reference systems and their transformation parameters.

For the purpose of this paper, the geo-referenced images of *Google Street View* implemented within *Google Maps* and *Google Earth* are particularly useful providing panoramic views of 360° horizontally and 290° vertically along the streets (at a minimum distance of 10-20 meters apart) and allows users to view portions of cities around the world at ground level.

Introduced in May 2007, the service *Street View* is active in Italy from October 2008; especially in 2009, there has been a rapid increase of the streets served: the cover is shown dragging an orange man ("*Pegman*", present in task bar) and placing him in a point on the road, in order to activate the corresponding panoramic photography. To carry out the photos, *Google Street View* uses special cameras (the *Dodeca 2360*, equipped with 11 objectives and produced by the Canadian company *Immersive Media*) located on the roof of cars. Pedestrian areas, parks and roads, bicycles are used instead of the specially equipped vehicle: the service is now extended to most of the main roads and urban streets of many large and small urban centers, with a coverage extended to all Italian regions, the coverage of the updated service is available *online* at
http://www.google.com/help/maps/streetview/learn/where-is-street-view.html

It is clear that the ability to view, at least, the street fronts of the areas already served by the service, can be of immediate and quick use in order to allow users a first visual access to the extrinsic characteristics of the buildings and surrounding areas.

4. Oblique Photogrammetry

On the national market, several companies are operating, able to realize, in addition to traditional nadir ones, photogrammetric surveys performed with sets of cameras arranged so as to capture the territory features with oblique angles, so as to give priority to the acquisition of the facades of buildings [14].

The industrial solutions going under the name of *Pictometry*®, *Midas*® of *Track'air*, *iOne*® of *Visual Intelligence* , ..., involve the use of survey systems consisting of several cameras rigidly connected to each other, mounted on a single support on which the inertial sensor is applied (IMU) for the acquisition of the angular components of the image.

In *Pictometry* and *Midas* systems there are 5 cameras, 4 of them are installed with an inclination of 40-45° from the vertical, according to the four directions of view and perpendicular to each other (forward, backward, left and right); the fifth chamber is installed as the traditional photogrammetric cameras in order to capture the territory flown over from the zenith. Frames are triggered simultaneously and are therefore five images that share the same instant. The *tools* available allow, as well as to manage the large mass of data in navigation environments from the base ortho image, to make queries and quantitative measurements on the plano-altimetric size of buildings, thus providing the operators with performing tools for the analysis and check of buildings.

As known to the authors, aerial oblique images are currently available, throughout the national territory, of all the provincial capitals and major towns with a population of over 50,000 inhabitants, with photos from 2005 (Figure 1).

***Figure 1**: Oblique Sensors Integrated into the Process of Photogrammetric Surveys*

Furthermore, during 2010 and 2011, the Autonomous Region of Sardinia has arranged for services relating to the contract for the capturing oblique images of the historical centers: all urban centers have been acquired, with technology *Pictometry* and with ground pixel resolution of the order of magnitude of 5 cm, so as to document the landscape context in which the centers ("*centri matrice*") are located and to highlight morphological and settlement differences between centers, with particular reference to the morphology of the plains, hills, mountains, coast, slope, etc. (Figure 2).

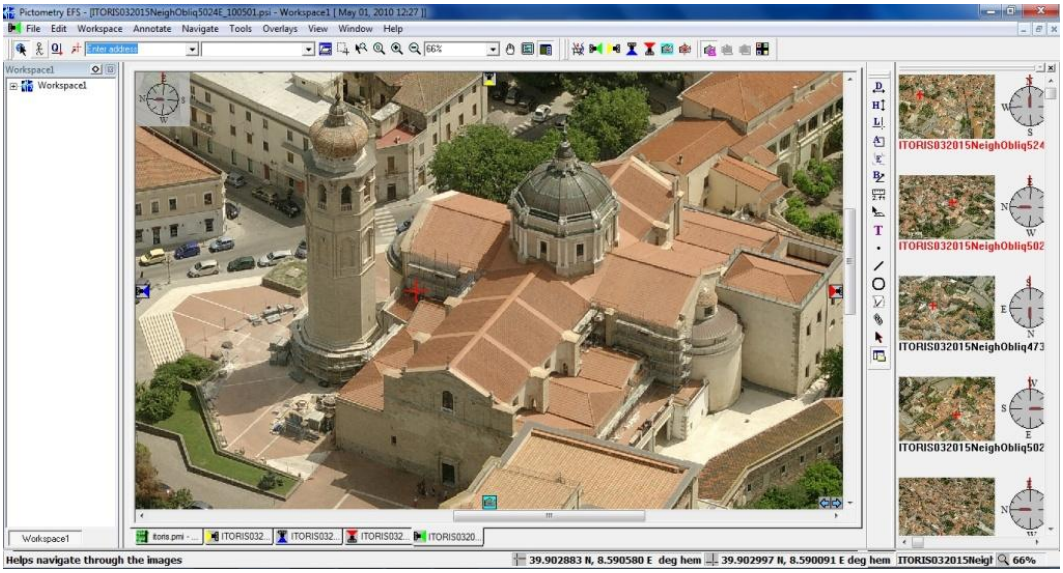

Figure 2: *Consultation of Oblique Images of a Center of the Sardinia Region*

The set of nadir and oblique photos allow to better understand the way in which these centers have developed, and to pick up the different building types through the analysis of the fronts of buildings and the internal parts, as well as to highlight the issues concerning the restoration and renovation of fine buildings, with a purpose of monitoring the territory, from the urban point of view in relation to the city center and the surrounding buildings.

The high definition allows documenting the current state of the buildings and road plots, so as to permit the establishment of a photographic support to institutional planning and regulation of the land [9, 10].

From the above, it therefore appears that the availability of already realized oblique images, relatively recent and, as previously described, directly relatable with cadastral maps with the technology to be described later, is not negligible, as it is likely to cover not less than 70% of built areas, so it is reasonable to hypothesize the development of this asset of information for the previously explained purposes, reasonably quickly, so as to avoid the natural obsolescence of the same.

Among the technologies readily available, the system BLOM-urbex allows you to integrate the cadastral maps with Orthophoto, displayed in the center of the screen, while the side shows the oblique images related to the same area. But it is still difficult, especially in city centers and in particular in those with complex morphology, to univocally identify the selected perspective views of the building on the cadastral map of which we want to know the characteristics. This ambiguity is resolved with the technology that will be discussed later, on the occasion of the description of 3D models of buildings.

Many have also considered the possibility of integrating photogrammetric surveys performed by *Agea*, already mentioned above, with at least 2 oblique cameras, in order to obtain, at the same time the acquisition of frames for ortho imagery and oblique images to be used for applications in the built environment [15]. Such surveys, if systematically realized, cannot of course be compared to the ones especially produced as oblique, because of the obvious shortcomings relative to the scale and therefore the size of the pixels, of insufficient capture directions and consequent deficiencies of information, with directions of building profiles completely excluded from the acquisition.

Anyway it is correct to consider that such possibilities, which should be produced with very low costs because of the simultaneity with the primary observations, could be profitably used in contexts outside the city, where there are less issues of mutual coverage between buildings and where it is not and, it cannot be economically feasible an oblique survey in canonical way.

In the economic context characterizing the present time, however is natural to consider the exploitation of what is available and usable with what can be achieved with sustainable costs, so as to ensure the economic feasibility to what is necessary to achieve the objectives.

5. Surveys with UAV

The only identification and documentation of the extrinsic characteristics of buildings could be obtained also with instruments of decidedly lower performance and less expensive than those described above as, for the applications in question, a metric quality is not required in order to perform measurements and quantitative estimates, but rather a good photographic quality that allows the operator to identify photographically all or most of the features to be detected in an inspection in the countryside, or at least to limit the visits to the controversial cases [4].

There is thus an increasing interest in the possibility of using pseudo-amateur photographic equipment on board of unmanned aircraft, technically defined *drones* or UAV (*Unmanned Aerial Vehicle*); this means aircraft with varying size from ones for military applications to small toy model aircraft.

The availability of GNSS positioning systems sufficiently precise can be obtained with very small size and weight, together with the existence of microscopic accelerometers and gyro sensors with MEMS technology, with software controlled now generally available in *open source*, opens new possibility of realization of systems for the acquisition of digital images on board of aircraft of various sizes [1].

The recent regulations issued by ENAC (*Ente Nazionale Aviazione Civile* - National Agency for Civil Aviation) NI-008-2012, dated August 2, 2012, defines precisely the activities of so-called mini-and micro-UAVs (respectively weighing less than 20 and 5 kg) and at up to a limit of 150 kg in respect of activities which, though still described as "experimental", can obviously have interesting professional consequences.

In the near future, it will also be possible to perform low altitude surveys, with tools like APR (*Aircraft in Remote Steering*), to recover photogrammetric information that would not be acquired through inspection, both for lack of access and for economic reasons.

6. Technology for the Virtual Reconstruction of Built Areas

The availability of information already acquired and also the possibility that other acquisition channels are activated, for large parts of the territory as for decidedly sub-regional context, allows defining a profitable use of these observation methods within the cadastral issues, even in relation to the availability of technologies that can be easily *customized* for these specific needs.

An operator setting himself the aim of verifying the extrinsic characteristics of buildings using aerial oblique images, should be able to operate in a dedicated software, which allows him to see the cadastral map integrated with the ortho image, and should be able to see oblique images with the help of software minimizing the possibility of misidentification of the building while synchronizing the oblique view on the building pointed on the map.

To this aim, in addition to the customization of the environments of consultation of the oblique images which we have been previously shown, the implementation is now feasible, albeit in a simplified mode, of a *3D City Model* dedicated to cadastral applications (Figure 3).

This term is technically defined as a consultation environment in which the buildings are reconstructed geometrically as solid and whose faces are "draped" from the information available on the radiometric frames: in this way the user forgets the frames and finds a virtual model reconstructed on which he can perform the observations or possibly measurements.

The construction of the *3D City Model* has long been present within the geomatic products available on the market, but only the recent improvements in the techniques of autocorrelation allow planning of generation processes achievable in entirely automatic mode, with consequent reduction of costs of production and therefore openings to more generalized use.

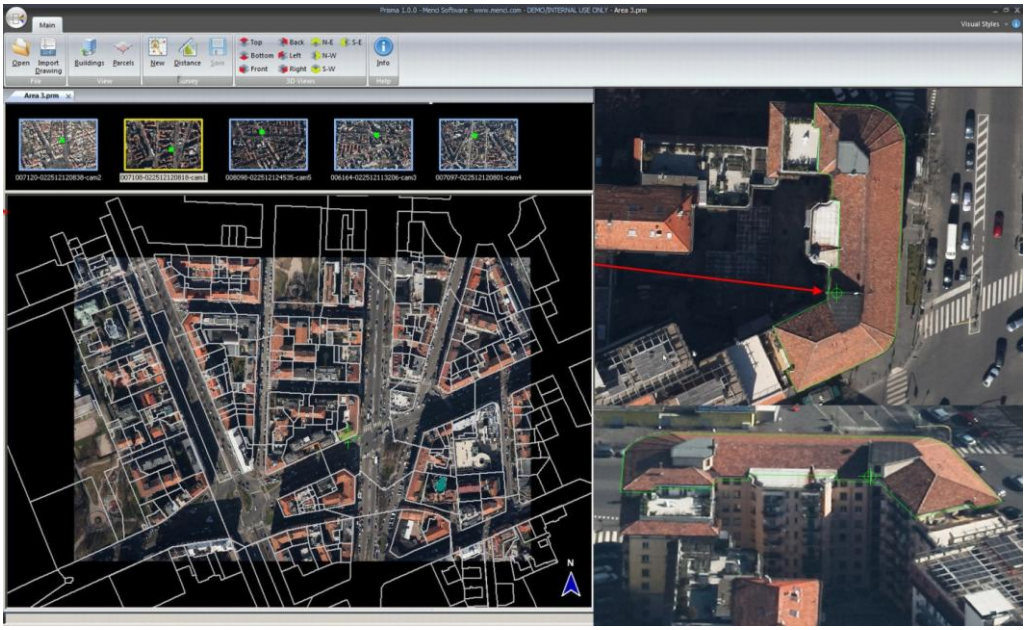

Figure 3: *Prototypal Realization of a 3D City Model using an Oblique Midas (Property Blom CGR) Survey with Menci Software Technology on the City of Milan*

Of course, once available for this aims, the performed basic may be exploited and also used for different purposes; for example, for the integrated protection and control, in municipal databases on in others various applications [16].

7. Integration of GIS Technology and Data Inside and Outside the Domain of AdT

As shown in the Introduction, it appears how for the implementation of plans of cadastral surveys reforming, geographic data (cadastral maps, orthoimagery, LiDAR data, oblique images captured by sensors, road graphs, real estate zoning, ...) and alphanumeric (cadastral DB, real estate DB, …) knowledge are strategic.

The effective exploitation of all these information components in a suitable environment that can integrate and correlate data from different sources is essential for the success of the project of reforming the estimate of the Building cadaster.

The environment able to integrate geographical and alphanumeric data along with the technologies, as known, is the GIS (*Geographic Information System*). For issues related to the reform of the Cadaster, GIS platforms allow for example to correlate data of the Urban Building Units (UIU) directly to the cadastral map: the operator can perform precise analyzes or statistics of any attribute of UIU (value/rent, classification, consistency, …) and represent reports on cadastral maps which, when suitably integrated with the high resolution orthophotos, allows to correlate the data position and/or overlooking with classification or consistency of the data of UIU.

The Figure below shows, for example, on the cadastral map integrated with the orthophotos, reports of a statistical analysis conducted on the data of classification of the Urban Building Units of a central area of Rome, a comparison between the statistical data of classification of building units both those within the same building and those in the same area of study, highlighting some of the inequalities in classification that the cadastral survey review should cancel or at least reduce (Figure 4).

Figure 4: *Cadastral Maps Integrated with Orthophoto Maps and Graphs - Results of the Analysis on Spatial Data "Classification" of Urban Building Units*

It is thus possible to integrate and analyze, on the same GIS platform, data relating to the characteristics of the extrinsic buildings: such information can be effectively drawn from close-up images of the sensors acquired simultaneously with the nadir images and allows, as indicated, relating the buildings fronts with "buildings' polygons" represented on the cadastral map, without any ambiguity.

8. Conclusion

The data on the position, the prospect and those relating to the extrinsic characteristics of the building, allow to effectively implement the estimation algorithm for the value of the building and severely limiting the direct intervention on the ground, with an obvious containment of time and costs.

The assumed GIS platform is crucial in analysis and management of data, in preparation for the estimation of property values, but it becomes particularly strategic in the final phase of the process, that is, when it comes to review and harmonize values and UIU rents of neighboring buildings belonging to different areas characterized by different values of the real estate market or to different municipalities or even to different provinces or regions.

It seems appropriate to point out, in conclusion, that, regardless of the technology platform, the effectiveness of the results depend strongly on the data quality (completeness, consistency, accuracy, updating, positional accuracy, etc.), especially by their degree of correlation in various archives.

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