Information Modeling Procedure to Represent a Territory Affected by Earthquake

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Abstract

ARIM (Assessment Reconstruction Information Modeling) procedure can be seen as the evolution and integration of the BIM systems used so far to monitor and document the transformations of the territory, such as HBIM, GeoBIM, LIM and SeismicBIM, representing at the same time their natural evolution for the management of prevention and reconstruction connected to natural disasters.
The application of the procedure is described on the case study of a building aggregate of Grisciano, a borough of the Municipality of Accumoli, describing the steps that constitute the part of the design/reconstruction of the BIM procedure, consisting of: cognitive framework, distinguished in 'direct knowledge' and 'deferred knowledge'; processing of the data collected; framework of the ARIM procedure, which provides a sub-articulation in data acquisition and their synthesis, finally the construction of the synthetic and informed 3D model.

Keywords: BIM, ARIM, 3D modeling, earthquake, VPL.

Introduction

Risks reduction deriving from natural disasters (DRR - Disaster Risk Reduction) and the building of settlements with resilient characteristics, have been discussed in several international symposia in recent years. Indications emerged in the "Sendai Framework for Disaster Risk Reduction 2015-2030" (last appointment in chronological order from this point of view), highlight the importance and role of a good planning to create less vulnerable and more resilient territories and communities, able to defend themselves against natural disasters and respond to environmental changes in progress.
The research [1] is based on the awareness that each earthquake has different impacts on cities and territories, based on a concomitance of factors that affect the specific characteristics of the earthquake, the territory involved, and also the socio-economic, cultural, institutional and administrative framework.
From this point of view, information systems (information modeling) can play a decisive role for a better knowledge and monitoring, a more effective management of both the built heritage and the territory as a whole, in a perspective in which prevention, management of emergency, recovery and post-earthquake reconstruction, sustainable urban regeneration of settlements, are thought not as separate but integrated actions.
President of the Italian Republic, Sergio Mattarella, on the occasion of the 20th anniversary of the earthquake that struck Umbria and Marche on 3rd of October 1997,

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issued a statement that goes precisely in this direction: "We need a general commitment to prevention. A kind of national pact. A pact for prevention that, overcoming political differences and oppositions, commits the entire country to prevention that would greatly reduce the risks and dangers of dramatic natural events and would allow to channel, into the normal life of our country, the solidarity that emerges with such force, passion and effectiveness on dramatic occasions" [2].
With this in mind, an information modeling procedure, called ARIM (Assessment Reconstruction Information Modeling), can be seen as the evolution and integration of the BIM systems used so far to monitor and document the transformations of the territory, such as HBIM, GeoBIM, LIM and the SeismicBIM, representing at the same time their natural evolution for the management of prevention and reconstruction connected to natural disasters.

Research methodology

ARIM procedure provides a flowchart, where the main variations, compared to a traditional BIM workflow, concern the part of the procedure linked to the 'design' sub-system, which can be interpreted as 'reconstruction design'. This is the part where the contribution of the disciplinary sector of representation and survey is central. As an example it is proposed the application to the earthquake that affected the Municipality of Accumoli in 2016.
The sub-system of 'reconstruction design' is organized as follows.
- Programming activities. Definition of reconstruction goals within an urban-spatial-territorial seismic approach (Accumoli and territorial context).
- Pre-earthquake cognitive framework, where sub-articulation includes: urban and territorial surveys, archive documentation, structural surveys, geological surveys, building survey, land reading. Urban and territorial surveys relate to the acquisition of the spatial planning framework and other planning documents (such as internal areas, etc.), emergency planning (Civil Protection Plan) and existing CLE (Limit Condition for the Emergency). The acquisition of archive documentation follows two different paths: institutional sources, where the existing cartography is available at various scales, collection of historical urban and territorial documentation (cartography, cadastre, historical photos, etc.), documentation on cultural heritage buildings; non-institutional sources, where the acquired material is related to private collections (photos, videos, historical prints, etc.). Structural surveys include the collection of existing studies on the vulnerability of strategic buildings, heritage sites, aggregates and infrastructures. Geological surveys foresee the collection of existing surveys on seismic microsomnia (MS), geological studies, hydrogeological layout plans. Building survey step provides a first distinction between 'fast survey' and 'detailed survey'. Data from the 'fast survey' comes from the web, the ones referring to 'detailed survey' comes from 3D laser scan or photomodeling campaigns. Collected data are organized for the achievement of a 3D model of the pre-earthquake situation. Territorial reading is an inquiry into socio-economic analysis, insights into specific built environments, the identification of aggregates and areas for specific insights, the history of urban and territorial transformations.
- Post- Earthquake cognitive framework defines the damage map, its sub-articulation includes: metric survey, geological investigations, urban and territorial investigations.
Survey step, foresees the same activities described for the step of the 'pre-earthquake cognitive framework', with the variant that the collected data are organized for the realization of a 3D model of the post-earthquake situation. Geological surveys include new seismic microzonations and the analysis of local seismic response. Urban and spatial surveys concern urban damage (physical damage, loss of functionality) in relation to a synthetic risk assessment of vulnerability, hazard and exposure.
- Reconstruction concept, whose sub-articulations are: urban and territorial proposals, geological proposals, structural proposals, architectural proposals.
- Reconstruction planning and prevention, are organized in: Urban and Territorial Proposals, Geological Proposals, Structural Proposals, Architectural Proposals.

Cognitive framework

In the knowledge of a territory one of the most relevant and innovative aspects is the risk prevention, which must be taken into account in several research areas,

ranging from the different stages of knowledge of the territory and urban centers (historical survey and metric survey of the physical reality), up to the direct application in the planning step of the interventions and the subsequent design.
In the definition of the cognitive framework it is foreseen a phase dedicated to knowledge and acquisition of data and information. In this step, we can identify two distinct levels of investigation of the studied territory and of all the inhabited centers related to it: 'direct knowledge' and 'deferred knowledge'.
Direct knowledge deals with the acquisition of information on the field, using both human resources (specialized and trained personnel for the purpose) and instrumental resources (3D Laser Scan, photogrammetric approaches, etc.).
The actions are organized according to gradual steps that follow a chronological order, and include at first the data detected at sight and recomposed in an overview and, in a second time, the instrumentation survey operations. Direct knowledge of a site is focused at acquiring information of different nature, ranging from geometric dimensions of the settlements and their boroughs, relative relationships of proximity and scale, typological characteristics of the anthropized space, of individual buildings and their sets, hierarchies of routes to small and large scale. All these data are used to compile a series of thematic maps (possibly also supported by audio and video data) that are not just mental maps based on simple perceptions, but real supporting information tools to form a correct cognitive framework.
At the same time, 'deferred knowledge' is focused at collecting and setting up archive, bibliographic and cartographic sources (of a traditional type, but also of the open data type in digital format on the web), to be used for the drafting of thematic maps described above. By 'deferred knowledge' we mean in fact a complex of actions that can be carried out simultaneously with those of 'direct knowledge', but also at a certain temporal distance (before or after) from the collection of data on the field.
Following activities are connected to this stage.
- Historical-critical analysis: it involves the research of bibliographic and archival information related not only to the events of local cultures (as often done in the past in an exclusive way), but especially those related to the most significant transformations of the region and of the building object of the research, according to the identification of the relative constructive, typological and structural criticalities. These, in fact, have often left important traces in archives and libraries and maps of different nature, especially if linked to the past during previous catastrophic events.
- Acquisition of open source data: finding of web data, today easily accessible by different databases and often not considered to form a reliable cognitive framework (databases of previous damage managed by INGV, satellite images, technical and geographical maps of the IGM and CTR type, cadastral plans, shape files present in institutional regional sites, such as for example the Lazio Region electronic archive).
With reference to these aspects, both the current technical standards on constructions released in 2008/2009, and the Directive of the President of the Council of Ministers of 2011, for the safety of the historical architectural heritage from seismic risk, establish the obligation to perform accurate cognitive surveys of both historical-critical and geometric-dimensional nature, using all the documentation that can provide useful information to understand the constructive stratifications and the more or less catastrophic outcomes on the buildings of past events [3].

Web data for a deferred knowledge of landscape
Freely accessible web data provide a good contribution both from a technical-scientific point of view and to deepen and provide a first knowledge of the perceptive aspect of the place.
For example, the use of Google Maps, associated with the ability to download the navigable panoramas of Google Street View, allows a first step towards the knowledge of the plan and the state of conservation of sites, helping to identify significant elements and to accelerate the subsequent stages of knowledge on the site itself.
Regarding the use of GIS files present in the official sites of land authorities, their potential derives from the informative structure that characterizes them, therefore the ability to collect simple primitives (points, lines and surfaces) associated with metadata. The metric reliability of the information collected in the files makes it possible to make initial formal considerations, but also attempts to represent urban models and the terrain on which they are based. A first experience was conducted on the representation of Accumoli and some fractions of which it is the capital, with particular reference to the borough of Grisciano (fig. 1).

In general, it is productive, to complete the framework of knowledge, to cross historical information obtained through consultation of archival documents (texts, cards, etc.), with web information obtained from the consultation of websites, Facebook pages, blogs and videos, able to give a more direct and personal reading (YouTube, fractions Facebook page, etc.).

Tools for direct knowledge

Survey operations provide the integration of different tools and methodologies, in order to have overlapping and verifiable data, which can cover the gaps that each instrumentation can present in different environmental situations. Instrumental surveying method foresees: data acquisition by means of 3D laser scanners; data acquisition for Structure from Motion (SFM); the acquisition by drone of the roofs of buildings and of all surfaces not detectable from a ground view. It is also possible to add to survey project data acquisition through a motorized panoramic head, both for spherical panoramas and flat or rectilinear panoramas.

In the acquisition of data by 3D laser scanners, scans are captured both by Leica C10 Scanstation and Faro Focus 3D (fig. 2).

SFM techniques or, more precisely, automatic digital photogrammetry, is a methodology that allows us to create a three-dimensional model starting from a large dataset of two-dimensional images. It is a set of techniques and technologies that fall within the field of Compurer Vision research and derive from the evolution of traditional photogrammetry (science that deals with extracting metric information from photographs). Whereas traditional photogrammetry involves manual intervention, in which the presence of an operator is required to process the images, the automatic one uses a digitalized procedure exploiting procedural algorithms.

Drone survey provides the acquisition of digital images, prepared on the basis of a careful calculation and according to the final scale required. There can be arranged a series of flights, with altitudes between 30 and 50 meters, bearing in mind that the higher the altitude increases the more decreases the resolution of the photos and the consequent level of detail of the cloud of points, therefore, it is desirable to have a good resolution of the final point cloud (lower 5 cm/pixel).

Data acquisition by means of a Clauss HD motorized panoramic head, allows to shoot a 360° subject. The sequence of images with which pin the spherical support of the representation takes place with a step-by-step confirmation, controlled by a special software that automatically manages the acquisition sequences,

Fig. 1. Municipality of Accumoli, borough of Grisciano after the removal of earthquake ruins.

Fig. 2. 3D acquisition of the borough of Grisciano with a Laser Scanner Faro Focus 3D (image by Leonardo Paris).

Fig. 3. Data acquisition with thermal imaging camera.

according to the set program. In particular, data can be collected to process spherical panoramas and rectilinear panoramas.
Data acquisition by thermal imaging camera (fig. 3) returns colored maps that document the heat emitted by objects and how this spreads over the entire building. The camera, working in the infrared wavelengths, represents variations through characteristic color ranges that describe certain behaviors of materials and structures.

Collected data processing

The spatial model (3D modeling of land morphology) is generated by using visual programming language (VPL) that allows to relate both the geometries and the attributes obtained by the acquisition processes foreseen in the direct and deferred mode.
Thanks to the VPL process, it is possible to merge data from different shape files into a single model for the 3D representation of the territory. Two models can be developed: a mathematical one (NURBS) obtained by the VPL programming of the traditional 3D building processes of simple models (projection and extrusion of geometries); then a numerical one (mesh) through the triangulation of points arranged at the correct altitude.

ARIM procedure framework

Assessment Reconstruction Information Modeling procedure (ARIM) framework (fig. 4) shows a stage of 'data acquisition', a 'synthesis phase' and a 'modeling' generation and management phase.

Data acquisition and their synthesis
As previously said, data acquisition can take place, with 'delayed' mode, with 'direct' mode and use of external metadata. In the first case we deal with web data, consisting of vectors and metadata available in the network; in the second case, a point cloud is generated by photomodeling, 3D laser scanning and topographic points; in the latter case, there are spreadsheets constructed specifically for encasing numerical and textual data related to different fields; these data, conveniently collected, can contribute to the construction of models.
Web data constituted by vectorial and/or editable nature are:
- shape files provided by the Regional Land, Urban Planning and Mobility of the Lazio Region, in vector format and provided with metadata concerning different properties of the represented buildings [4];
- data provided by the Copernicus website;

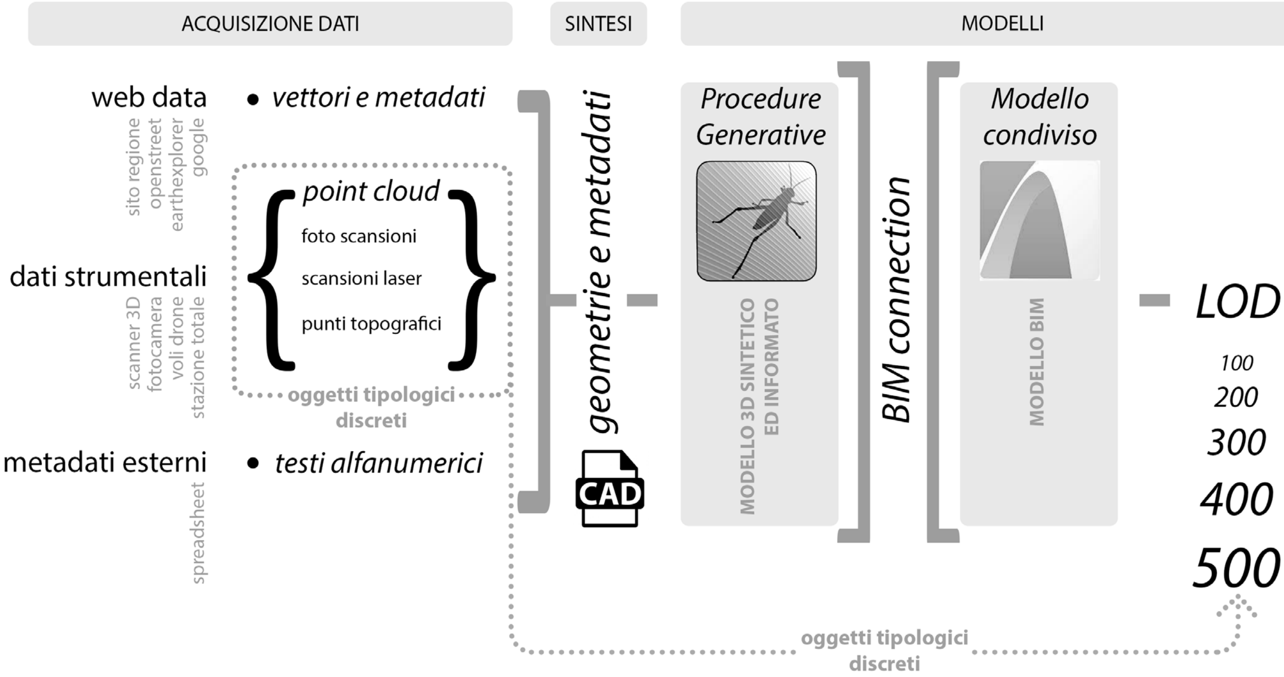


Fig. 4. Assessment Reconstruction Information Modeling procedure (ARIM) framework (image by Michele Calvano).

- data downloadable from the site www.OpenStreetMap.org (file .osm). It provides vector data associated with additional metadata of a numeric and textual nature (building height, number of floors, type of seismic failure, etc.). In web data management a visual computational procedure (Visual Programming Language or VPL system) has been used: different documents and data coming from the web are crossed and coordinated, such as, for example, the specialized site OpenStreetMap, whose information can be overlapped to the traditional maps of the territory (CTR - Regional Technical Map). Therefore, using, a procedure that foresees the download of the data related to the chosen area, the conversion of the native format (.osm) into a CAD format and finally the georeferencing of the downloaded data in a global coordinate system, it is possible to homogeneous data otherwise difficult to use. More accurately, the same procedure is applied to shape files, which, being technical sources, guarantees metadata and attributes collected with greater accuracy.

Downloading spherical panoramas of the areas covered by Street View it is possible to implement the image of the synthetic model.
Software used for the collection of photographic data from Google are on the web and freely downloadable (Street View Grabber and Street View Download 360). Downloaded data is an equirectangular image that shows the perspective aberrations typical of this projection.
Spherical images are subsequently used in a reverse return procedure compared to the shooting phase. The process is useful to give a photographic quality to the elevations of the synthetic 3D model and, at the same time, it allows the control of the measurements of the buildings. In this phase, a further research objective is set up [5], which envisages the creation of automated procedures that allow, starting from the spherical panoramas of Google in Street View, to construct the models represented in the equirectangular image that is being surfed.

Fig. 5. Photoplan of the 3D model taken from the point cloud (image by Leonardo Paris).

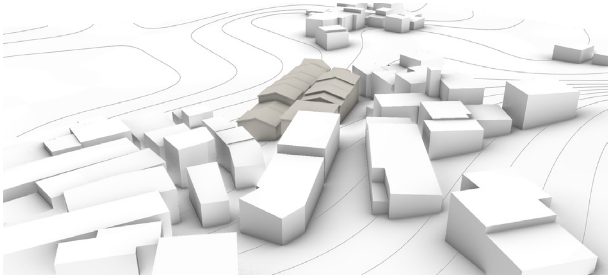


Fig. 6. 3D synthesis model of Grisciano: geometry and metadata (image by Valentina Adduci, Adriana Caldarone, Michele Calvano).

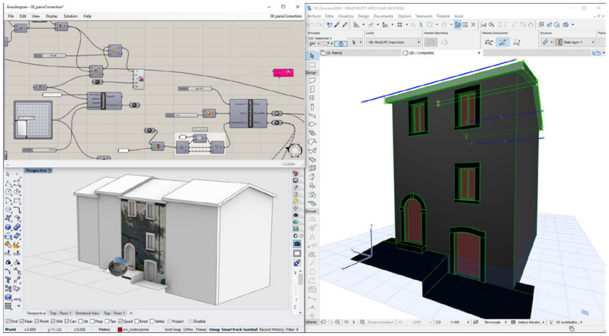
Once tested and perfected, the procedure will become, a plug-in that will be added to the VPL system described above. The value of this tool consists of the possibility of carrying out indirect surveys even in inaccessible places or in those places affected by unexpected natural events.
A shift in scale takes place with the use of "instrumental data" coming from "detailed surveys", which refers to campaigns carried out with direct or instrumental surveying in the sites affected by the earthquake both before and after the disastrous event. Generally, the data consist of campaigns performed with 3D laser scanning, from the ground or from drone, or with photomodelling campaigns.
Point clouds taken from the above described activities are processed with specific softwares (such as Cyclone, Recap, Scene, etc.) (fig. 5), which allow the subsequent passage in mathematical and numerical modelers, as seen for the VPL procedure.
Data collected with the 'deferred survey' and the 'detail survey' are organized in a three-dimensional 'synthesis model' (fig. 6), after having undergone a process of decimation and selection of the significant elements. The obtained result is a synthetic 3D model (polyhedra that summarizes the boundaries of each building and the related roofs) informed by the individual metadata [6]. A sort of three-dimensional GIS model with greater communication and interactive capabilities.

Construction of the synthetic and informed 3D model

In the case of Accumoli, the 3D modeling software used is Rhinoceros + Grasshopper [7] (fig. 7), which allows the management of generative procedures, in which a synthetic geometric model is returned by interpolating the data coming from the regional technical map, .osm data, orthophotos, panoramas from google, data obtained with point clouds detection. The result is a simplified NURBS model that shows, according to the measure, the ground, the consistency of the buildings and the roofs of a urban settlement, of the hamlet of Grisciano. Thanks to a Grasshopper plug-in (Gh-AC connection), the synthetic geometric model is linked tothe Archicad parametric environment (shared model). This is the best application for model information, where geometric parts become architectural objects, enriched by several kinds of data.

ARIM procedure applied to Grisciano

Below we describe the workflow carried out to generate the ARIM procedure for an urban context such as Grisciano, completely demolished after the earthquake (direct demolition due to the earthquake and subsequent controlled demolition for the safety of the area). In Grisciano area are available photographs, point clouds obtained with 3D laser scanners and GIS maps. 3D tool used in the procedure is Rhinoceros software, which allows to view the operations programmed in Grasshopper. Grasshopper is a Visual Programming Language (VPL); useful to create a synthetic model by relating geometries and metadata, even of a non-homogeneous nature. The goal is the creation of an ARIM system able to memorize both the form and the data of the pre-earthquake urban space. To do that, we have used Archicad, a Graphisoft BIM software, which today, thanks to the add-on Archicad-Grasshopper Live Connection, allows Archicad to use the capabilites of programming in VPL.



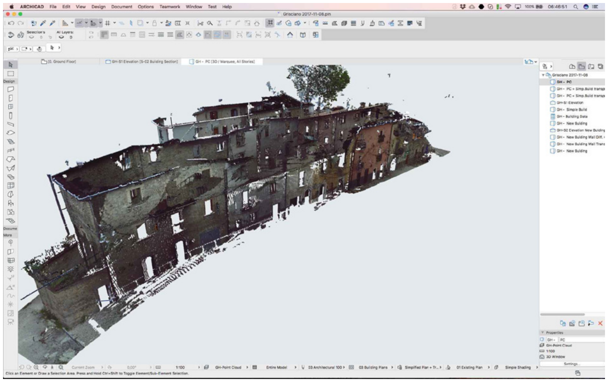
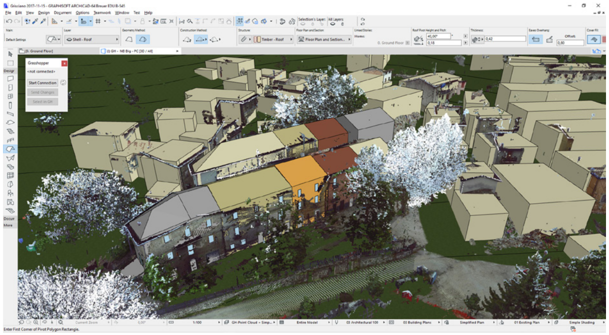


Fig.7. 3D reconstruction of a housing block of Grisciano with the Rhinoceros + Grasshopper procedure (image by Michele Calvano).

Fig. 8. Overlap and orientation of the point cloud, obtained from the laser scan survey carried in Grisciano's housing block (image by Michele Calvano).



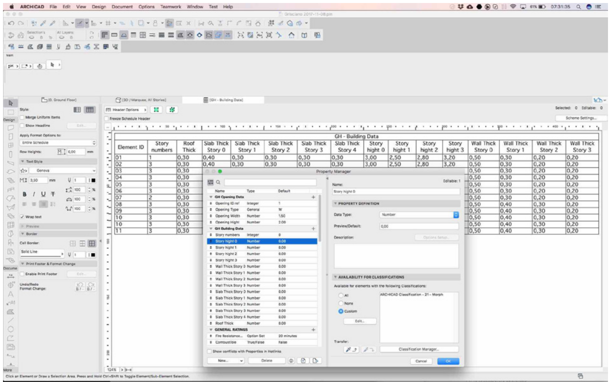


Fig. 9. Construction in a BIM environment of 'synthetic volumes' adhering to the actual dimensions of the buildings (image by Michele Calvano).

Fig. 10. Synthetic volumes created in BIM environment are equipped with additional parameters (metadata) that describe, through alphanumeric data, some intrinsic characteristics of each building (image by Michele Calvano).

Main steps of the workflow are:

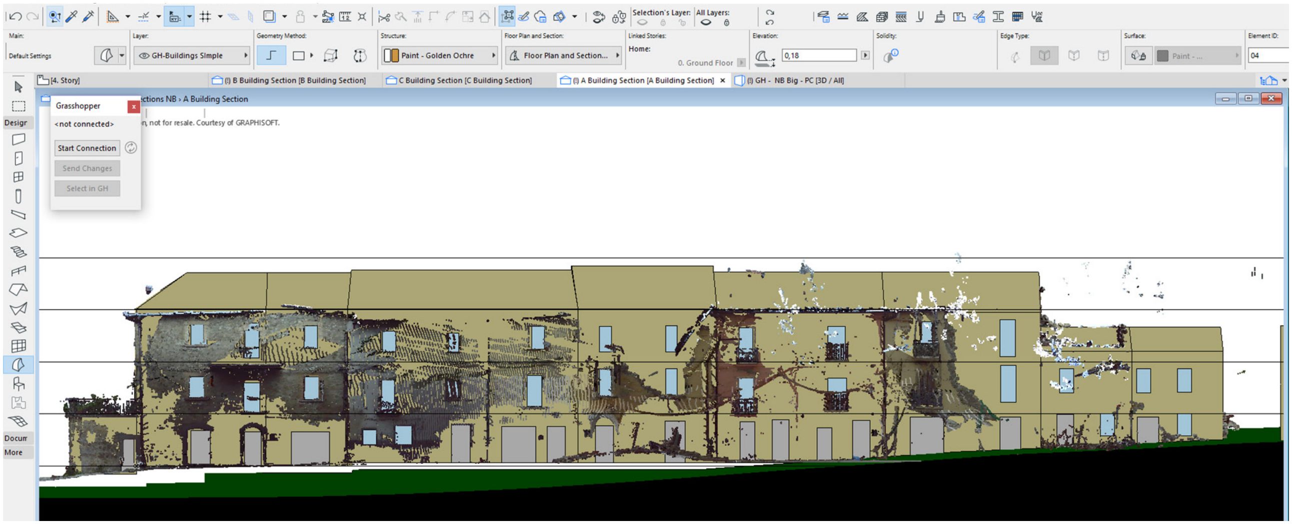
- External GIS data (retrieved from the network in specialized sites) that are used for the generation of the ground of the borough affected by the earthquake and the development of the volumes that make up the urban structure. This first step has been carried out with a conceptual modeler, where the synthetic geometries that describe the urban spaces with 'synthetic volumes' are modeled with an accuracy equal to a scale of representation 1:5000. Both the volumes and the terrain have been generated by an automatic 3D construction process using the VPL approach.

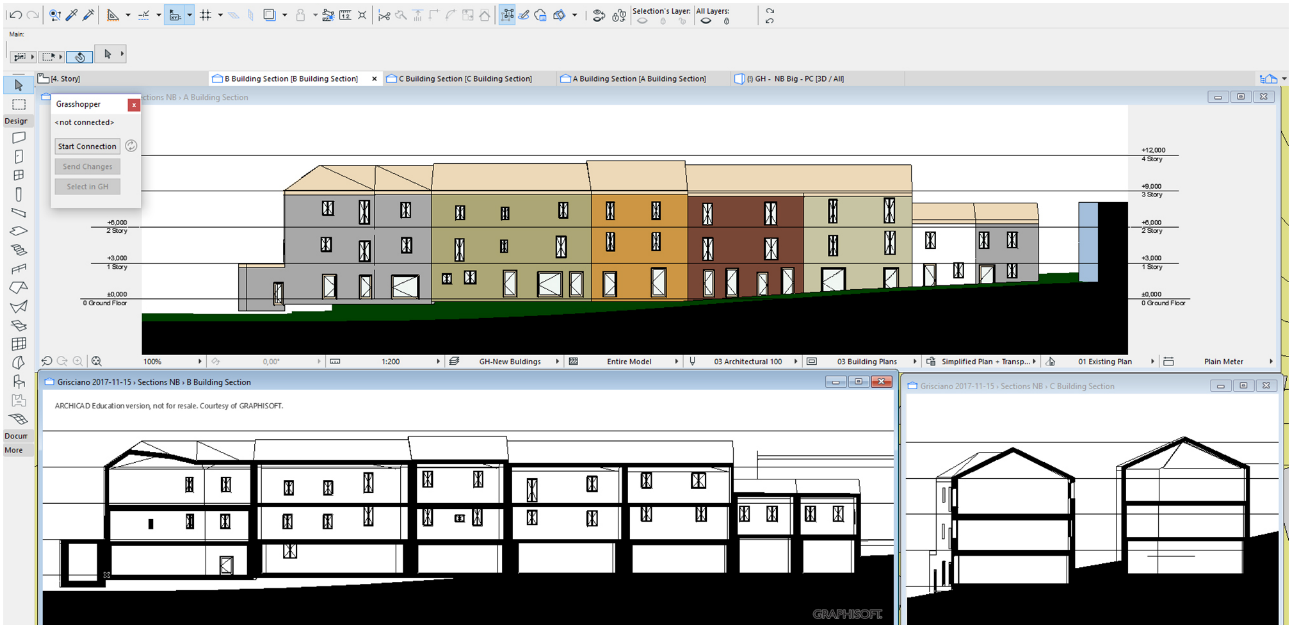
- Through the use of specific components, it is possible to import the conceptual geometries generated with the programming system in BIM environment. This step refers to the translation into the BIM modeler of the ground and of the 'synthetic volumes' previously modeled with the aid of VPL.

- In step 3 the overlap and orientation of the point cloud is carried out, obtained by the scan of the borough (fig. 8); this operation is useful for the construction of 'synthetic volumes' in the BIM environment more closely related to the actual dimensions of the studied buildings (fig. 9). Point clouds survey allows a leap of scale (similar to 1:50) in the reconstruction of the buildings, initially rebuilt with

Fig. 11. Point cloud model allows to view the shape of the windows and their position along the surface of the walls (image by Michele Calvano).

Fig. 12. Programming in VPL and connection with the modular architectural objects in BIM environment (image by Michele Calvano).





only GIS data. Points cloud model must be able to represent, through the numerical model, an exhaustive condition, from which it is possible to deduce the real model to be interpolated with continuous surfaces.
- Synthetic volumes created in the BIM environment are equipped with additional parameters (metadata) that describe, through alphanumeric data, thanks to the direct or visible survey, some intrinsic features of each building. Among the memorized properties we mention the number of floors, the thickness of the walls and floors, the roof type and the, building materials (fig. 10). Point cloud model allows to view the shape of the windows and their position along the surface of the walls. Also in this case the holes can be interpreted with plans that synthesize the shape and the position. Rectangular vertical planes that overlap with window images (fig. 11). Also to these geometries can be attributed alphanumeric properties, thanks to the on-site observation and the direct survey, for the typological description of the frames.
- Through the programming in VPL and the connection with the modular architectural objects in the BIM environment, the synthetic geometry of the volumes and the doors and windows are deconstructed, associating the dimensional data and the metadata previously attributed to the architectural objects, which, in this way, are recomposed in an informed architectural model, able to describe in detail the buildings partially destroyed by the earthquake (figs. 7-12).

Conclusions

Validity and potentiality of the ARIM procedure, in the BIM environment, is recognized by the Graphisoft company, that is working to increase the flexibility of BIM modeler Archicad, in order to communicate directly, to create and manipulate a complete or partial BIM model, through the interface of visual scripting of Rhino/Grasshopper [8].
New scenarios are opened in the field of 3D modeling; and, BIM representation: parametric modelers are able to acquire, manage and manipulate shapes deriving from objects that no longer possess, due to a natural disaster, any form generable or editable directly with traditional geometric tools.
The research has now the goal to identify an automatic procedure for defining discrete typological objects (fig. 4), deriving from a complex reality, at different levels of detail (LOD).

Notes

[1] The author is the coordinator of the Research Unit 'Urban Seismic Risk: prevention and reconstruction', established in 2017 by the Department of History, Representation and Restoration in Architecture - Sapienza University of Rome. The RU presents a working group of 30 people, interdisciplinary and interdepartmental. This article is the first issue of the research program, of which the author is the principal investigator, funded by Sapienza University of Rome and titled 'Urban/territorial restoration and seismic risk prevention: a methodology. Learning and experimenting from the case of 2016 Central Italy earthquake'.

[2] <http://www.ilsole24ore.com/art/notizie/2017-10-03/terremoto-mattarella-serve-patto-nazionale-la-prevenzione--140309.shtml?uuid=AEJHfvdC&refresh_ce=1> (accessed 2017, December 27).

[3] New Technical Standards for Construction (Decree of the Minister of Infrastructures dated January 14, 2008, G.U. No. 29 of February 4th, 2008, No. 30).

[4] <http://dati.lazio.it/catalog/it/dataset?category=Territorio+e+urbanistica> (accessed 2017, December 27).

[5] This part of the research is developed by Michele Calvano, Andrea Casale and Leonardo Paris, Department of History, Representation and Restoration in Architecture - Sapienza University of Rome.

[6] Part of the procedure was used in the 'Instant Modeling' operation conducted for Amatrice (Francesca Guadagnoli and Michele Calvano) which led to an efficient and accurate 3D modeling operation, which returned 'what is not there more' and gave back 'a form to absence'.

[7] This part of the research is still ongoing and is conducted by Michele Calvano and Mario Sacco with the Graphisoft software house, as an implementation of Archicad.

[8] <https://architosh.com/2017/12/graphisoft-dramatically-reshaping-the-power-of-bim-the-new-rga-live-connection-2-0/> (accessed 2017, December 30).

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