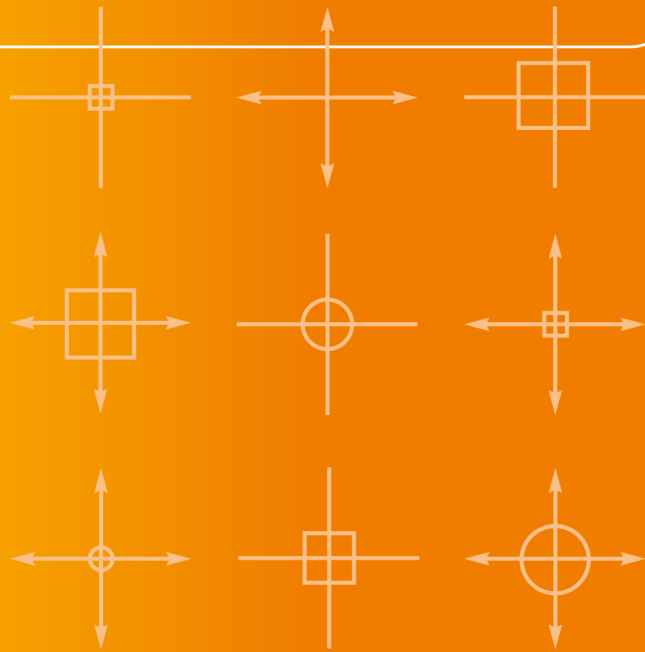# CHNT 20

Conference on
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Cover [pdf 603 kB]

SESSIONS

Public Relations and Archaeology – Presenting Cultural Heritage in Urban Area

Chairs: Ingeborg GAISBAUER, Austria | Ann DEGRAEVE, Belgium

Morten Valdorff RASMUSSEN, Denmark: On-site communication, old bones and new audiences [pdf 382 kB]

Colleen MORGAN | Robert CARTER | Michal MICHALSKI, UK | Qatar : The Origins of Doha Project – Online Digital Heritage Remediation and Public Outreach in a Vanishing Pearling Town in the Arabian Gulf [pdf 699 kB]

Matthias PACHER, Austria: The museum of prehistory MAMUZ as a cultural touristic impulse for a rural area in Lower Austria [pdf 783 kB]

Carmen LOEW, Austria: Examples for Stakeholder Values in Hallstatt-Research [pdf 169 kB]

Elisabeth MONAMY, Austria: Experience archaeology or bringing archaeology to a wider public [pdf 141 kB]

Nadja DEBENJAK | Kaisa MÄKI-PETÄJÄ, Austria: Revealing hidden histories with modern technology – Archaeological Information Systems and geolocalisation [pdf 824 kB]

Conflict as Cultural Heritage: Cultural Heritage in Conflict

Chair: Stephen STEAD, UK

Max VAN DER SCHRIEK, The Netherlands: Dutch Military Landscapes: Heritage and Archaeology on WWII conflict sites [pdf 1,75 MB]

Marzia MERLONGHI, Italy: CAAD: Crisis Areas Archaeological Database [pdf 1,56 MB]

Saadet GUNER, Turkey: History of the Protection of the Cultural Heritage in Conflict [pdf 178 kB]

Cultural Heritage in Danger

Chairs: Benjamin DUCKE, Germany | Anita GACH | Friedrich SCHIPPER | Hubert SZEMETHY, Austria

P. PERAKIS | T. THEOHARIS, Norway: Simulating Erosion on Cultural Heritage Monuments [pdf 1,72 MB]

Ralf HESSE, Germany: Possibilities and challenges in the application of multi-temporal airborne lidar data sets for the monitoring of archaeological landscapes [pdf 991 kB]

Konstantinos PSARRAS | Nikolaos MYRIDIS | Ioannis TEGOS, Greece: Development of New Technologies for the Earthquake-Resistant Design of Churches Threatened by Tsunamis [pdf 1,13 MB]

Mohammad Esmaeil Esmaeili JELODAR | Mahsa VAHABI, Iran: The challenges and opportunities of archeology excavations of Urban Rescue in Tehran City based on emergency excavations in the region of Molavi [pdf 939 kB]

Public Appearance – Heritage researchers, stakeholders and public interaction
Chairs: R.J. VAN LANEN | J.E. ABRAHAMSE | B.J. GROENEWOUDT | M.C. KOSIAN, The Netherlands

Marion GROßMANN, Austria: Carnuntums Appearance and its Mediation of Roman Culture [pdf 1,5 MB]
Matteo SCAMPORRINO, Italy: A 3D model to safeguard and transform the port of Livorno – Toward a View management framework [pdf 642 kB]
Kerstin DOHR | Josef GSPURNING, Austria: The Appearance of Istanbul's World Heritage Site in Terms of Accessibility and Embedment into the Urban Environment [pdf 1,3 MB]
Cristina CORSI, Italy: Good practice in management of 'invisible' archaeological townscapes [pdf 1,34 MB]
Luca GIORGI | Pietro MATRACCHI, Italy: Florence: knowledge and usability of the archaeological heritage [pdf 2,24 MB]

Newbies & Young Scientists
Chairs: Michael DONEUS | Benjamin STANGL, Austria

Pedro CABEZOS-BERNAL | Paolo FORMAGLINI | Filippo GIANSANTI | Raana KAYNIA, Italy: From the suggestion of viewing to the understanding of photography: a case study over rephotography [pdf 714 kB]
Martina POLIG, Sweden: The original Holy Cross Church in Dalby – new interpretations through digital archaeology [pdf 1,94 MB]

Disclosing the Dead
Chairs: David BIBBY, Germany | Ann DEGRAEVE, Belgium | Raphael PANHUYSEN, The Netherlands |Karin WILTSCHKE-SCHROTTA, Austria

Maja D'HOLLOSY, The Netherlands: Facing the Past – The use of facial reconstructions in connecting people to the past [pdf 1,25 MB]
David BIBBY | Hildegard BIBBY | Joachim WAHL, Germany: The Life, Times and Death of "Grave 700" from the Holy Trinity Church Konstanz, Germany [pdf 1,35 MB]
Peep PILLAK, Estonia: Disclosing the Traumas of History: The Case of First Estonian President [pdf 2,11 MB]
Liisa SEPPÄNEN, Finland: Buried in secrecy, surrounded by mystery, saved as curiosity – Animal grave from the early 20th century in town of Lahti (Finland) [pdf 682 kB]

The Use of UAVs in Virtual Heritage
Chairs: Peter DORNINGER, Austria | Benjamin DUCKE, Germany | Bernhard FRISCHER, USA | Rebeka VITAL, Israel

Stefanie WEFERS | Philipp ATORF | Jörg KLONOWSKI, Germany: UAV photogrammetry and 3D analyses of CH sites [pdf 2,38 MB]
Benjamin GEHMLICH | Marco BLOCK-BERLITZ, Germany: Diversity of Flight Strategies in UAV Recording [pdf 1,78 MB]

Digital 3D Reconstruction – Methods, Strategies and Challenges
Chairs: Piotr KUROCZYŃSKI | Mieke PFARR-HARFST | Sander MÜNSTER , Germany | Benjamin STANGL, Austria

Fabrizio APOLLONIO, Italy: Classification schemes and model validation of 3D digital reconstruction process [pdf 461 kB]
Dmitry KARELIN | Yulia KLIMENKO | Serjey KLIMENKO, Russia: The methods and approaches to the visualisation of 3D reconstructions [pdf 584 kB]
Dominik LENGYEL | Catherine TOULOUSE, Germany: The consecution of uncertain knowledge, hypotheses and the design of abstraction [pdf 3,21 MB]
Giorgio VERDIANI, Italy: Reading the project and "reverse design": an architectural approach to digital reconstruction [pdf 1,47 MB]

New realities: Virtual, augmented reality and other techniques in Cultural Heritage for the general public
Chairs: Willem BEEX, The Netherlands | Peter FERSCHIN, Austria | Bernhard FRISCHER, USA | Giorgio VERDIANI, Italy

Dragoș GHEORGHIU | Livia ȘTEFAN, Romania: Augmenting Immersion: The Implementation of the Real World in Virtual Reality [pdf 4,98 MB]
Samanta GREGGIO | Giuseppe SALEMI, Italy: A mobile Augmented Reality system

integrating 3D model and radiance scaling to enhance epigraphical inscriptions [pdf 846 kB]

Adele MAGNELLI | Matteo VENTRELLA, Italy: How the AR can help to appreciate the hidden value of pictorial masterpiece: Venice's Gallerie dell'Accademia case history [pdf 542 kB]

Takehiko NAGAKURA | Daniel TSAI, USA | Diego PINOCHET, Chile: Viewing the impossible: Photogrammetric Models of Palladian Villas and Other Works [pdf 1,34 MB]

Eiman ELGEWELY, Egypt | Willeke WENDRICH, USA: Reviving Karanis (Egypt): From Mud Bricks to Urban and Social Fabric [pdf 755 kB]

Giorgio VERDIANI | Mirco PUCCI | Mauro MARIOTTINI , Italy: The St. Donato Cathedral in Arezzo, digital reconstruction of a completely lost architecture [pdf 630 kB]

Anja WUTTE | Peter FERSCHIN | Georg SUTER, Austria: Excavation goes BIM. Building Analysis of an Egyptian Funerary Monument with Building Information Modeling Methods [pdf 556 kB]

Giulia DIONISIO | Anna Margherita JASINK, Italy: Teaching new technological methodologies applied to ancient history [pdf 570 kB]

Georg ZOTTI, Austria: Archaeoastronomical simulation in a desktop planetarium [pdf 1,06 MB]

Storytelling for Tourism in the Virtual Age. High Tech Travel for the 21st Century:
Chairs: Wolfgang H. BÖRNER, Austria | Eleni PANAGOU, Greece | Linda POTTER, USA

Claudiu SILVESTRU, Austria: Experiencing Medieval Vienna – New Approaches towards the Presentation and Interpretation of Invisible Cultural Heritage [pdf 1,4 MB]

F. GABELLONE | I. FERRARI | F. GIURI | M. CHIFFI , Italy: What communication for museums? Experiences and reflections within the project for the virtualization of the Museo Egizio in Turin [pdf 794 kB]

Nevena RADOJEVIC; Italy: Looking the Pazzi Chapel's umbrella vault from its oculus [pdf 982 kB]

Marino JAÉN ESPINOSA, Republic of Panama: Digital Storytelling of the Perote, a Traditional Festivity Held in Panama [pdf 235 kB]

Jochen SCHMID, Germany: The palace facade of Tell Halaf as part of the reconception of the Museum of the Ancient Near East – Material monumentality or virtual multiplicity [pdf 1,37 MB]

Davide PANTILE | Valerio ROSSI, Italy: Magna Carta Rediscovered: enhancing tourism through a travelling multimedia exhibition [pdf 412 kB]

Posterpresentation – NEW TECHNOLOGIES
Chair: Peter DORNINGER, Austria

Stefano BERTOCCI | Mattia VENTIMIGLIA, Italy: Augmented Reality for the documentation of Villa Adriana in Tivoli, Rome [pdf 853 kB]

Carmine CANALETTI | Alessandro CAMIZ, Italy: Reading and designing the area of Lambousa-Karavas, Cyprus: Acheiropoietos monastery [pdf 584 kB]

Francesco GABELLONE | Maria Teresa GIANNOTTA, Italy: New data from buried archives: the late Roman mosaic at Otranto [pdf 1,13 MB]

Iacopo GIANNINI | Angela MANCUSO | Mauro MARIOTTINI, Italy: The Church of St. Maria and St. Stefano on the Hill of Pionta, Arezzo – Italy. Studies, comparisons and hypothetical reconstruction [pdf 998 kB]

Irmela HERZOG, Germany | Alden YÉPEZ, Ecuador: The impact of the DEM on archaeological GIS studies [pdf 1,27 MB]

Serjey KLIMENKO| Dmitry KARELIN | Julia KLIMENKO, Russia: The methods and approaches of the scientific 3D-reconstructions of architectural monuments: the research experience in the Moscow Institute of Architecture [pdf 284 kB]

Angela MANCUSO | Andrea PASQUALI, Italy: Digital Micro-Photogrammetry: new ways to dialogue with future researchers (Winner of the 7th Poster-Award) [pdf 851 kB]

Jana MINAROVIECH | Margareta MUSILOVA, Slovakia: 3D Reconstructions of Roman buildings from 1st century B.C. on the Celtic Hillfort in Bratislava [pdf 2,02 MB]

Posterpresentation – CULTURAL HERITAGE
Chair: Wolfgang BÖRNER, Austria
Giulia BALDI, Italy: The Romanesque Complex of SS. Trinita' of Saccargia in Sardinia [pdf 506 kB]

Silvia D'ANDREA | Gianluca BELLI, Italy: From Porta alla Croce to Piazza Beccaria –

The evolution of Florence from city to Capital [pdf 2,12 MB]
Stéphane GIRAUDEAU | Andrea LEONARDI, Italy | Teresa GIL PIQUERAS, Spain: When an isolated building becomes a guideline for the urban pattern. The case of "Torrenostra" in Torreblanca, Castellón, Spain [pdf 402 kB]
Petar PETROV, Bulgaria: Walk Into Tranquility (Winner of the 7th Poster-Award) [pdf 601 kB]
Tatiana PIGNATALE | Ilenia TRAMENTOZZI, Italy: Anonymous heritage-Integration of technology and visitors' active involvement as a revaluation method of cultural assets [pdf 645 kB]
Pablo RODRÍGUEZ-NAVARRO, Spain | Roberto ATZENI | Valentina NALDINI, Italy : Coastal towers between Spain and Sardinia: proposals for a documentation strategy [pdf 354 kB]

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On the occasion of the 20th edition of the Conference:

Giorgio VERDIANI | Willem BEEX | Francesco ALGOSTINO, Italy | The Netherlands: The making of the "Golden Rathaus" – Story and methods of a very specific 3D printed model [pdf 654 kB]

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Presented on CHNT 19 | 2014 in the Session
Rubble, Ruins and Reading, specific approaches in analysis – Trying to let the remains telling the story
Chairs: Stefano COLUMBU / Giorgio VERDIANI, Italy

Oliver HAUCK | Piotr KUROCZYŃSKI, Germany: Cultural Heritage Markup Language. How to Record and Preserve 3D Assets of Digital Reconstruction [pdf 1,03 MB]

Scan for CHNT APP:

The St. Donato Cathedral in Arezzo

Digital reconstruction of a completely lost architecture

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Abstract: 3D modelling tools allow to reconstruct what is not clear to the eyes. This simple and short phrase is quite obvious, but when it meets lost architectures it becomes the key vault of a complex puzzle made of evidences, knowledge, reading strategies and later communication strategies. In the research presented here, the case study of the St. Donato Cathedral in Arezzo, becomes the occasion for analysing a full digital reconstruction process, its adaptation to virtual interactive usage and how this process can bring back useful information on the ruins that today are the last traces of its existence. The St. Donato Cathedral was the core of an ancient and independent citadel out of the Arezzo's walls. A settlement developed starting from the VIII century over previous Etrurian and Roman remains. It has been completely demolished in the XVI century for its political misalignment in front of the Cosimo de Medici's domination strategies. Only few remains of the citadel plot are now visible in place. Significant traces of these cathedral walls were never be found during the archaeological investigations, but a various set of representations documents its main aspects. These representations go from very detailed and pictorial images to schematic sculpted items, to plan drawing. Using an accurate and articulated digital reconstruction project a complete 3D digital model is produced out of all the possible traces. The process will be described in all its key passages, from the digital survey of the area, to the definition of architectural elements. An interactive model of the cathedral will be presented in first release. Beyond the common features for this kind of models it will have two specific peculiarities: the indication of the level of liability of each part and the system of references used to guide the process.

Keywords: Arezzo, Pionta, San Donato, Virtual Reconstruction, Digital Survey.

Introduction

Arezzo is placed in the middle of Italy, in its central part, a town in Tuscany with a rich and intense story. Even if such a thing is true for a lot of old towns in Italy and abroad, the story of Arezzo has a quite dark spot, fascinating for its blurred definition and almost transferred from the reality of the evidences to the fantasy of fragmentary remembering and ideas. In fact, there is an ancient and complex event which has destroyed a piece of the timeline in the history of this town (FATUCCHI 1969). There was a time when the hillock named "Pionta" was closed by walls protecting a small independent citadel, governed by bishops (TAFI 1995), with its own churches and politically aligned with the Pope and the Vatican State. The hill is still there, rising in an area out of the Arezzo walls, surrounded by the recent urban fabric and isolated from the town centre by the railway (PATURZO 2007). But until the XVI century it had its own fortifications and was a completely independent settlement (PASQUI 1899). The Place was not chosen by chance, in the past it has been used by Etruscan and later by Romans, it was also a burial place (DELUMEAU 1987). Because of its use as a cemetery the San

Donato burial was placed here, creating all the conditions of faith and devotion that chanced this place from an ancient graveyard to a holy place. San Donato was an important Saint, he is the patron of Arezzo, the cathedral still keeps his name (TRISTANO and MOLINARI 2005). He was born in Arezzo at an unspecified date (even if some studies try to locate his place of birth in Rome, or even in *Nicodemia*, Turkey) and died as a martyr in Arezzo on the 7th August 362 AD (or in the 304 AD, according to other studies).

The presence of such an important tomb may explain the reason for the first Christian settlements with the building of chapels and churches, but the reasons for creating a separated, self-governing town must be found in more articulated motivations. On one side probably the Pope was interested in having there a political and strategical outpost, not so far from Rome, but directly in the heart of Tuscany. But on the other hand it is possible to find some philosophical reasons following the words from Jaques Le Goff in *L'imaginaire Médiéval* (LE GOFF 2011). Here, presenting the urban concept from Guglielmo d'Auvergine (Aurillac, 1180 – Paris, 1249) in his *Opera Omnia* (pp. 407-416), the author underlines the following passages:

> *"Let's imagine a town made by the grouping of such perfect men (imaginabimur civitatem aggregatam ex hominibus sic perfectis) that all of their life is focused on giving honour and respecting God, a life dedicated to reach and apply the noblesse of the soul (honestas), a life dedicated to serve the others" (...)*

> *"It comes out clear how in front of such an admirable town (preclara), the rest of humanity is like a savage forest (quasi silva) and all the men outside are like raw wood (quasi ligna silvatica)".*

To the contraposition between town and forest, Guglielmo d'Auvergine adds a second contraposition: the one between the natural materials and the construction materials, in the specific of the natural stone and wood against wood beams and sculpted stones.

> *"On the contrary of the brute stones, raw pieces from the quarry (lapidicina, lapides rudes) and of the natural wood, the cemented stones, nailed or connected and the manufactured wood (coementum, et clavi, e carteraeque ligature inter lapides, et ligna) are the symbols of the mutual love and of the spiritual needs coming from humanity".*

 He defines:

> *"this admirable town is exactly the society, the aggregation of men or the city (societas, aggregationes hominum, seu civitates)".*

This town is the real alternative to the "fake" towns, which are forests and caves. The town is defined by the work of men whose capacity of artistry and work is a gift of God (*vires, et artem, et artificium*). In the end: the towns are men (*Cives civitatis procul dubio sunt veri nomiinis homines*). Such ideas can be imagined in their materialization as a rich, well constructed and "ideal" settlement, placed like a satellite on the borderline of the main town, a place of faith influencing its urban surrounding, showing and at the same time preserving, the meaning of Christian values in front of the common political and social context. This particular condition seems to find its graphical representation in one of the most famous frescos from Giotto (or at least attributed to Giotto), the "The expulsion of the devils from Arezzo", realized in Assisi, in the Upper Church between 1295 and 1299, but representing the town of Arezzo. The town is painted as closed by walls, with the apses of an independent church creating the background for San Francesco and other Friars. The chaos of the town in parallel with the well organized lines of the church. The message, clearly connected to ideas close to those expressed by Guglielmo d'Auvergine: the devils can be banned from the town because of the strength of faith,

but the faith needs proper places to host its intermediaries with humanity. Symbols and signs catalyse the will of humanity and must be shown properly. Such a reflection was maybe the base for the concept at the origin of the consolidation of the Pionta citadel as a religious outpost in front of Arezzo.

The tolerance for this small enclave ended in the XVI century. In 1561 Cosimo de' Medici ordered the destruction of the walled citadel, bringing to the ground all the buildings and trying to obliterate its existence not only from the terrain, but apparently from the historical memory (FATUCCHI 1998). But this did not happened: the memory of the place remained, supported by some elements saved and reused in other churches, some frescos and paints representing the Citadel, but most of its consistence is due to the "myth" developed around the first Arezzo Cathedral, the St. Stefano e St. Maria Church and the second one: the St. Donato Church. Not a simple legend, but the story of two Cathedrals, one near the other, one larger than the other, one ancient and coming from an early period of Christianity and a second one, rich and almost experimental, because of its articulated plant, enriched by marbles and spolia elements.

The traditional reading of these events indicates the presence of two large churches in this area, both once used as cathedrals. The ancient one was dedicated to the Saints Mary and Stefano, it was a quite common construction in the system of the Romanesque churches, while the following St. Donato, was characterized by a very complex asset, with a central and symmetric layout organized around a large empty space. The literature, in general, considers the St. Vitale in Ravenna as the inspiration for the work of Maginardo (PIZZI 1995), the architect of this cathedral. After the destruction of the whole settlement, the hillock felt in a long period of partial abandon, and even if the presence of this area remained at a latent state in the memory of the population, the buildings on the hill were demolished and their materials were most probably reused somewhere else, while only minor parts of the previous churches and chapels were reused and adapted in combination with new constructions, like the small church of St. Stefano, built in 1610, incorporating a small crypt from the original settlement (ARMANDI 2003). Various interventions through the centuries have rearranged the terrain of the hill and after some very early investigations (GALLI 1915), only starting from the 1960 a real archaeological excavation campaign was started, aimed to discover the remains of the ancient town (DONATI 1965). The ruins of the Romanesque church of St. Maria and St. Stefano were brought to light and various minor remains were excavated in the following archaeological campaigns. But a large part of this settlement is still unclear. There are no significant traces of the large church of St. Donato, the real cathedral of the walled town nor there are remains of the walls protecting the citadel (MELUCCO VACCARO 1985). The organization and the aspect of the area is barely testified by some paints and drawings (, which include a plan view of St. Donato made by G. Vasari (STEFANELLI 1970), but this large church seems just disappeared, with no findings or traces left at all.

The Digital survey of the archaeological site

In 2014, new research for this area was started, based on the collaboration between the cultural association "Academo, Roberta Pellegrini" and the "Dipartimento di Architettura" of the Florence University. A general photographic shooting operated by UAV, using an Aeromax drone was done just before the beginning of the main survey campaign. Then a new survey of the whole area has been made with the use of a 3D Laser Scanner and a Total Station. During these activities all the emerging walls have been photographed to allow

further reference and texturing. Specific photogrammetric surveys were made for the main finds, like various Roman marble urns, original mosaics and sculptures. The survey data treatment, the reading of the architectural traces and the interpretation of the original projects were made according to the logic of the architecture. At the same time a specific investigation about the state of knowledge of this area was brought on. These two research lines formed the basis of a starting hypothesis for a map of the next possible excavations. Other common solutions to investigate the underground (like georadar survey and visual analysis of the anomalies) turned out to be not so usable. This limit is due to the strong transformation of the ground which is mixed with ruins and fragmented parts. In this way the data can be very "noisy", so only a direct excavation, planned by clear guidelines, can give results.

The ideas about this place are easy to be resumed. The hillock hosted a very rich citadel, with the presence of two cathedrals, the older one dedicated to St. Mary and Stefano and the "newer" one designed by Maginardo in the XI century and dedicated to St. Donato, additionally to the cathedrals there was a set of minor chapels and small churches, the presence of defensive walls and an undefined number of buildings and facilities composing an urban pattern. All of this was built over older remains, coming from the Etruscan and Roman ages. During the destruction all the buildings were demolished to their basements. It is worth to underline that one of the most surprising element is the total destruction every parts. No traces of the St. Donato Cathedral, no traces of the defence walls. Most of the ruins seem to come from a level underground which was underground even at the time of the demolitions. It seems more proper not to formulate the question "Where are the remains?" but "Why these remains are still in place?".

In order to start the definition of a virtual reconstruction of the churches, seen the state of the ruins and the poor remains of most of the excavated areas, it was decided to proceed by comparing other architectures and getting the digital survey of any elements "connected" to the original settlement and its architectures. While the gathering of all the possible indications is still in progress, the virtual model of the whole area, in its current condition, has been completed, allowing the presentation and the browsing of all the parts of the ancient Basilica. The study and analysis of the architectural traces and indications allows the gradual interpretation of the original design of the larger parts of the buildings. All the digital tools, from the survey to the data treatments, to the post processing of the information have been used focusing on the will of understanding and discovering traces of the original asset of this place.

The whole research started from the digital survey. While, in a situation like this one, it is the first meaningful way of knowledge, a first approach to separate the mass of data from place and start structuring ideas. The organization of the survey followed multiple actions. For first the whole area around the site of the church of St. Mary and St. Stefano was photographed using an UAV, an Aeromax model equipped with a Canon PowerShot S100 12.1Mp compact digital camera (offering RAW shooting and GPS function). The pictures were taken from a single height with the camera parallel, most of the time, to the ground and with only few shots taken from a tilted position. All the shots were taken in raw format and this allowed the recovery of a certain amount of details from the shadows. Indeed the weather conditions at the time of this survey offered a clear sky and bright sun causing deep shadows. The total aerial survey was done in one morning, with a shooting session of 1.5 hours (from the first to the last shot). The pictures were later used to create a first textured 3D model of the area. This was done using photogrammetry, in the specific case with Agisoft Photoscan. This solution produced a light and practical 3D model capable of giving a first, generic,

visualization of the site, with all the main elements visible and readable. But this was not a complete and fully usable result: the quite large pixels describing the stones and the area and the quite simple mesh resulting from the photogrammetric process were not fully satisfactory.

The 3D laser scanner survey was planned in the form of an integrated survey, combining 3D LS to a topographic survey, the solution is quite classic and well suited for a situation like this, allowing the reduction of the need for a large and overlapping scanning area. The 3D laser scanner used was a phase-shift type, a Zoller+Fröhlich Imager 5006h. This unit offers good accuracy combined with robust construction, fast operations and the possibility to use the same tripod of the topographic unit. This last feature can turn to be quite useful during integrated survey operations: with three or four tripods around the area it is possible to swap from one to the other, reducing the operational time of the entire process. The working range of this instrument ranges from 0,4 to 79 metres (according to the technical specification of the manufacturer), in this survey the most usable data was ranging from one to 50 metres. The positioning of the scan stations was decided according to the shape and to the specific conditions of the terrain and of the remains. The surveys were completed taking 112 stations, all of them operated in full panoramic mode, and exploiting the characteristics of the 3D laser scanner in use, which was capable of scanning 360° on the vertical axis and 310° on the horizontal axis. The site has generous vegetation, with various trees and brushes and at the same time it has various "empty" space with no relevant structures, the excavated areas are at a certain distance one from the other, but the terrain is at the same time interesting for investigation and design aims. So the topographical network worked well in connecting all the scans together and allowing a lower density of the scans for the terrain and the "connecting" parts and applying a high level of details only for the excavated parts and the sectors where it was really needed.

Drawings, paints and other references

The poor ruins on the Pionta hillock are not the only witness of the ancient condition of this place. A various set of iconographic examples are here and there in Arezzo and they testify, in their own way, the original aspect of the citadel. Some of them are very interesting and so it was decided that photographic or photogrammetric surveys of each of them were to be taken. The first was the sign engraved on the main door architrave of "St. Maria of the Old Dome" Church in the Arezzo downtown, probably realized immediately after the destruction of the citadel. The second was a baked clay plaque from and altar, now located in the Diocesan Sacred Art Museum in Arezzo. For both items the photogrammetry was based on the use of Agisoft Photoscan, with the use of a measurement taken in place to put the final model in scale. The use of 3D models to study such elements is very interesting, because it allows the detailed reading of the shape of the elements and it makes it possible to take a look from different and specific perspectives. There are also other graphical descriptions of the place before its destruction, but they are paintings or drawings, thus a simple flatbed scanner was enough to create a digital copy starting with a good quality reproduction of these documents. One of these is currently conserved in the Uffizi "Gabinetto dei Disegni" and it's a work by Giorgio Vasari the Young. The drawing shows the plan of the original St. Donato Church. This is a very important document, describing a rare and innovative medieval church, with a spatial organization running all around a central space, something existing in other architectures, but only in churches built centuries later. The

combination of this drawing with the other traces left in paintings and in sculptures are the only possible bases to start a virtual reconstruction of the St. Donato church. While the presence of a certain set of ruins from the Church of St. Mary and Stefano allows to start investigating this ancient church with more ease.

Giving back a shape to a lost Architecture

The first data treatment was dedicated to the alignment of the point clouds; this was done using Leica Geosystem Cyclone. The topographical network was the base of all the work, but to ensure a solid result each couple of scans were consolidated using geometrical matching between the clouds: the so called "cloud constrain". This process took time and produced the first 3D digital point cloud model of the archaeological site. During the following post processing of the point clouds special attention was given to the trees, the parts of the point clouds describing them were separated and heavily decimated. In this way the overall work, was simplified to a little less than 2 billions points. Thus this was still a "heavy" and not easy to use dataset, so it was used only for data extraction and not for interactive usage. A final version of the global point cloud was exported into Pointools Viewer (now Bentley Pointools) with interesting benefits in interaction and visual performance.

The dataset was later divided into multiple parts, according to the structure of the site. The first to enter the process for multimedia aims was the sector of the ruins of the Church dedicated to the Saints Mary and Stefano. This is indeed the "best" preserved monument of the whole hill, but it's more or less a collection of low walls and fragments. But it remains the only clearly readable architecture and a very important reference for any further study.

The dataset of this ancient structure was treated using a well-consolidated practice, derived from the video games graphical solutions and still useful for Cultural Heritage items in digital survey processing. Starting from the point cloud of the church ruins a very detailed mesh was created. Then it was considered as the "high poly" (high number of polygons) mesh: this very complex model was exported using the .OBJ format into Raindrop Geomagic Studio. Using the specific tools of this software it was decimated to became a "low poly" (low number of polygons) mesh. The "high poly" model was then used to extract its details in the form of a normal map and displacement map; these two bitmaps were then applied back on the "low poly" model. In this way the lightweight model was capable to be used with ease in multimedia and interactive use, apparently preserving its original level of details. For the remaining walls of St. Mary and Stefano the decimation was quite strong, the original model, made of around six million faces was used to apply texture. This one was created starting from a large set of shots taken on the ruins at the time of the survey. Then, after the extraction of the normal/displacement maps, it was simplified to be made by only 50 thousands faces, but with the texture, the normal and the displacement maps applied, it still looks rich and useful for the reading and interpreting of the site. The processing of the texturing was done using Maxon Cinema 4D, the model was then exported again in OBJ and DAE formats for further use in multimedia and interactive software.

If the St. Mary and Stefano church offers many walls and various elements to base a reconstruction, the St. Donato cathedral seems a sort of vanishing building, with no remains to support hypothesis. None of the previous excavations have ever found traces of this building. The list of possible references are quite short, the most relevant are: few written lines about the St. Donato in "Le Vite" from Giorgio Vasari (VASARI 1986); a

plant of the cathedral made by Giorgio Vasari the Young; various paints and frescos, all realized after the demolition, representing an apses view of the cathedral. Probably most of them are based on the same drawing and one follows the other altering an original version of this view; the two representation in marble and baked clay mentioned in the previous paragraph; various ideas coming from previous studies, most of them oriented to find a reference in the St.Vitale in Ravenna.

For sure it was a quite particular building, rich, articulated, maybe "experimental" for its time, with the effort to find a balance between the need of a Cathedral and keeping a central space, opened to the roof. For this complex nature it is not simple to find existing reference buildings, none of them seem available in Tuscany, almost none of them from the same age. At the state of the research it has been possible to find two interesting reference: the church of St.Sofia in Benevento and the church of St. Erasmo in Capaci. Both are not to be considered in connection with the St.Donato, but probably they present a similarity in the spatial aspect (LADNER 2008), with a central volume articulating the shape of the church all around. The two churches come from different historical periods, but both present the complex will to design a central space developing into the naves of a church. There is no doubt that reconstructing this old church is literally the recreation of "a new reality", where intuition and partial evidences guide the research.

The digital reconstruction moved from the plant view made by Vasari the young: once oriented and putted in scale (the drawing has clear notes to help it), it has been the start of any further development. The first reflection can come from placing this first drawing over the ruins of the St. Mary and Stefano church. They look compliant, it is possible to suppose the St. Donato built over the previous church, a renewal of the Cathedral in place of a double Cathedral. No other evidences can support this idea, but this is something happened in other context, the old church leave space for the new one, the ancient basement remains beneath the new building. This hypothesis should explain why there are remains of the St.Mary and Stefano, they were underground at the time of the demolition and so they remained. Obviously there is no way to demonstrate this, but in the lack of any archaeological finds this can take place in the various number of ideas about this place.

The definition of the digital reconstruction was here operated using directly a 3D modelling process, starting from the inside and then going to the apses, then back to the interior and in the end completing the external sides. For the interior a *matroneo* (women's gallery) has been thought to match the St. Vitale in Ravenna structure.

The development of the model confirms the complex and rich characteristic of this architecture, confirming it as one of the most peculiar lost building from that age.

Dissemination

As a first test for the possible export and sharing of the models coming from this research, all the main models were brought inside the *Sketchfab.com* online community, this interesting service and site allows high quality real time browsing and at the same time protects the original 3D contents from unauthorized access and download.

The results are easy to browse in high quality graphic, both the models coming from the main and the secondary surveys are well integrated inside the website interface. In this way, technology enthusiast and

scholars can browse and analyse the 3D models of this monumental and mysterious area appreciating the size and the articulation of each part of this complex puzzle.

Conclusions

The virtual reconstruction of the St. Mary and Stefano church and of the St. Donato was just the first step of a complex work, the models defined interpolating between existing architecture and inverse design procedures allow to have a first look at the possible aspects of the area, yet it leaves all the questions about the St. Donato cathedral open, as its original place remains a mystery and nothing seems successful in finding its traces. Even the most promising excavations turned out to discover only fragments belonging to other buildings. While the presence of the underground chapel, gives not enough suggestions to be used as a possible reference in locating of the main monument. In the end the total destruction applied to all the buildings of the area and the numerous rearrangements of the terrain seems to have destroyed everything to such a level that the main question seems to be "why did only the St. Mary and Stefano Church ruins remain intact enough to be read?" Such a question may be able to open new and interesting scenarios about the state of knowledge of the area, while the attention raised by the use of contemporary archaeology may be able to bring back attention and understanding about this rich and unlucky part of the town.

Acknowledgements

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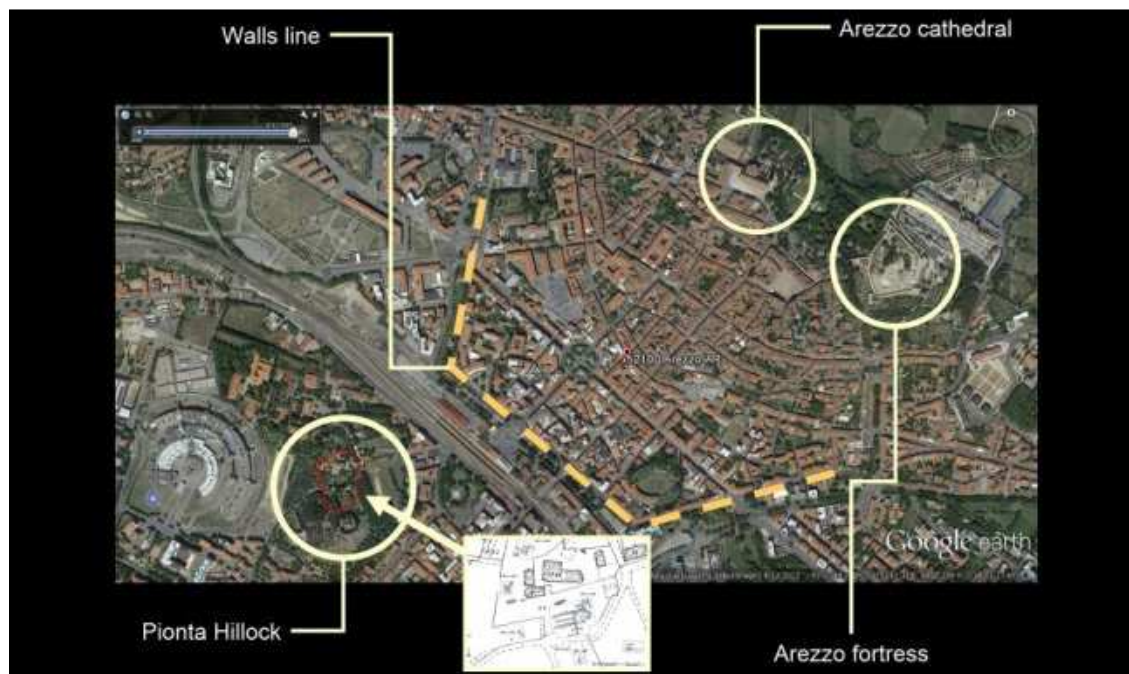
Figures

Fig. 1 – Arezzo and the Pionta Hillock

Fig. 2 – The expulsion of the devils from Arezzo attributed to Giotto, 1295-1299, Assisi, Basilica Superiore and the ruins of the St. Mary and St. Stefano Church
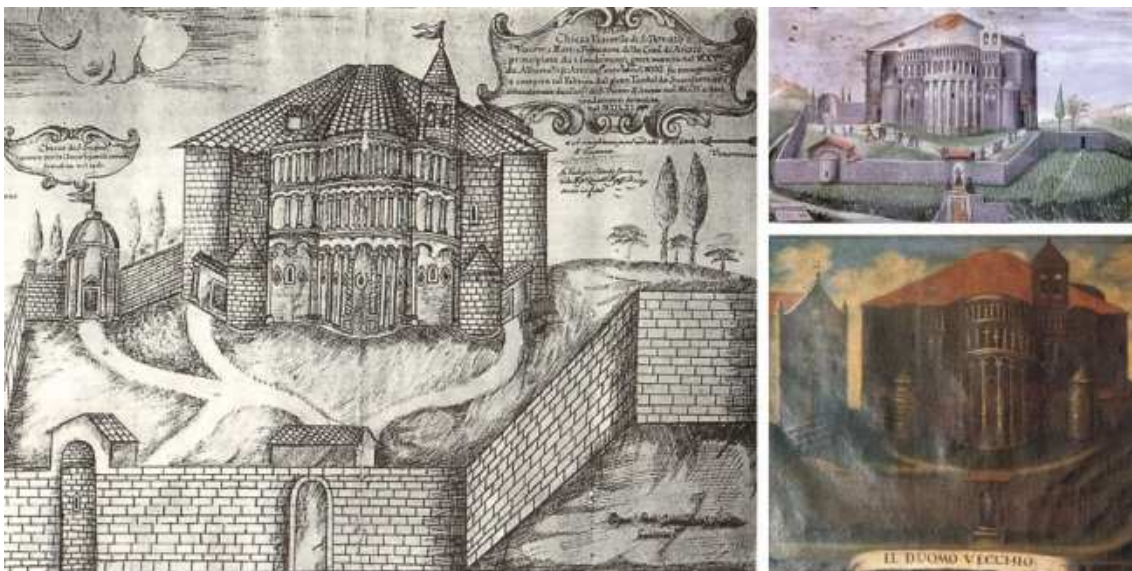

Fig. 3 – Various representations of the St. Donato Cathedral

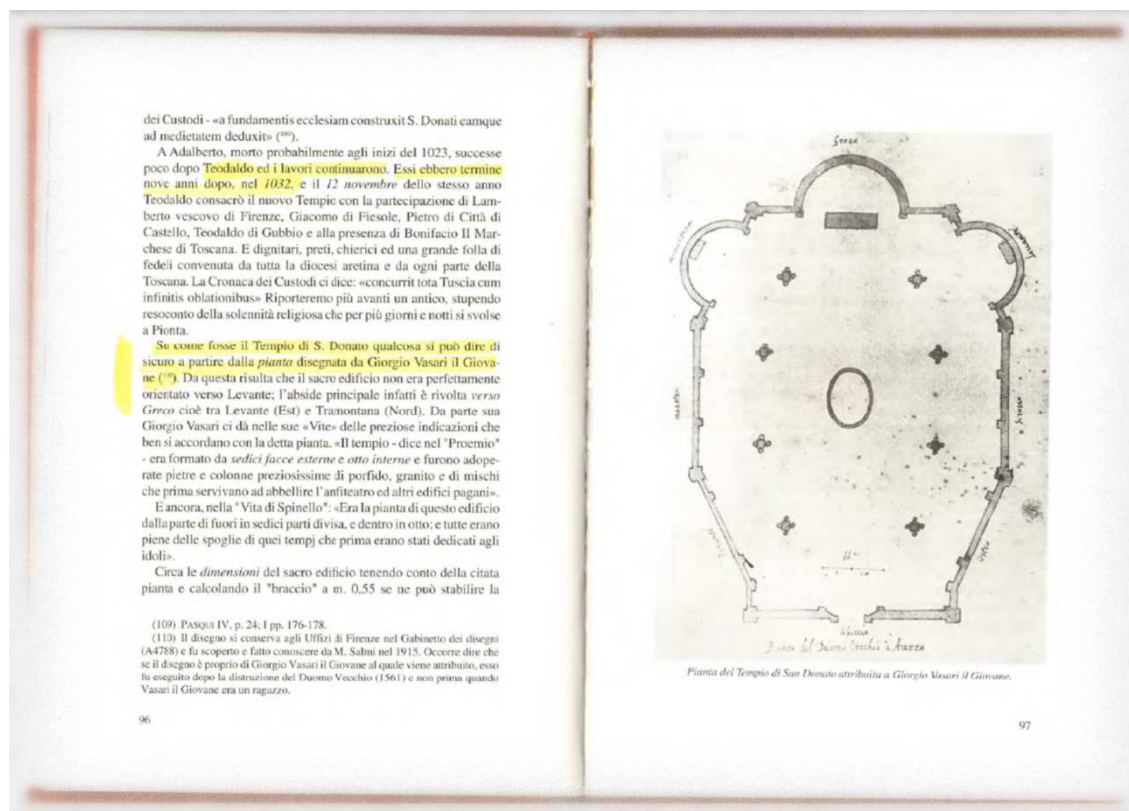Fig. 4 – Photogrammetry of the Crest representing the front of the St. Donato Cathedral

Fig. 5 – The plan drawing of St. Donato Cathedral by Giorgio Vasari the young, as published in the A. Tafi book
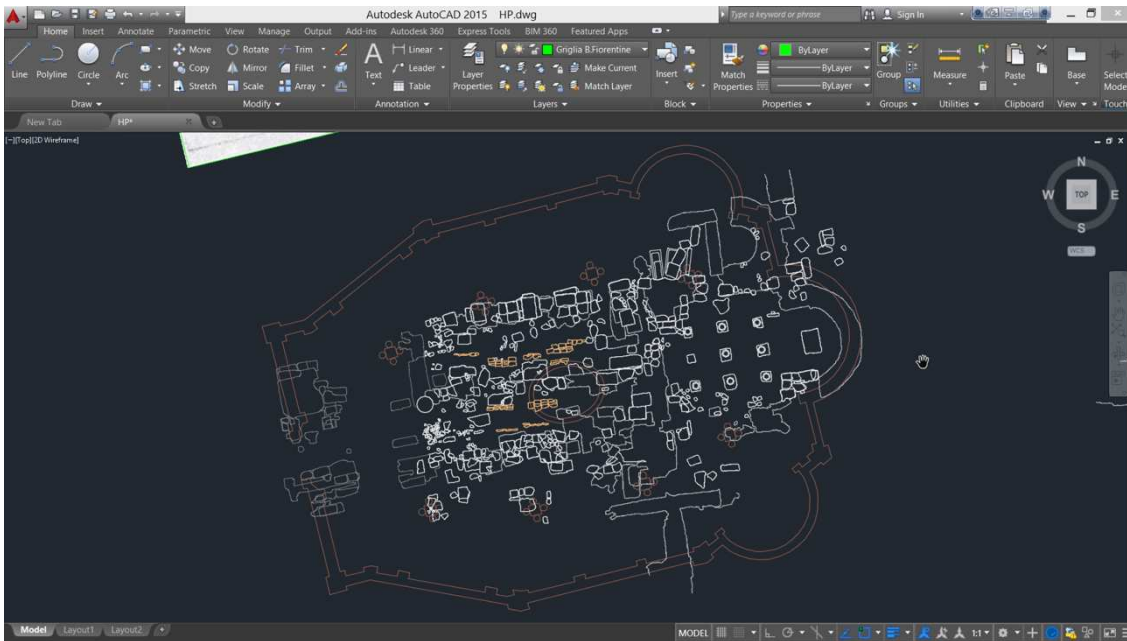
Fig. 6 – Matching test between the plans of the St. Mary and St. Stefano and the St. Donato Cathedral Churches
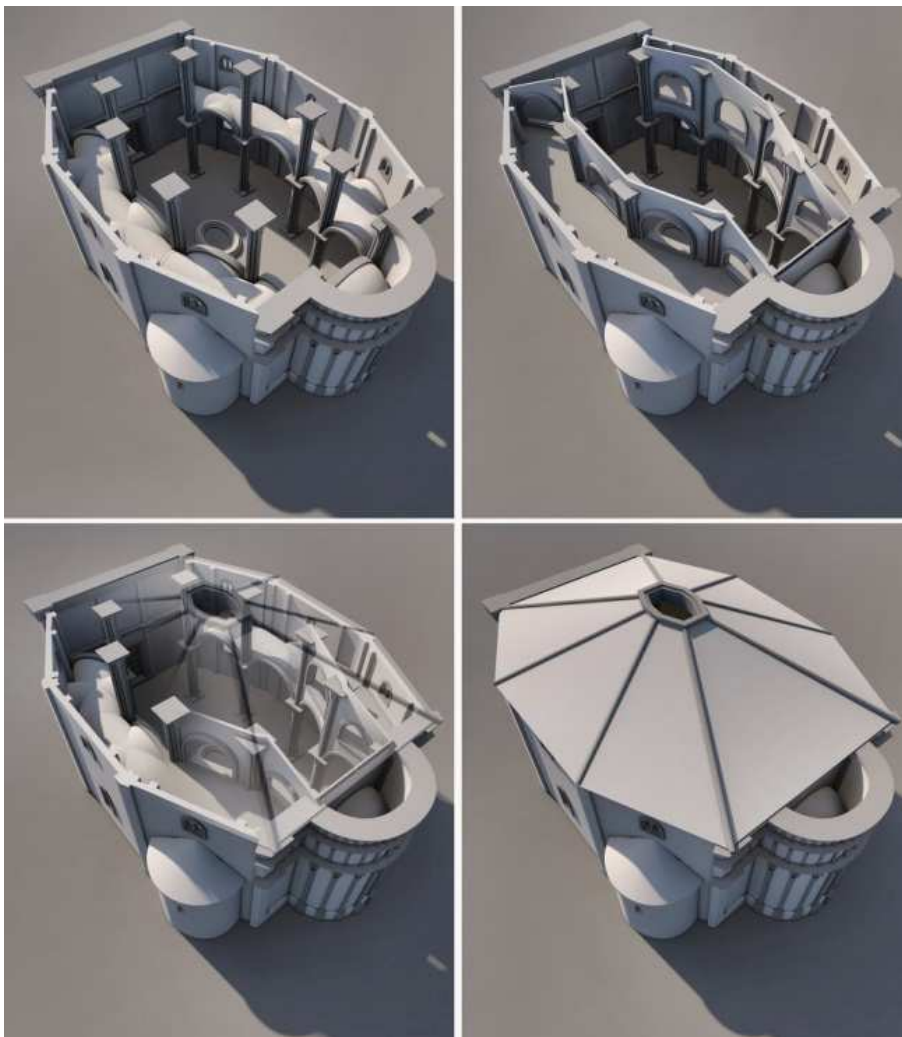
Fig. 7 – Virtual reconstruction of the St. Donato Cathedral
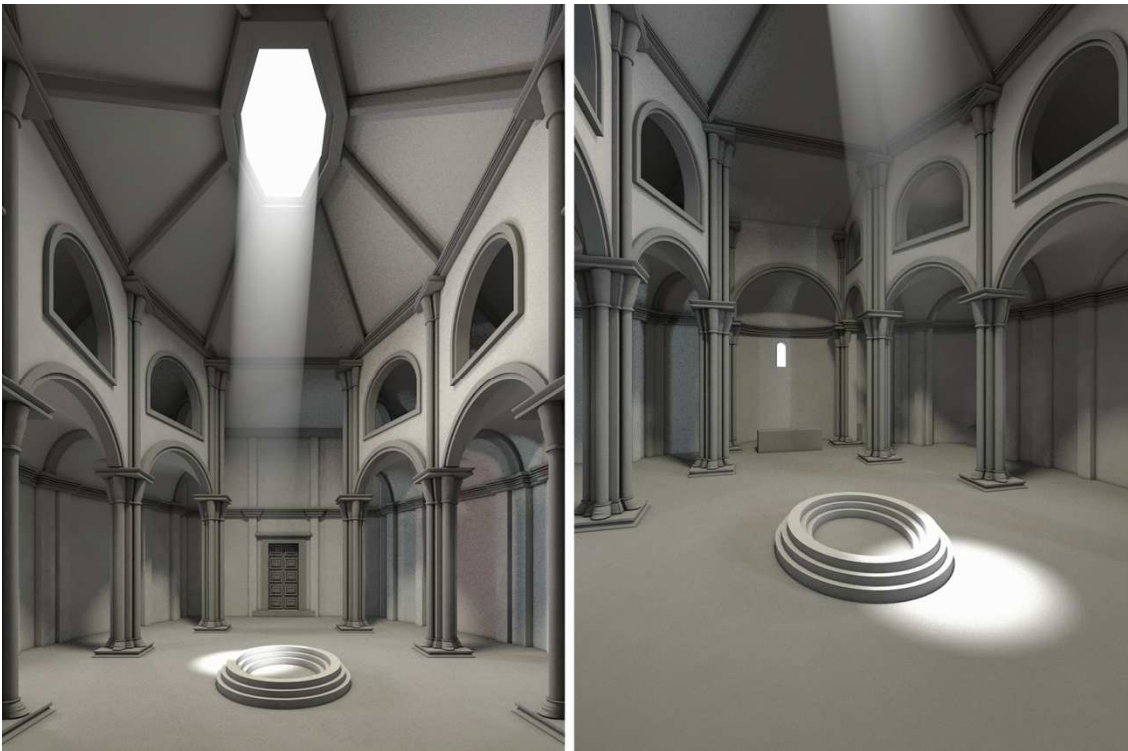
Fig. 8 – Virtual reconstruction of the St. Donato Cathedral
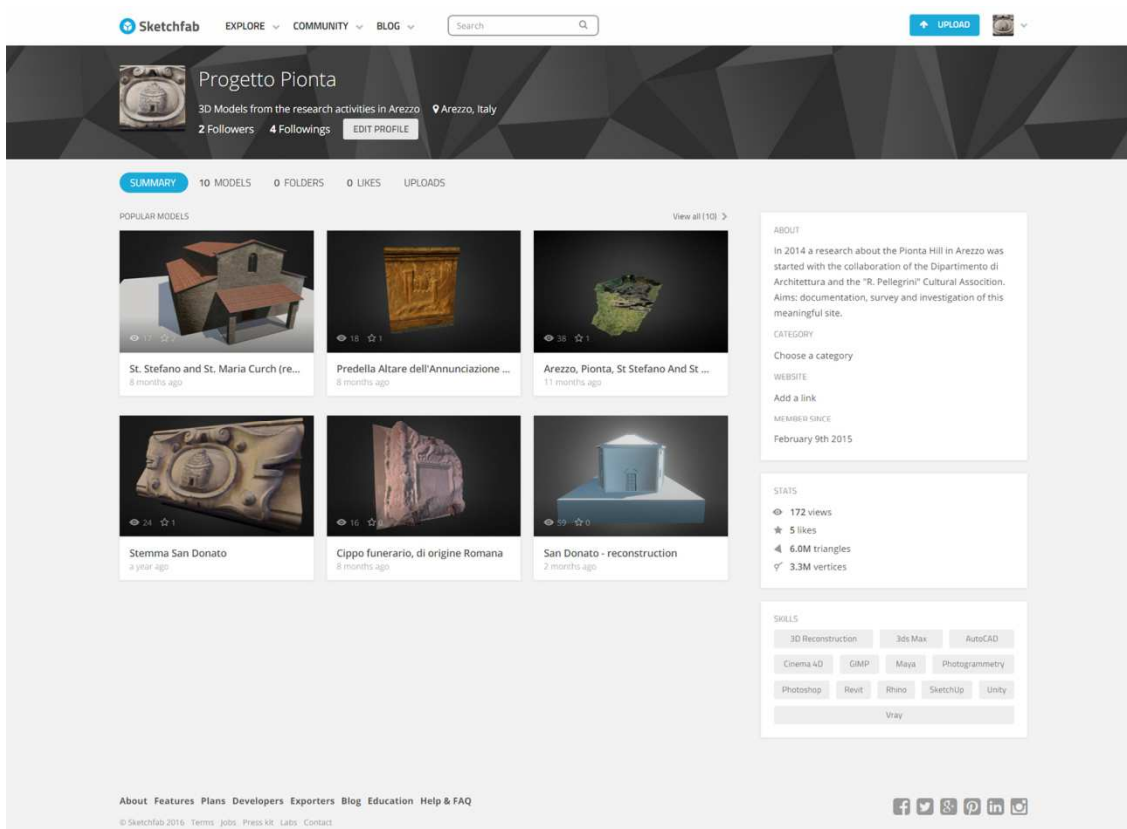

Fig. 9 – Virtual reconstruction of the St. Donato Cathedral

Fig. 10 – The Sketchfab account dedicated to the Pionta Project