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Virtual Reconstruction Information Management

A scientific method and 3D visualization of Virtual Reconstruction Processes

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Contents

Abstract

3D modeling and ICT technologies for representing processes of knowledge in virtual reconstructions / Modelli tridimensionali e l'uso di ICT per la rappresentazione dei processi nell'ambito delle ricostruzioni virtuali.

This research project takes up the challenge of creating a system to document transparency of processes creating virtual 3D reconstructions. The virtual reconstruction of artefacts just designed, no longer existing, or nor fully documented is obviously a subjective process that simplifies a visualization of the original one. Nowadays, due to a growing number of multidisciplinary projects, scholars commonly recognize the importance of transparency in 3D virtual reconstructions.

The goal of this research project is defining a methodological procedure focused on the validation of the 3D reconstructive model and finding a methodological solution to visualize its multiple representations, defining standards from data processing through documentation to visualization of each 3D hypothetical reconstruction of Cultural Heritage (CH) artefacts.

The new technologies potential to manage information immediately became a topic of great interest in order to understand the current dynamics of virtual reconstructions, that are processes not only based on the procedure of modelling an artefact using 3D software but on focusing the attention to the complexity of information that models convey.

The research, therefore, was primarily aimed at understanding the design of processes and those methodological strategies used in the field of virtual reconstructions, starting from a consolidated but non-heterogeneous theoretical background.

The collection of a vast and thematic literature,

Il progetto di ricerca raccoglie la sfida di creare un sistema per documentare la trasparenza dei processi mediante i quali vengono create ricostruzioni virtuali in 3D. La ricostruzione virtuale di manufatti unicamente progettati, non più esistenti, o parzialmente documentati è ovviamente un processo soggettivo che semplifica la visualizzazione dell'originale originale. Molti studiosi a causa di un numero crescente di progetti multidisciplinari oggigiorno hanno riconosciuto l'importanza della trasparenza dei processi nelle ricostruzioni virtuali in 3D.

L'obiettivo è definire una procedura metodologica incentrata sulla validazione del modello ricostruttivo 3D e trovare una soluzione metodologica per visualizzare le sue molteplici rappresentazioni, definendo alcuni standard: dall'elaborazione dei dati alla visualizzazione di singole ipotesi ricostruttive 3D di beni culturali, ottenibili mediante la documentazione a disposizione.

Le potenzialità fornite dall'applicazione delle nuove tecnologie alla gestione delle informazioni è sembrato da subito tema di grande interesse per comprendere le attuali dinamiche interne allo sviluppo di ricostruzioni virtuali intese non tanto nella loro accezione tridimensionale ma quanto nella loro complessità informativa.

La ricerca dunque è stata in primo luogo indirizzata alla comprensione di quei processi e di quelle strategie metodologiche utilizzate nell'ambito delle ricostruzioni virtuali partendo da un consolidato ma non eterogeneo background mainly focused on the description of case studies, has allowed to identify potential and criticality of existing methodologies, applied in the context of virtual reconstructions.

Among the negative elements, that even represent one of the gaps highlighted by the thesis, there was the absence of common application methodologies as well as the absence of shared standards and procedures to manage information, processes, and products.

A second survey phase has therefore attempted to identify, in the field of complementary lines of research, such as the tools and existing methods related to information management by identifying the potential applications of metadata, paradata, controlled vocabularies and ontologies.

The investigation concerning those issues subsequently directed research aimed to a digital management model of information processes in the context of virtual reconstructions called "Virtual Reconstruction Information Model" (VRIM) which shows itself as the main originality of the research element.

This model was concerned to try to fill the gap highlighted by the presence in scientific bibliography of extremely different approaches from both the observed lack of approaches that consider the process in its methodological and procedural complexity.

In the last few years the research has shown how the BIM allows to gather in a logical and uniform way the information related to a building, then the HBIM process focuses on the importance and definition of the conservation status of the architectural artefacts.

The Virtual Reconstruction Information Management (VRIM) proposes a method focused on cognitive processes to clarify the relationship between the available resources and material, the implicit knowledge, the explicit assumptions and finally the display

teorico esistente.

La ricognizione di una vasta letteratura tematica di riferimento, principalmente focalizzata sulla descrizione di casi studio, ha permesso di identificare potenzialità e criticità delle esistenti metodologie, applicate nell'ambito di ricostruzioni virtuali.

Tra gli elementi negativi, che costituiscono anche uno dei gap evidenziati dalla tesi, si è registrata l'assenza di comuni metodologie applicative così come l'assenza di standard e procedure condivise per la gestione delle informazioni, dei processi e dei prodotti.

Una seconda fase conoscitiva ha quindi cercato di individuare, all'interno di indirizzi di ricerca complementari, quali potessero essere gli strumenti e i metodi esistenti legati alla gestione delle informazioni individuando le potenzialità applicative di metadati, paradati, vocabolari controllati e ontologie.

Le macro tematiche di indagine preferenziali hanno successivamente indirizzato la ricerca nella proposta di un modello di gestione digitale dei processi informativi nell'ambito delle ricostruzioni virtuali denominato "Virtual Reconstruction Information Model" (VRIM) che si propone come principale elemento di originalità della ricerca.

Tale modello è stato concepito per cercare di colmare il gap evidenziato sia dalla presenza in bibliografia scientifica di approcci estremamente differenti sia dalla constatata mancanza di approcci che prendano in considerazione il processo nella sua complessità metodologica, procedurale e applicativa.

Se negli ultimi anni la ricerca ha evidenziato come il BIM permetta di raccogliere in maniera logica e uniforme la documentazione relativa ad un fabbricato, il processo HBIM si concentra invece sul rilievo e sulla definizione dello stato di conservazione dell'artefatto architettonico.

Il Virtual Reconstruction Information Management (VRIM) propone un metodo che

of the results into BIM environment.

The use of correctly managed BIM tools, could be considered as a valid response to the issue of transparency in virtual reconstruction processes as it is can discretise information and reorganize them using the digital model as a graphical index of the information system: Building Information Modelling (BIM) can be used to manage 3D archives with considerable potential in terms of research and dissemination.

Transparency and traceability of interpretation processes are necessary for a better understanding of knowledge embodied by 3D models and their visualizations. Transparency is also necessary for interdisciplinary communication and evaluation of results for the benefit of future generations.

The problem of interpretation which features reconstructions where multidisciplinary approaches is crucial to re-use information by those who own a different background but are called to collaborate on the same project.

In any research related to virtual reconstructions, the first step, acquiring a “pre-knowledge”, it is necessary to define a system where everyone can be user and creator of traceable knowledge.

The proposed methodology, named ”Virtual Reconstruction Information Management” (VRIM), aspires to systematize some general processes related to 3D Virtual Reconstructions (VR) and the management of data information related to those models.

The VRIM proposes a set of methodologies and procedures:

Workflow for Virtual Reconstruction
A workflow for VR that identifies phases of Virtual Reconstruction processes:

- Collection & Acquisition
- Analysis
- Interpretation
- Representation

si focalizza sui processi cognitivi con lo scopo di chiarire le relazioni esistenti tra risorse/materiali a disposizione, conoscenza implicita, presupposti espliciti e visualizzazione finale dei risultati in ambiente BIM.

L’uso di tale interfaccia se opportunamente gestita si dimostra una valida risposta al problema della trasparenza nei processi di ricostruzione virtuali perché capace di discretizzare le informazioni e riorganizzarle utilizzando il modello digitale come indice grafico del sistema informativo: il Building Information Modelling (BIM) nasce infatti per essere utilizzato come gestore di dati relazionati ad un modello 3D con un potenziale considerevole in termini di ricerca e diffusione.

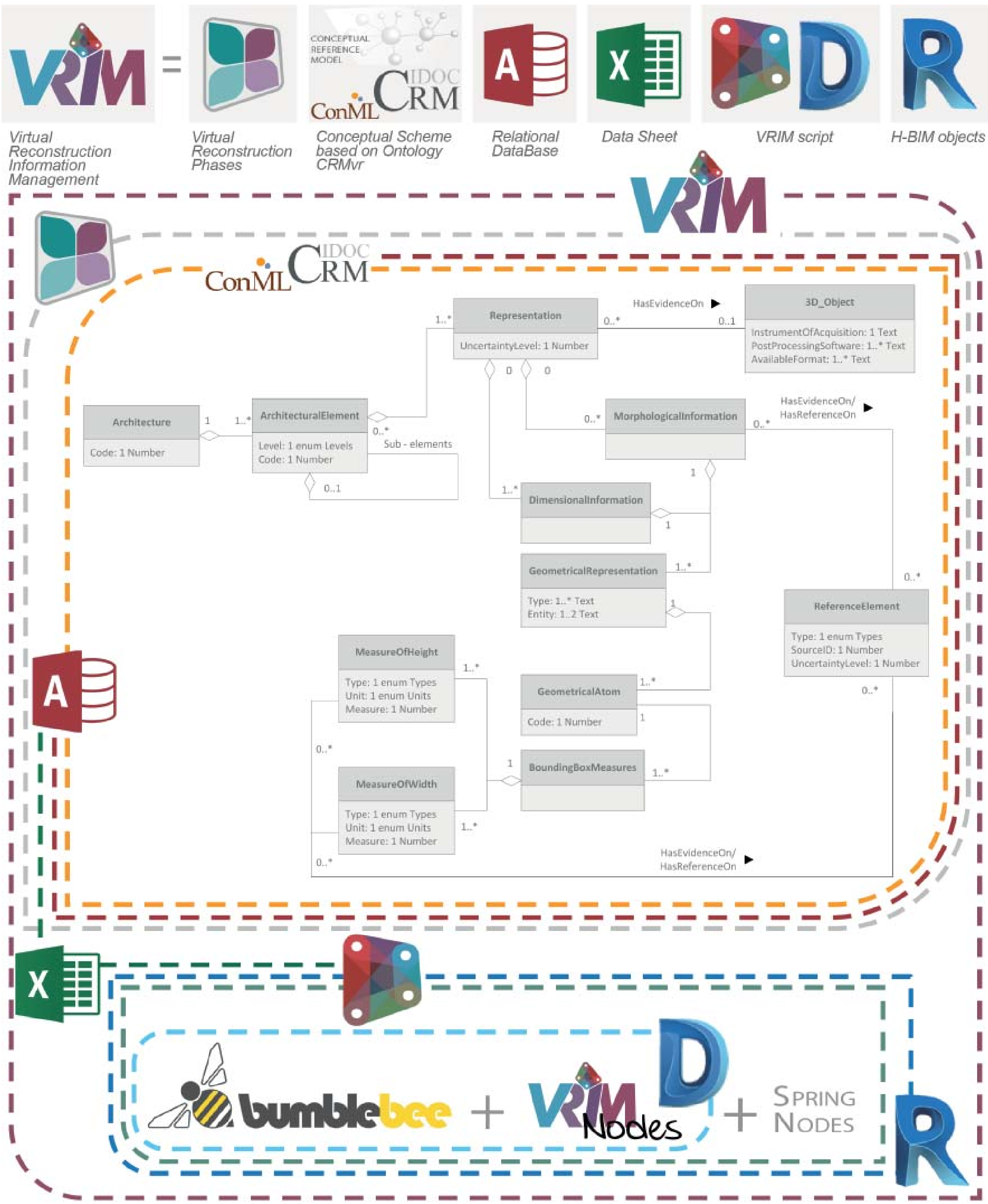
Trasparenza e tracciabilità dei processi di interpretazione sono necessari per una migliore comprensione delle conoscenze incorporate nei modelli 3D e nelle loro visualizzazioni: entrambe concorrono alla comunicazione interdisciplinare e alla validazione dei risultati a beneficio delle generazioni future.

Il problema dell’interpretazione che caratterizza le ricostruzioni in cui sono richiesti approcci multidisciplinari è cruciale per il riutilizzo delle informazioni da parte degli utenti che possiedono un background diverso ma che vengono chiamate a collaborare ad uno stesso progetto.

In ogni ricerca legata a ricostruzioni virtuali, prima si acquisiscono informazioni di “pre-conoscenza” quindi è necessario definire un sistema in cui tutti possano essere utenti e creatori di conoscenze tracciabili.

La metodologia proposta, “Virtual Reconstruction Information Management” (VRIM), ha l’intento di sistematizzare alcuni processi generali relativi alle ricostruzioni virtuali 3D e alla gestione delle informazioni dei dati legati a tali modelli.

Il VRIM propone una serie di metodologie e procedure:


VRIM
=
CONCEPTUAL REFERENCE MODEL
ConML CIDOC CRM
Virtual Reconstruction Information Management
Virtual Reconstruction Phases
Conceptual Scheme based on Ontology CRMvr
Relational DataBase
Data Sheet
VRIM script
H-BIM objects
Representation
UncertaintyLevel: 1 Number
HasEvidenceOn
3D_Object
InstrumentOfAcquisition: 1 Text
PostProcessingSoftware: 1..* Text
AvailableFormat: 1..* Text
Architecture
Code: 1 Number
ArchitecturalElement
Level: 1 enum Levels
Code: 1 Number
Sub - elements
MorphologicalInformation
HasEvidenceOn/
HasReferenceOn
DimensionalInformation
GeometricalRepresentation
Type: 1..* Text
Entity: 1..2 Text
ReferenceElement
Type: 1 enum Types
SourceID: 1 Number
UncertaintyLevel: 1 Number
MeasureOfHeight
Type: 1 enum Types
Unit: 1 enum Units
Measure: 1 Number
GeometricalAtom
Code: 1 Number
BoundingBoxMeasures
MeasureOfWidth
Type: 1 enum Types
Unit: 1 enum Units
Measure: 1 Number
bumblebee
VRIM Nodes
Spring Nodes

VRIM Scheme

A conceptual Scheme that clarifies the relationship among research sources (collection), implicit knowledge (acquisition and analysis), explicit reasoning (interpretation), and 3D visualization-based outcomes (representation). The conceptual schema is based on an ontological schema that can link metadata and paradata as well as architectural semantic segmentation.

VRIM Data Base

A database based on the conceptual schema

VRIM scripts

A series of algorithms developed using visual programming software and its interoperability with BIM platform.

For each phase, a set of procedures are proposed. Those procedures widely follows concepts accepted and used by scholars in twenty years of scientific debate.

The proposed methodology can handle and manage new 3D models into BIM environment starting from architectural drawings. It can also be used, with the necessary modifications, to manage data from point clouds, closing the gap between the original data and related interpretations by a visual and immediate control on mathematical modelling.

The integration between visual programming and BIM simplifies the virtual reconstruction processes, coupled with the parametric modelling of information management that is intuitively accessible and editable in the BIM environment.

These considerations can confirm that BIM and HBIM can be considered as emerging standards for the construction of parametric models and can handle information with an interoperable aim, not only regarding the transformation process, conservation and recovery, but also for the study, the valorisation and the representation of intangible architectural heritage of virtual reconstructions of artefacts.

The growing interdisciplinary nature of

Workflow for Virtual Reconstruction

La definizione di un flusso di lavoro nell'ambito delle VR che identifica le fasi fondamentali dei processi ricostruzione virtuale:

- Collezione & Acquisizione dei dati
- Analisi
- Interpretazione
- Rappresentazione
- VRIM Schema

Uno schema concettuale che chiarisce il rapporto tra le fonti di ricerca (raccolta dei dati), conoscenza implicita (acquisizione e analisi dei dati), il ragionamento esplicito (interpretazione), e gli esiti di visualizzazione basati sul modello 3D (rappresentazione): basato su uno schema ontologico capace di relazionare metadati, paradati e segmentazione semantica architettonica

VRIM Data Base

Un database che si fonda sullo schema concettuale proposto

VRIM Scripts

Una serie di algoritmi sviluppati utilizzando un software di programmazione grafica integrata e la sua interoperabilità con una piattaforma BIM.

Per ciascuna fase della metodologia VRIM, viene proposta una serie di procedure, seguendo quegli approcci e concetti ormai consolidati e utilizzati dagli studiosi nell'ultimo ventennio di dibattito scientifico.

La modalità operativa proposta si mostra capace di gestire ed elaborare nuovi modelli in ambiente BIM a partire da disegni di architettura, ma può essere utilizzato, con le dovute modifiche, anche per la gestione di dati provenienti da point cloud consentendo di colmare il divario tra i dati originali e le relative interpretazioni mediante un controllo visuale e immediato sulla modellazione matematica.

L'integrazione tra programmazione e BIM semplifica di fatto il processo di ricostruzione

the study on virtual reconstruction processes calls for the establishment of a reference methodology framework that promotes a digitized, collaborative and dynamics workflow, where data and information produced can be managed and shared, promoting their dissemination and reuse.

In addition to the methodological proposal, this research has produced a small application tool that, following further research, may eventually be implemented.

Key Words
Digital Heritage, Virtual Reconstruction, BIM, Knowledge Information Management

virtuale affiancando alla modellazione parametrica la gestione delle informazioni che sono accessibili e modificabili in maniera intuitiva in ambiente BIM.

Tali considerazioni confermano come il BIM e l'HBIM si possano considerare standard emergenti per la costruzione di modelli informativi parametrici e interoperabili, non solo nell'ambito dei processi di trasformazione, conservazione e recupero edilizio ma anche per lo studio, la valorizzazione e la rappresentazione del patrimonio architettonico intangibile delle ricostruzioni virtuali di architetture.

Il crescente carattere di interdisciplinarietà che investe il processo oggetto di studio pone l'esigenza di definire un quadro metodologico di riferimento che favorisca dinamiche di lavoro collaborative digitalizzate, dove dati e informazioni prodotte possano essere gestite e condivise, favorendone la divulgazione e il riutilizzo.

La ricerca, oltre alla proposta metodologica ha prodotto un piccolo strumento applicativo che, a seguito di ulteriori ricerche, potrà essere eventualmente implementabile sul mercato.

Parole chiave
Patrimonio Culturale Digitale, Ricostruzioni Virtuali, BIM, Gestione dei processi informativi

1 Introduction

The research aims to investigate virtual reconstruction processes and management information systems to focus our self on transparency of information concerning cognitive processes. More in detail, the study tries to approach the virtual reconstruction of a specific topic: designed buildings that have been left only drawn and others that are no longer in existence. In the last case, it is common, but not necessary, that some finds, if physical evidences are still available, can be used as a valid reference on the reconstruction process.

Virtual reconstructions are commonly known as vehicle of communications but are not usually intended as a product of knowledge generated by critical and methodological processes.

Despite a huge amount of scientific literature, where the topic of virtual reconstructions has been developed specifically for a single case study, only some authors propose methods or guidelines that may be used for a reliable evaluation of a virtual reconstruction, regarding different kind of Heritage.

The objective of this research is proposing a methodological workflow for the visualization of 3D model's intrinsic information together with a procedure to formalize connections between 3D reconstruction and its semantic enrichment.

This introduction is intended as an overview of some themes related to Virtual Reconstructions. This part speaks about State of the Art, starting from the beginning to the last recent initiatives. After the introduction about "history" of virtual reconstructions, the chapter goes on describing some initiatives, promoted by communities, about the main issue of transparency of processes: The London Charter and the Sevilla Principles. Both documents were developed about ten years ago, then some recent research projects tried to follow those principles and set procedures aiming to define a sharable approach to transparency and information traceability problems.

The chapter analyses developed solutions to trace those kinds of subjectivity that compromise the validity of the whole virtual reconstruction.

In the second part, a definition of some common terms regarding types of information is proposed. Types of information are relevant to understand better the use of a specific terminology that is commonly used in Digital Heritage studies and that, nowadays, with the growth of ICT technologies became important to know; knowing the terminology is important because allows to learn how to correctly structure data information.

The last part of the introduction regards the modelling processes and software usually used to digitally represent an object. It illustrates the state of art in 3D modelling and the potentiality of some new modelling software, plug-in and tools that, even if developed for a different purpose, are becoming new standards to model Cultural Heritage (CH) and structured information data-set related to it.

1. Virtual Reconstructions

Virtual reconstructions are the nowadays way to visualize and analyse the past.

Virtual reconstructions are usually used as a way of communications: as a tool to communicate the appearance of a building or of an architecture and they are the result of the development of a common way of thinking produced by a huge amount of Academic research related to the use of Computers and IT Technologies applied to Archaeology and Heritage.

VR are the consequence of a digital revolution that began approximately everywhere from the late 1950s to the late 1970s. One of the main topic studied by archaeologist at that time was first related to geophysics and the role of survey in archaeological excavations and studies, then to how to store all data related to the campaign (Pryor, 1973).

Computer Applications in Archaeology are nowadays part of the archaeological method but in the early 1970s only few scholars really thought that IT technologies could promulgate archaeological information. In Britain archaeologists and the Institute of Field Archaeologist (IFA) considered *"important that archaeologists are properly trained in the use of computers and in encouraging the provision of appropriate courses, and the development of computing resources"* (Cooper & Richards, 1985). At that time, the community already started to have annual meetings on Computer Applications in Archaeology and today that conference has been renamed Computer Applications and Quantitative Methods in Archaeology (CAA).

In 1970s archaeologist had in fact access to first generation of computers and had started to explore the impact of technological innovations to representing and exploring data. In the early 1990s Paul Reilly introduced the term of *"Virtual Archaeology"* where the key concept was the *"virtual"* definition as *"an illusion to a model, a replica, the notion that something can act as surrogate or replacement for an original"* (Reilly, 1991)longer textual descriptions appear. The correctness and truth of the ob-servation or interpretation was confirmed by the personal standing of the reporter (cf. Hodder 1989.

The Reilly considerations first introduced at CAA, opened the debate concerning the multidisciplinary approach to a huge amount of virtual reconstruction projects and 3D modelling processes. Initially, those projects were carried on by archaeologists, but then even other figures started exploring the potential of virtual reconstructions together with their benefits on communication. Nowadays is commonly recognised that we cannot avoid a multidisciplinary approach on studying ancient buildings and the scientific purpose to hypothesize their original aspect using VR.

Historical Background

Since the 1980s, 3D modelling software has been used to visualize archaeological fragments and make hypotheses about destroyed historical buildings and their transformations upon time.

Fig 1: *View of Gebel Barkal in Sudan (Ancient Nubia) showing computer reconstructions of major structures (temples, palaces, and outbuildings) superimposed on a current view of the site. ©1991 Bill Riseman; ©1999 Learning Sites, Inc.*

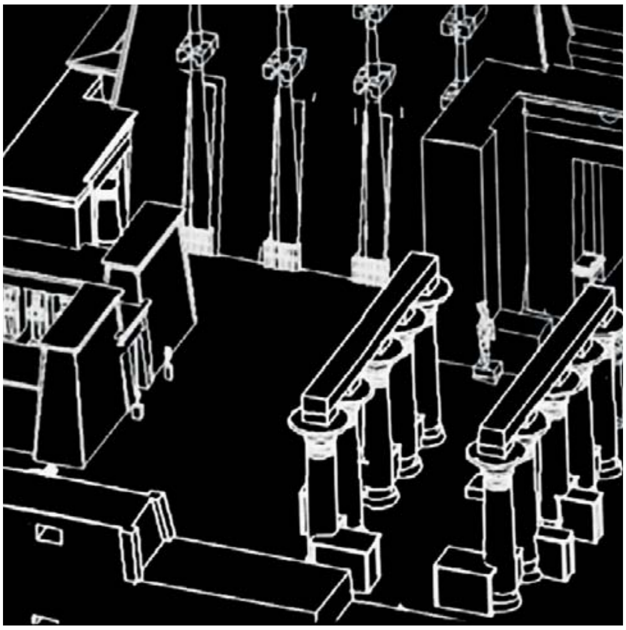


Fig 2: *Visualization of Karnak Temple ©1985 Boccon-Gibod*

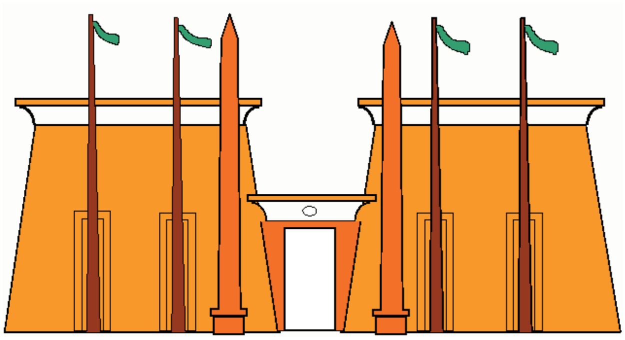


Fig 3: *Facade of Karnak Temple ©1985 Boccon-Gibod*

In the late 1980s, the Museum of Fine Arts in Boston, Timothy Kendall, Peter Der Manuelian and Bill Riseman started working at *"The Buhen Project"* on creating simply shaded and wire-frame 3D computer models of the site and the major buildings of Gebel Barkal in Sudan (Ancient Nubia). This was one of the earliest archaeological projects taking full advantage of the growing 2D and 3D computer graphics.

In 1985, a partnership between Department of Studies and Research of Electricity of France (EDF), the Franco-Egyptian Centre and CNRS was started. From 1987 to 1989, the research team led by Jean-Claude Goyon and Jean-Claude Golvin followed the computer modelling at the EDF premises, and Boccon-Gibod had the opportunity to lead the first numerical modelling initiative for architectural ensembles of the Ancient Egypt to produce representations of the evolutionary phases of the architectural ensembles of the temples of Karnak and Luxor. His studies focused on architectural principles that had been broken down into a vocabulary of about fifty common archetypes to all the temples of that period, facilitating a modelling work otherwise unimaginable. The research team, to make virtual reconstruction of the temple of Amon-Re at Karnak, first used the 3D

Fig 4: *A still from the shortfilm "1789" by ExMachina ©1989 ExMachina*

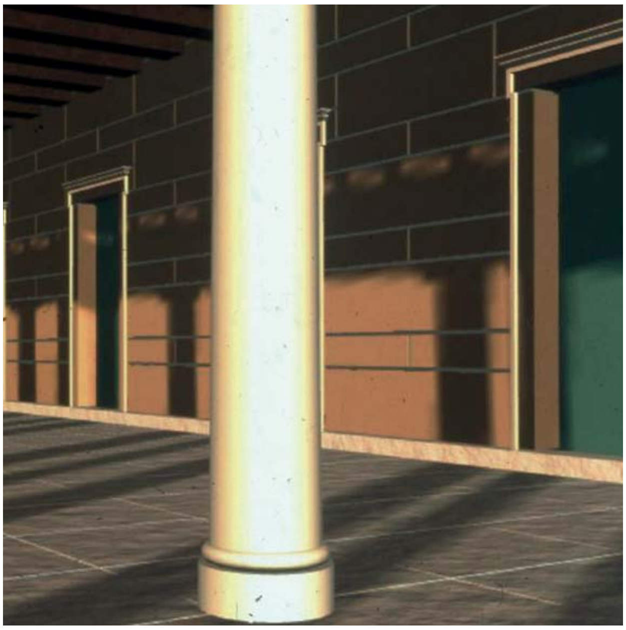


Fig 5: *A still from the film "Les Envois de Marseille: Mémoire du port antique" by Paul Quintrand et François Pages*

modelling software package known as CAO, Conception Assistée par Ordinateur. (Boccon-Gibod & Golvin, 1990).

This first experiments had a strong impact in heritage specialists' community and contributed to the dissemination of the infographic modelling principle to visualize a past state of a monument or a city. In 1989, the French company Ex Machina contributed to *"1789"*, a short film with virtual reconstructions of Paris in 1789. The short film was a composite film (3D images for architecture and animated cartoons for the characters) made on the occasion of the celebration of the bicentenary of the French Revolution. (Segura, 1989)

In 1990 archaeologist Christian Sapin and architect Jean Bermon presented a reconstruction of the various phases of construction of the Saint-Nazaire Cathedral in Autun and its cloister. The Virtual reconstructions were produced using CATIA software from Dassault System. The models were successively integrated into a stereoscopic film called *"Sine Die"* and displayed the same year during a temporary exhibition at the Musée Rolin d'Autun. (Fèvres, 2012)

Except from the archaeological context, during the years also heritage became a subject of reflection for architects. Paul Quintrand, at GAMSAU, worked to the production of the film *"Les Envois de Marseille: Mémoire du port antique"* that was a clear example. This experimentation aimed to introduce students to architecture to the synthesis of images and could be considered as an *"archaeological fiction"* more than a true scientific restitution. As explained in the end of the film *"This film is pure fiction but any resemblance to reality would not be fortuitous"*, the three-dimensional modelling were in the service of reconstructing already disappeared architectural and urban landscapes. ("Les Envois de Marseille: Memories of the ancient port," 1991)

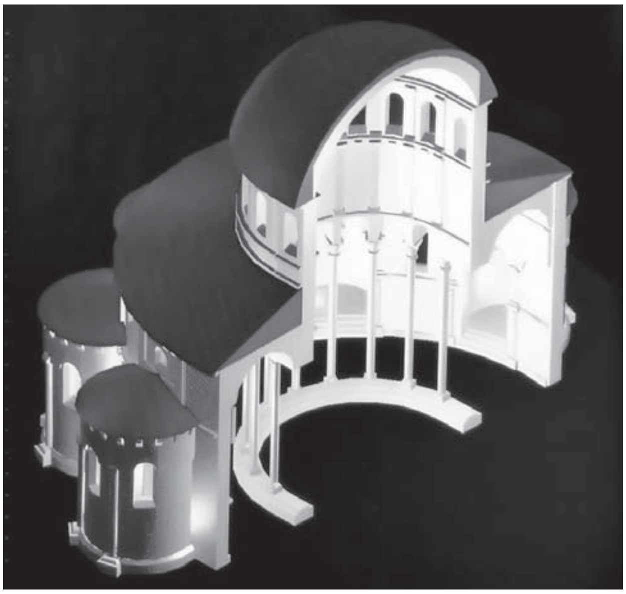


Fig 6: *3D model of the Cluny Abbey from the film "Memories of Pierre" also known as "Major Ecclesia" produced by IBM and TDI Image. ©1992, IBM and TDI Image.*

Fig 7: *3D model of the Dresden Frauenkirche produced by IBM modelled using CATIA and rendered using TDImage. ©1993, IBM and TDI Image.*

Between 1990 and 1991, the Ecole Nationale Supérieure d'Arts et Métiers ENSAM, sponsored by IBM, used a CATIA CAD system to recreate the medieval Cluny Abbey (France). ENSAM created a special lab in Marseille that working with 3D and virtual reality: the MAP-Gamsau. The film "Major Ecclesia" was modelled thanks to the research of the American archaeologist Kenneth John Conant, who rediscovered the abbey at the beginning of the 20th century. *"Les relevés récupérés dans le puissant modeleur volumique, sur station de travail IBM RS 6000, permirent l'élévation des murs, des colonnes et les "détails" de Catia, la définition des éléments répétitifs."* (Chaigneau, 1992) The models were made using CATI (conception assistée tridimensionnelle interactive which is the French for interactive aided three-dimensional design). CATI, nowadays also known as Catia is a software developed by Dassault Systèmes. The CATIA software is commonly used for 3D Product Lifecycle Management. IBM was one of the first companies to sell the software and sign a non-exclusive distribution agreement with Dassault Systèmes.

In 1993 IBM continued supporting many projects of public interest under the framework of its Corporate Social Responsibility Program. One of those projects was the one of reconstructing the Dresden Frauenkirche. Its detailed architectural drawings that were produced, and contemporary photographs taken during the restoration campaign were used to ensure that the reconstruction was "not only historically correct, but also conveyed an authentic "atmosphere" and "emotions". (Collins et al., 1995)

In 1996, classical archaeologist Bernard Frischer founded the Cultural Virtual Reality Laboratory (CVRLab) at the UCLA to use 3D virtual reconstructions in his researches about Rome and the Roman Forum that shows the

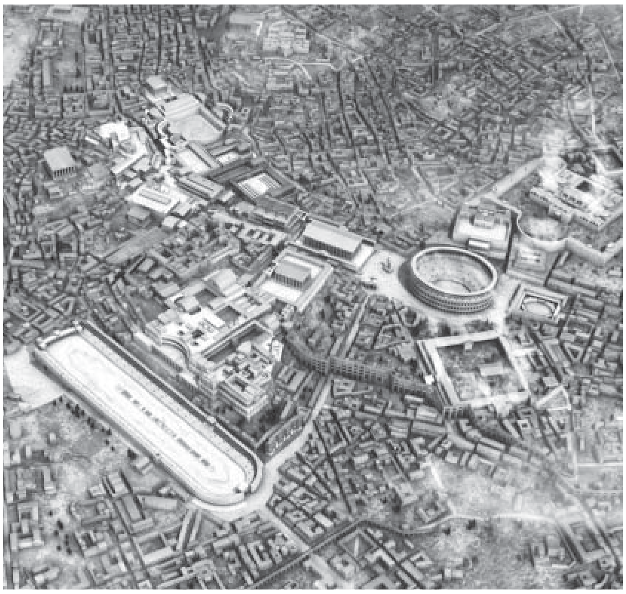


Fig 8: *Rome 320AD. Elements of the model © 2008 The Regents of the University of California, © 2011 Université de Caen Basse-Normandie, © 2012 Frischer Consulting. Image © 2012 Bernard Frischer*

Forum as it appeared in the late antiquity. The Roman Forum was part of the CVRLab's Rome Reborn Project. The Rome Reborn v.1.0 was available online since 2007 and it was carried on by Frischer at the Institute for Advanced Technology in the Humanities at the University of Virginia (IATH). The Rome Reborn project (now version 2.2) shows Rome in 320 AD, based on virtual reconstructions by a large number of experts. The most recent visualisation of the 3D model was developed in 2014 by NoHo, and it is called Rome320AD: an online available application.

In 1997, Donald Sanders founded the company Learning Sites, with the aim of developing an information system for public education and scholarly researches in the field of archaeological visualisations.

The same year, Maurizio Forte compiled the book called "Virtual Archaeology", listing many examples of early virtual reconstruction projects in famous archaeological sites. In Italy he was Chief of Research at CNR (Italian National Research Council) of *"Virtual Heritage: integrated digital technologies for knowledge and communication of cultural heritage through virtual reality systems"*.

One of the first project of Virtual reconstruction in Italy was carried by a Research Doctorate in History and Information Technology in 1996. In 1999, CINECA made one of the first virtual reconstructions of the evolution of a historical city of Bologna. The NuME project, that reconstructed the city of Bologna in virtual reality, based upon a defined methodology.

Virtual Reconstructions are in fact the product of a methodological interpretation of the past and must be read as a scientific activity with a still not well-defined workflow in term of procedures and technological approaches. The big potential of Virtual Reconstructions is being able to represent the past and produce stunning images, educational resources and interactive applications, both in museums and online. Nevertheless, virtual reconstructions do not exactly reconstruct the past, but give us only a representation of what we know about the past.

A virtual reconstruction is just a hypothetical representation of a personal interpretation of a past which is now lost due to the fact that *"To understand how a building might have appeared, there is no better method than to attempt to reconstruct it digitally (or physically, if there are sufficient resources). The effort itself creates a new form of knowledge consisting of the type of information used and the design constraints applied"* (Johanson, 2009).

Another important project is the Visualizing Venice project, a big project born in 2009 as an initiative that uses archival sources (documents, plans, images) to map growth and change in the city of Venice (Huffman, Giordano, & Bruzelius, 2018).

Transparency of processes

The growing importance of 3D visualisation of cultural heritage showed during years the importance to set standards and guidelines about working processes in terms of documentation of knowledge.

The London Charter was one of the first approaches to the need of transparency of processes and it could be considered as the starting point of a debate that is still going on. The huge amount of possible applications and techniques can affect the way using of 3D models in CH research in terms of knowledge evidence, sustainability and long-term archiving of research outputs. (Rizvić & Tsiafaki, 2016)

The Preamble of the Charter notes that *"a set of principles is needed that will ensure that digital heritage visualization is, and is seen to be, at least as intellectually and technically rigorous as longer established cultural heritage research and communication methods."* (Denard, 2009)

The principles defined by the London Charter are the following six:

1. Implementation
2. Aims and Methods
3. Research Sources
4. Documentation
5. Sustainability
6. Access

The principles were going to close the gap between interpretation and original data with the aim to define a guideline for the use, in research and communication of cultural heritage, of computer-based visualisation related with intellectual integrity, reliability, documentation, sustainability and access of heritage artefacts: a necessity declared also by Reilly in 1991

A decade later also Mark Gillins agreed with Reilly and with the fact that new technologies were used in an improper way that was mainly focused on the production of an attractive

Fig 9: *London Charter*

'end-product' without any intellectual and scientific purposes, analysing *"Issues such as authenticity, the representation as fake and role of Virtual-model as static end-product."* (Gillings, 1999)

Following his predecessors, Zhukovsky, spoke about archaeological interpretation, recognising the big contradiction between what people think about a 3D model and what about truly represents. (Zhukovsky, M., 2001)

The process of reconstruction is essentially composed by decisions, based on various sets of input data that are interpreted and integrated. This subjectivity, if not correctly reported, compromises the validity of a whole virtual reconstruction. Then, after The London Charter, wich set principles for visualisation methods and their outcomes in heritage contexts, another important document were produced: *"The Sevilla Principles"* that established some basic principles that should govern the practices of growing discipline of Virtual Archaeology (López-Menchero & Grande, 2009).

The Sevilla Principles are the following and are precisely defined for Virtual Archaeology and not for general purpose related to Computer-Based Visualization of Cultural Heritage as were The London Charter ones.

Fig 10: *Sevilla Principles*

The Sevilla Principles generated applicable criteria for the whole community of experts, whether they are computerized, archaeologists, architects, engineers, general managers or specialists in the Virtual Reconstructions field:

1. Interdisciplinarity
2. Purpose
3. Complementarity
4. Authenticity
5. Historical thoroughness
6. Efficiency
7. Scientific transparency
8. Training and assessment

The community involved in VR started to assume that a 3D model could be considered as *"a constructive, intellectual process and a valid methodology for historical research and its communication"*.(Bentkowska-Kafel, Denard, & Baker, 2012). The virtual reconstruction practiced over the years, showed many theoretical problems related to documentation, analysis and interpretations of archaeological artefacts (Dell'Unto et al., 2013), also because different discipline have their own methodology, the theme of scientific transparency, introduced by Sevilla Principles, is still largely discussed but rarely applied. (Hermon, Sugimoto, & Mara, 2007)

To validate the 3D modelling reconstruction process and to facilitate the exchange and reuse of information and collaboration among experts in various disciplines (Munster, 2013) we have to give a look to new standards due to reusability and accessibility of knowledge of 3D digital models: for a better interpretation of digital heritage artefacts we need a comprehensive interpretive method. As many hypothetical reconstructions are the result of highly complex design decision (Koller et al.) we decided to focus our attention to the cognitive-process.

The process of reconstruction is essentially composed by decisions based on various sets of input data that are interpreted and integrated. This subjectivity, if not correctly reported, compromises the validity of a whole virtual reconstruction. Within the theoretical and methodological framework of the challenges and the opportunities offered by 3D models digital archives, one of most critical topics is related with defining new protocols to process spatial data, to support a project of virtual reconstruction, able to validate the results and guarantee full transparency of any reconstructive study. The design and representation became the precursors to the three-dimensional modelling that becomes a vehicle for the development of interpretative models.

Three-dimensional models are often created with the intention of re-proposing an original and designed but never realized idea, which is mediated, however, by an individual's personal interpretation during the documentation of analysis and study.

A research concerning 3D Cultural

Heritage models has already suggested a few approaches related to the inherent uncertainty of communication in the digital model by (i) the development of a new symbology, (ii) digital animation techniques, (iii) rendering techniques, (iv) an information system based on meta-data and 3D visualization (Koller et al. 2009).

Within the theoretical and methodological frameworks of the challenges and opportunities offered by 3D models digital archives, one of the most critical topic is related to defining new protocols for spatial data processing, to support a virtual reconstruction project, which is able to validate the results and guarantee full transparency of any reconstructive study (Brusaporci, 2017).

Many studies focused the attention to anastylosis process. Anastylosis can be considered as an "archaeological" term whereby a ruined building is virtually reconstructed using the original architectural elements to the greatest degree possible. The Venice Charter (ICOMOS, 1965) details criteria for anastylosis. The use of new technologies allows to define different procedures for the virtual Anastylosis of elements belonging to an archaeological site, based on the 3d modelling of single fragments (Canciani et al., 2013).

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2. Types of Informations

The CAA was the first conference dedicated to the study of Computer Applications and Quantitative Methods in Archaeology since 1973. The 1970s were in fact the years of Data Banks: in the US a huge amount of Data Base was produced to hold all the information about Archaeology and Excavations and ,at that time, like nowadays many scholars' debates about standards and possibilities of reusing and exchanging information among different groups of research. Many Data Bases projects were developed with the intention of setting and creating standards able to link different databases and create a common way to read data (Robinson, 1975). At that time the Data Base design were affected by limits of Computers and by the fact that were very difficult to make groups with Computer scientists and archaeologists together because "the most difficult part of the cataloguing is not the computing but the problem of the overcoming the inflexible attitudes of traditional archaeologists" (Cutbill, 1974): this was the main reason why was necessary to have a conference about that.

Nowadays, new tools are able to acquire, store, manage and visualize different kind of information in a digital way but this approach was firstly introduced by the Southampton-York Archaeological Simulation System (SYASS) (Flaherty, 1988). The SYASS were created to develop a simulation system "to assist in teaching the principles of archaeological excavation and analysis to students"(Rahtz, 1988).

It's certain that, at the end ,SYASS wasn't developed to simulate an archaeological site but itself was simulating a big archive about archaeological excavation. That archive was actually a Big Database where it was possible to have a return in terms of different types of information: hypertext, integrated multi-media systems, solid modelling and other techniques for representing and exploring data. (Reilly, 1991)longer textual descriptions appear. The correctness and truth of the ob-servation or interpretation was confirmed by the personal standing of the reporter (cf. Hodder 1989

The recoding, documentation and information

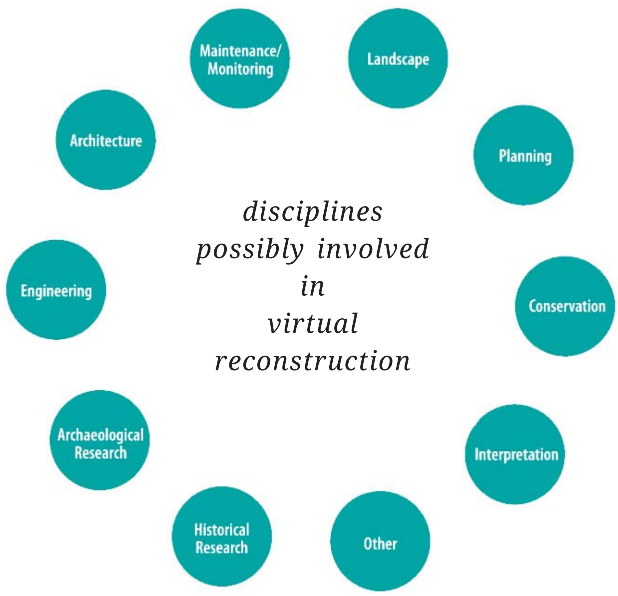

Fig 11: *Set of disciplines that could be involved in VR and that doesn't have a standardize data sharing*

management about virtual reconstructions is strictly related to how all this type of information are collected, archived and made available. Nowadays electronic databases and the World Wide Web can in a better way manage information: a well-designed information system can facilitate data access and become a powerful tool for interdisciplinary communication.

This chapter will analyse the fact that different kinds of information are nowadays available and recognized to manage cultural heritage knowledge systems such as a Database

DataBase

A Database is a Collection of various types of data including photographic images, sketches ,measurements, condition assessments, and other pieces of information stored in a systematic way for security and easy retrieval. Individual records or data are divided into sets, themes, and fields, with unique identifiers in order to allow data to be linked and queried together. Databases can connect separate "pieces" of information together,also allowing new information to be derived.

Data

A data is an information converted into a binary digital form. It is acceptable for data to be used as a singular subject or a plural subject. Available data for processing have come to be complemented by metadata, sometimes referred to as "data about data," that help administrators and users to understand database and other data.

Metadata

The debate on scientifically and methodological approaches to transparency of subjective processes using metadata and paradata is nowadays accredited by some international documents that set up some guidelines in this direction:

The incorporation of metadata and paradata is crucial to ensure scientific transparency of any virtual archaeology project. Paradata and metadata should be clear, concise and easily available. In addition, it should provide as much information as possible. The scientific community should contribute with international standardization of metadata and paradata (López-Menchero & Grande, 2009)

The notion of Metadata is:

Metadata is an information about data: a set of data that describes and gives information about other data.

Paradata

The notion of paradata is defined as:

information about human processes of understanding and interpretation of data objects. Examples of paradata include descriptions that are stored inside of a structured dataset about how much evidence was used to interpret an artefact, or a comment on methodological premises within a research publication. It is closely related, but somehow different in emphasis, to "contextual metadata", which tend to communicate interpretations of an artefact or collection, rather than the process through which one or more artefacts were processed or interpreted. (Denard, 2009)

The topic of heritage paradata involved several scholars as Forte (Forte, 2011)1996, 97 Hermon (Hermon & Kalisperis, 2011)in the archaeological / historical research and a more frequent one, as a communication medium in CH museums. While technological effort has been mainly invested in improving the \u201caccuracy\u201d of VR (determined as how truthfully it reproduces the \u201cCH reality\u201d and Niccolucci (Hermon & Niccolucci, 2010) who proposed various approaches to represent the process of interpretation. On February 2012 a book titled"Paradata and Virtual Cultural Heritage Visualisation" (Bentkowska-Kafel, Denard, & Baker, 2012)was also published with the aim of focusing the attention on cognitive processes on heritage visualization. And the effort also concerns contributing to set up shareable standards and methodologies concerning lots of publications which are more technical than theoretical (Huvila, 2012) and closely linked to the case study they are referring to.

Thesaurus

A thesaurus is an index to information consisting of a comprehensive list of subjects concerning that information may be retrieved using a set of proper key terms.

For Heritage purposes many thesauri are available and stored online in response to the needs of the user community. Thesaurus are structured resources that can be used to improve access to information for many subjects such as art, architecture, and other material culture.

Ontology and ontologies

In the cultural heritage domain information systems are increasingly deployed, and digital representations of physical objects are produced in a massive way.

According with Guarino " ontology is a logical theory accounting for the intended meaning of a formal vocabulary, its ontological commitment to a particular conceptualization of the world. The intended models of a logical language -using such a vocabulary- are constrained by its ontological commitment. Ontology indirectly reflects this commitment (and the underlying conceptualization) by approximating these intended models." (Guarino, 1998)

In a cultural heritage context, the most used ontological reference model is the CIDOC Conceptual Re-ference Model: CIDOC-CRM became an ISO standard in 2006 and it's aimed to a highly specific representation of information about cultural heritage, together with a representation of the concepts of space and time, thus supporting operations of reasoning and inference. The CIDOC CRM model was developed mainly to manage the cataloguing of cultural heritage documentation and not to describe heritage processes. Other domain-specific ontologies were progressively introduced as extensions of CIDOC CRM to represent other aspects of the heritage conservation processes.

Some projects on ontology for architectural heritage are ARMOS, a project related to Architecture Metadata Object Schema for cataloguing architectural heritage. (Agathos & Kapidakis, 2013);

MONDIS is an example of ontological framework that can link documentation about damaged historical structures,and also about how the diagnosis was made and what possible interventions might be made (Cacciotti, Blasko, & Valach, 2015). The goal of "EAH conservation KM system" was to test an advanced knowledge management approach to preserve Vernacular Architectural Heritage. (Mecca, Masera, & Cirinnà, 2006) Recently, Acierno has focused the attention on the possibility of developing a connection between a BIM environment with an appropriate, semantically enriched and flexible representation of information, provided by an Ontology CIDOC-CRM based.(Acierno, 2017) The application of ontology-based models to heritage representation, documentation, and analysis have been recently used as a way to integrate semantics in the 3D representation of historical artefacts, sometimes filtered through IFC templates (Pauwels, Bod, Di Mascio, & De Meyer, 2013) or directly connecting them to building information models.

Unfortunately, all experiments are specialized on specific domain and could be not considered as general knowledge-based models: one that is able to formalize all the information related to an architectural heritage artefact in a homogenous way, is still missing.

The need to explain these concepts was introduced in order to understand better the complexity of Information management on heritage documentation, conservation and information management. Even few institutions or government agencies have developed standards and guidelines for documentation, in the heritage system are close between disciplines and a set of information sharing, management, and tools are still not fully considered. The aim is to close the gap and try to define information management practices accessible to all people involved in virtual reconstruction.

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3. 3D Information Modeling

Building Information Modelling for Architectural Heritage

Building Information Modelling (BIM) is a digital representation of physical and functional features of a Building. (Eastman, Liston, Sacks, & Liston, 2008)

The diffusion of building information modelling in the field of Cultural Heritage (H-BIM) (Murphy, McGovern, & Pavia, 2009) creating full 2D and 3D models including detail behind the object's surface concerning its methods of construction and material makeup, this new process is described as HBIM. The future research within this area will concentrate on three main stands. The initial strand is to attempt improve the application of geometric descriptive language to build complex parametric objects. The second stand is the development of a library of parametric based on historic data (from Vitruvius to 18th century architectural pattern books highlighted the necessity of exploring new procedures and methods in order to model parametric objects in Architectural Heritage domain.

Since historical architecture elements are usually not supported by existing BIM platforms, many studies are focused on the creation of parametric objects, starting from architectural treatises and their proportional rules (Valenti, Casale, Romor, & Calvano, 2012) (Aubin, 2013).

The process of creating a set of models based on classical and renaissance treaties doesn't allow the generalization of the modelling process ,as a restricted group of architectural artifacts follows those rules.

Each building is unique and composed by a specific sequence of elements of architectural language that are usually combined in different ways.

Nowadays , the use of BIM for Virtual reconstruction (VR) is not properly documented , and the lack of BIM protocols and procedures for the modelling of architectural heritage opened the debate about issues related to HBIM objects.

In virtual reconstruction, there is a clear need to manage information related to semantically organized objects that have been generated by interpretations of the collected data. The use of BIM platform can be suitable to manage information and view the outcome of -otherwise detectable-valuable research. (Brusaporci, 2017)

Following the intent of creating a semantically-aware set of objects for a library of architectural elements , the proposed workflow tries to model components (families according to Revit) starting from survey drawings of no more existant architecture, where the virtual reconstruction process can generate multiple hypothesis related to a set of properly organized documentation.(Koller, Frischer, & Humphreys, 2009)with standard mechanisms for preservation, peer review, publication, updating, and dissemination of the 3D models. However, fully realizing this vision will require addressing a number of related research challenges. In this article, we first give a brief background of the virtual heritage discipline, and characterize the need for centralized 3D archives, including a preliminary needs assessment survey of virtual heritage practitioners. Then we describe several existing 3D cultural heritage repositories, and enumerate a number of technical research challenges that should be addressed to realize an ideal archive. These challenges include digital rights management for the 3D models, clear depiction of uncertainty in 3D reconstructions, version control for 3D models, effective metadata structures, long-term preservation, interoperability, and 3D searching. Other concerns are provision for the application of computational analysis tools, and the organizational structure of a peer-reviewed 3D model archive.(Koller, Frischer, & Humphreys, 2009

The use of BIM platform for virtual reconstruction studies didn't see a consolidation in procedures and methods. Modelling the former cultural heritage is a challenge that requires a review about data acquisition processes and their knowledge visualization.

The use of photogrammetry and laser scanning became the most popular technologies to acquire and process data in architectural heritage.

Otherwise , Virtual reconstructions of just designed buildings don't allow the use of new technologies to acquire data, because they are usually based on sketches, drawings or textual documentation. In case of no more extant buildings, where architectural fragments are still available, the point cloud, considered as a digital copy of the original one , is usually not suitable for a "rigorous BIM" representation. (Lo Turco & Santagati, 2016)

Some studies developed workflows related to the process of transition from point cloud to parametric object tried to generalize geometrical information related to architectural elements showing how to connect geometrical-historical survey with a descriptive thematic database. (Quattrini, Malinverni, Clini, Nespeca, & Orlietti, 2015)

Other studies developed systems where relations, attributes and LoD are connected with the parametric object. (Fai & Rafeiro, 2014)

Another way of processing 3D models is-first of all- normalizing the model analysing geometries ,and then turning information into parametric model (Paris & Wahbeh, 2016) and sometimes BIM models can be integrated with a knowledge base developed by ontologies. (Simeone, Cursi, Toldo, & Carrara, 2009)

Regarding studies of reconstruction methodology many are focused on issues of standards in visualization (Kuroczyński, Hauck, & Dworak, 2014) and visualization of Uncertainty. (Apollonio, 2016)(Apollonio, Gaiani, & Sun, 2012) Data enrichment in Bim-based modeling (Apollonio, Gaiani, & Sun, 2013) and a paradata documentation methodology (Apollonio & Giovannini, 2015) are nowadays guidelines available to better understand documentation, interpretation and visualization of a drawn architecture.

The use of BIM for Virtual reconstruction starting from drawings may seems distant from stakeholder's point of view, but the methodology can be applied also to tangible heritage and could be useful for further activities as restoration, communication or interoperability for users with different knowledge background.

Even if more tools and software are available ,the direct connection between point clouds and BIM is not a common practice. Using point clouds into Revit platform, for example,doesn't guarantee a real benefit in term of time consuming and accuracy of results. During the reconstruction process, it is probably better to decompose each procedure with the most suitable software. A clear example of this kind of approach was held by Canciani , using Mathematica software and CAD, developing a semi-automatic algorithm to reconstruct a geometrical CAD model of the object.

The VRIM methodology proposal is to create a sharable workflow that tries to simplify processes in virtual reconstruction modelling processes and manage data information system using tools and softwares that best fulfill the needs of a specific kind of reconstruction.

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2 Virtual Reconstruction Information Management

The study takes up the challenge to explore the use of 3D modeling visualization as a methodology for architectural research and its communication. The first part of the study involved the analysis of conference proceedings and papers related to 3D virtual reconstructions. The analysis showed that visualization-based research is commonly recognized as a constructive and intellectual process. In Heritage Visualization, due to the fact that the knowledge of the past is usually partial and uncertain, the debate is still ongoing. Most of the studies are related to reconstruction based on archaeological evidences where and important phase is the data acquisition, but it's clear that for those studies where the evidences not allows to recreate the entire structure, or for the ones focused on architectures that are no longer or never existed physically, a valid theoretical and methodological framework is request. Starting from this assumptions, last year scholars developed the thought that transparency and traceability of processes of interpretations are necessary for a better understanding of knowledge embodied by 3D models ,and their visualizations. Transparency is also necessary for an interdisciplinary communication and evaluation of results for the benefit of future generations.

Everybody is taking information out in order to acquire "pre-knowledge" before starting a virtual reconstruction, so it is necessary to define a Virtual Reconstruction Information Management (VRIM) where is possible to put new information in when the final result become available: a system where everyone can be user and creator of traceable knowledge.

Starting from sources to the 3D model the main problem is the traceability of subjective decisions and conjectures affecting the process of a certain grade of uncertainty that open the possibility to alternative options of reconstruction usually not declared (McCurdy, 2010). For this reason, the use of a correct and sharable methodology for the VRIM is required.

Part 1: Definition of virtual reconstruction processes and levels of information

Part 2: Methods and criteria for information modelling

Part 3: Design Tools for parametric modelling

2. Virtual Reconstruction processes and Levels of Informations

Virtual Reconstruction Processes

The processes beyond virtual reconstructions were largely discussed and here are identified and collected:

Data Collection and Acquisition:

This part of the study concerns the collection of data available at first stage of research that can be collected on three macro-categories: Images, Archaeological/Architectural evidences, Textual Documentation.

The acquisition process is related to the existence of some physical evidence that can be record by recording tools and technologies such as photogrammetry and 3D laser scanning.

Data Analysis:

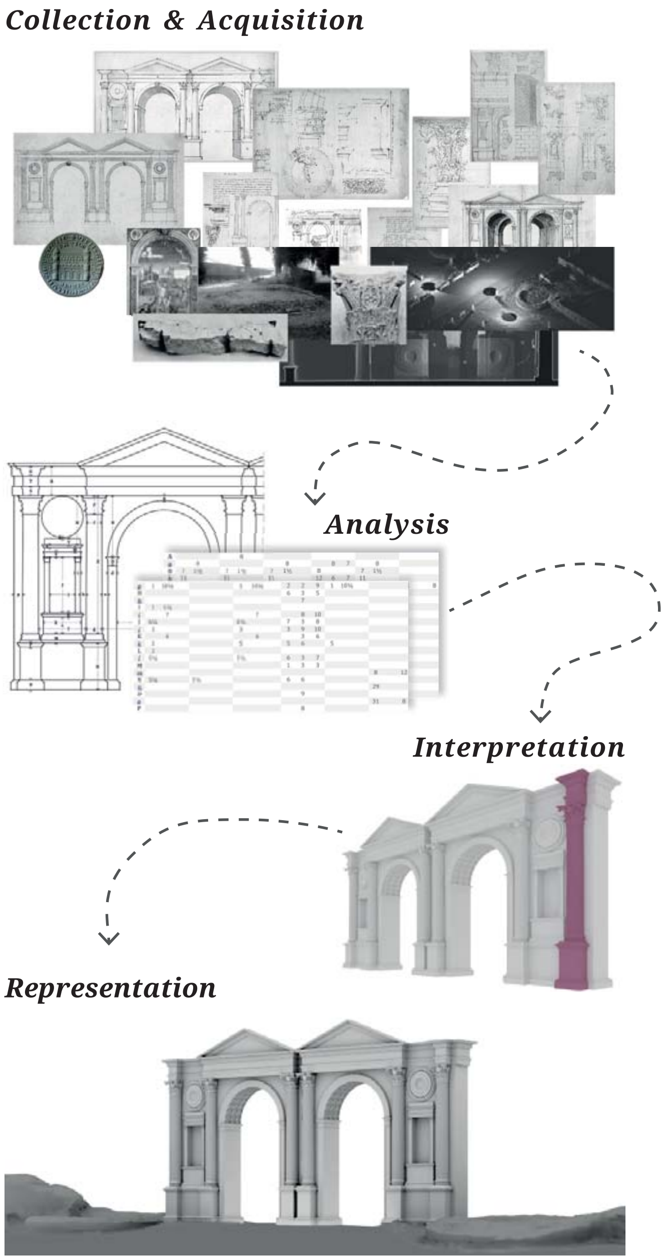
The analysis of the collected documentation, and the transcription of information that can be deducted from it: morphological information, measurements, semantic structure.

Data Interpretation:

The interpretation phase is to transform the collected and acquired data into a valuable evidence. This phase concerns all subjective cognitive-processes related to a VR managed through the use of visualization tools and new approaches, strategies and concepts: metadata, paradata, controlled vocabularies and notations, ontologies.

Data Representation:

The paradata scheme shows the semantic contents of the virtual reconstruction processes, helping in understanding and interpreting data objects. The geometrical documentation allows different kind of reconstructive hypothesis based on a controlled use of documented



information about interpretation that is showed using colors that label the sub-elements of 3D model.

Collection & Acquisition

As explained before three macro-categories of documentation data are proposed: Images, Archaeological/Architectural evidences, Textual Documentation.

Some descriptions are required in order to explain better these categories.

An Image is a representation of an external form of a thing in architecture. It could be a visible impression obtained by a camera, a picture or a diagram made with a pencil,a pen, or a crayon rather than paint. During the data collection for a 3D Virtual Reconstruction is common to find this type of Image Source:
Technical drawing:

The practice or skill of delineating objects in a precise way using certain techniques of draftsman ship, as employed in architecture or engineering
Sketches:

A rough or unfinished drawing, often made to assist in making a more finished picture
Maps:

A diagrammatic representation of an area of land or sea showing physical features, cities, roads, etc.
Photograph:

A picture made by using a camera
Landscape:

The kind of landscape painting or drawing

As *Archeological/Architectural Evidences* are those physical entities, such as the archeological site or finds useful for the virtual reconstruction that are subject to Data Acquisition process.

Finally, a *Textual Documentation* is all kind of written document that presents or communicates narrative of tabulated data in the form of a scientific article, letter, memorandum, report or treatise.

Analysis

As explained before from each kind of documentation is possible to extract different kind of information that together contribute to the creation of the 3d model. The semantic-based 3D models have become necessary since the increase of 3D models databases where morphological information and measurements can be used as semantic

DATA COLLECTION	***DATA ANALYSIS***		
	Morphological Informations	***Measurements***	***Semantic Structure***
Technical drawing			
Sketches			
Maps			
Photograph			
Landscape			
Archeological/Architectural Evidences			
Textual Documentation			

data for the modelling process. As explained by De Luca it's possible to define a semantic modelling and representation of classical elements able to model architectures by morphological information (shapes), spatial information (measurements) and a set of terms commonly used to describe architectural elements used as semantic concept to label 3D model (semantic structure).(De Luca, Véron, & Florenzano, 2007)

Interpretation

Another relevant issue is the largely use of textual metadata, that shows the need of looking at a new approach that maybe avoid the use of scripting, preferring the tool of media communication which is closer to the visualization (Hermon, Nikodem, & Perlingieri, 2006)and reliability - how the user can scientifically analyse the model. In this article, we will presenta solution to these issues based on concepts deriving from fuzzy logic and fuzzy sets. Taking into consideration the \"real nature \" of humanities data, more often fuzzy than crisp, a different logic (fuzzy logic and probably more intuitive and accessible for a multidisciplinary approach and reliable sharing of data.

In a process of virtual reconstruction, we take decisions firstly based on archaeological or architectural evidence and secondly, we need to refer to different kinds of resources so we decide to define a gradient colour scale to indicate the grade of Uncertainty related to different kind of sources involved in the reconstruction. This methodology is suitable to track and document the cognitive process related to the dimensional and morphological definition of each architectural element, but it is not enough.

Another issue was the need to make the management of information more user-friendly so in addition to the information related to the sources we define a metadata encoding of classical architectural elements. Metadata, considered as data about data, can help to organize information and provide digital identification.(Kang, Yuanyuan, & Zhanhong, 2011). The encoding is necessary because the redundancy of architectural terms in the whole reconstruction (Apollonio & Giovannini, 2015).

Finally, if Paradata could be considered process of data, VRIM methodology try to create a system to document and visualize through a conceptual model the management of information related to the reconstruction and cognitive process in Virtual Heritage.

Representation

The representation of data might have different outputs and shows different kind of information: into VRIM called Levels of Information (LoI). These levels are the summa of the structure of the data management and are related to data, metadata and paradata

Uncertainty

The use of a color scale within the disciplines that utilize the virtual reconstruction as an investigative tool is not so frequent. Contrarily to what happens in other disciplines, in which, false-color image even sacrificing natural color rendition (in contrast to a true-color image) have been long lasting, using in order to ease the detection of features that are not readily discernible otherwise (e.g. the use of near infrared for the detection of vegetation in satellite images, remote sensing satellites, space telescopes or space probes, or even weather satellites that produce grayscale images from the visible or infrared spectrum. In the field of architecture and archaeological virtual reconstruction use of colour sometimes defines a temporal correspondence (De Luca, 2013)and sometimes (Bakker, Meulenberg, & De Rode, 2003)(Borra, Forte, Pietroni, & Ruffa, 2002)(Borghini & Carlani, 2011)(Callieri et al., 2011)(Pollini, J., Dodd, L.S., Kensek, K., Cipolla, 2005) is used to depict uncertainties . Therefore the use of colours in 3D visualization could be considered as a simbology able to allow the traceability of uncertainty that characterize each element based on a subjective but controlled understanding and interpretation of data objects. (Bentkowska-Kafel, Denard, & Baker, 2012)

The VRIM Uncertainty gradient colour scale is based on the one of Apollonio et al.nwith some differences related to colours and kind of available documentation. The first difference is on the colours because the VRIM version propose colours in the middle of the scale better understandable. Then the first level of the scale is referred to the archaeological/architectural evidences, that in the wide range of virtual reconstructions case is possible to have: this because VRIM has the purpose to investigate solutions for generical virtual reconstructions and not only for reconstruction based on drawings. Finally sketches and drawings were put together because, even if they can carry different kind of information, the Uncertainty refers to the certainty of the used source, and doesn't refer to the level of accuracy of information that can be extrapolated from it: in this case,later we will talk about the Level of Accuracy.

Metadata

Controlled vocabularies and notations for Classical Architecture

The use of 3D models in virtual reconstructions opens a debate on how electronic resources related to the reconstruction are classified , and about how to visualize their hierarchical and other relationships, in order to provide a standardized vocabulary for information storage and retrieval system so it is necessary to create a simple notation to classify classical architecture and its elements. Due to the use of numbers,letters and symbols the result will be a mixed notation that follows the general principle of expressiveness: notation shows hierarchy.(Batley, 2005) The final notation is an unique identifier for the 3D model. In this study there is only one 3D model that refers to a single case-study but the idea is

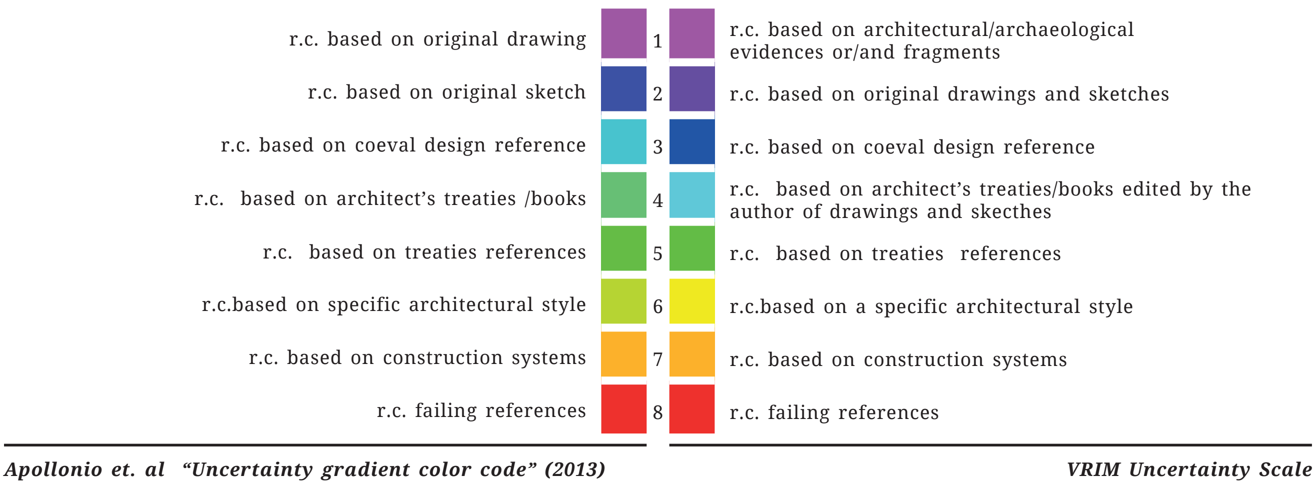


Fig 12: *Comparison between Apollonio et. al Uncertainty Scale and the VRIM Uncertainty Scale proposal*

Subject

Subject	***codF***
Architecture	A
Sculpture	B
Paintings	C

Type of Architecture

Type	***codT***
City walls and gates	01
Roads	02
Public Squares	03
Aqueducts	04
Reservoirs and Dams	05
Fountains and Nymphaea	06
Sewers	07
River Banks and Bridges	08
Political and Administrative buildings	09
Religious buildings	10
Basilicas	11
Porticoes	12
Buildings for public Spectacles	13
Baths	14
Libraries, Schools, Museums	15
Shops, Markets, Warehouse	16
Triumphal columns and Honorary Arches	17
Residences	18
Tombs	19

List of Locations

Name	codL
VERONA	VR
RAVENNA	RA

List of Architecture in Ravenna

NameOfArchitecture	codRA
Porta Aurea	01
(...)	

List of Architecture in Verona

NameOfArchitecture	codVR
Arco dei Gavi	01
(...)	

Architectural Elements

I LoE	*II LoE*	*III LoE*	*IV LoE*
10 Order	**1** Entablature	**1** Cornice	**1** Console
11 Giant Order			**2** Dentil
12 Superimposed Order			**3** Modillion
13 Intercolumniation		**2** Frieze	**1** Metope
14 Balustrade			**2** Triglyph
15 Door		**3** Architrave	**1** Guttae
16 Window			**2** Regula
			3 Taenia
	2 Column	**1** Capital	**1** Abacus
			2 Acanthus
			3 Caulicolum
			4 Eye
			5 Necking
			6 Volute
		2 Shaft	**1** Apophyge
			2 Annulet
		3 Base	
	3 Pedestal	**1** Cap	
		2 Die	
		3 Plinth	
	4 Pediment	**1** Racking Cornice	
		2 Tympanum	
		3 Acroteiron	
	5 Brackets		
	6 Panel		
	7 Sill		
	8 Stylobate		
20 Arch	**1** Archivolt		
21 Vault	**2** Impost		
	3 Keystone		
	4 Intrados	**1** Coffer	
			10 Astragal
			11 Cavetto
			12 Corona
			13 Cyma
			14 Cyma Reversa
			15 Fascia
			16 Fillet
			17 Ovolo
			18 Plinth
			19 Scozia
			20 Torus

to imagine an hypothetical scenario from wider proportions.

In the chart below,there is a series of classes that are encoded in order to form a final notation.

The first part of the notation follows the code of classes of Subject and Architecture that can be specialized through the "type of" relationship into multiple specialized classes as City walls and gates, Roads, Public Square, etc. following the classification of Marta (1996).

The second part of the notation is related to the architectural entity and its Location class that can be specialized into specialized classes for each location involved in the case-study and for each specialized class we have the list of Architectures in that area.

According to the declared classification an unique code to identify Porta Aurea and its 3D model it could be this: [A1:2.1]

With the aim to put order between the 3D model and its documentation we enrich our classification to a specific classification of classical architectural elements and their notations. This step make cognitive reconstruction data semantics more transparent and it is necessary to manage unstructured information related to measurements contained in the drawings and their use in the 3D modelling process because the goal of representing the architecture as a whole, usually makes it difficult to understand the difference among the elements based on evidence, and the others based on interpretation due to an overabundance of conflicting or lacking data.

The classical architecture elements classification that we propose is hierarchically structured into four levels (LoE).

Each level is based on different level of information with an increase scale of detail for each level and to each elements we assigned a code that is subsequently referred to the level above. In some cases we can have groups of elements through each level.

An example of its use it could be the notation for the pedestal elements related to the order:

10 Order
10.3 Pedestal
10.31 Cap
10.32 Die
10.33 Plinth

As showed above the expressiveness of the notation clearly show the hierarchy of elements with a not very long notation.

In the end ,special attention was given to the IV LoE as at this level we include all the elements that can't be divided, but can only be combined to form the element in the level above.

Even if some of those elements are directly connected to others (due to their specificity), there are others that can't be used in a specific but ,instead,in a generical way: these element correspond to moulding elements ,and for this reason we assign them a specific notation from 10 to 20.

A set of previous knowledge related to classical architecture and a generic formalism for the semantic modelling and representation of architectural elements (De Luca, Véron, & Florenzano, 2007) explains how we can read an architectural artefact as an entity composed by number of sub-elements with a whole-part relationship that can be displayed in a hierarchical-tree: Rattner (1998) defines mouldings as the smallest physical unit of classical architecture.

For this reason, an important consideration concerning their physical position may be done. As explained before, all elements from I to IV LoD have a notation that hierarchically corresponds to its order in space, for the final notation of the moulding this is not possible because of the redundancy of the use of each moulding in different situations, and for this reason we add other 2 elements in the notation: a number before and one after. The first number in the notation identifies its position according to an upper-down approach, and the final number of the notation is useful to avoid the repetition of the same moulding notation if it is necessary.

An example of the final notation for the pedestal elements of Porta Aurea is:

10.31 Cap
- 1:10.3113 Cyma
- 2:10.3111 Cavetto

10.32 Die

10.33 Plinth
- 1:10.3313 Cyma
- 2:10.3320 Torus
- 3:10.3319_1 Scozia
- 4:10.3319_2 Scozia
- 5:10.3318 Plinth

Knowledge visualization

Inside VRIM is possible to talk about Levels of Knowledge Visualization: The Database has the aim to store different kind of information related to virtual reconstruction. That kind of information are organized according to the list above:

Level of Elements (LoE)

it concerns the information about architectural Elements semantically defined. About mouldings, the list of Codes of geometrical Atoms that compose them will be listed.

Level of Measures (LoM)

visualization of information related to Measures. The Measures of Height, Width ang Length have their own information related to their “value” and “Unit of Measure”.

Level of Reference (LoR)

visualization of Source reference that define that architectural element or geometrical atom.

Level of Uncertainty (LoU)

visualization related to accuracy of measures based on the “Type of Measurement” as indicated, deducted or interpreted.

Level of Accuracy (LoA)

is referred to the potential accuracy that could be deducted from a single documentary source. The LoA is the result of interpolation between Morphological and Dimensional information.

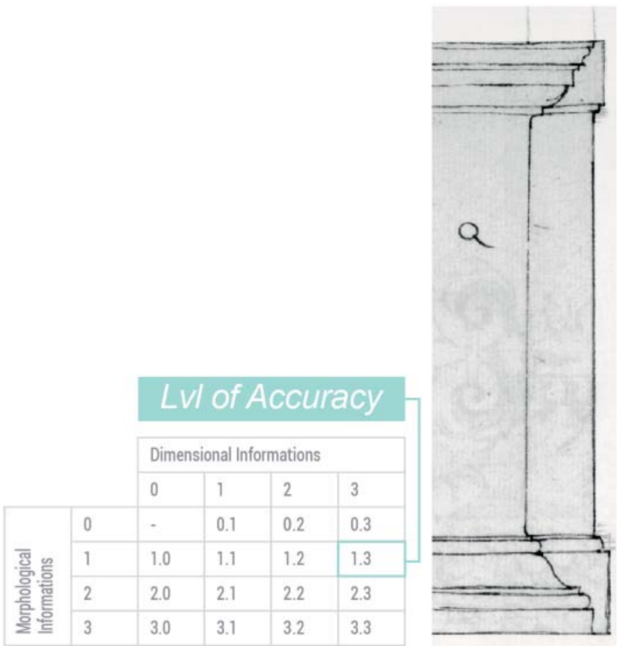
The Morphological Information were divided into 4 grades to whom is assigned a number from 0 to 3.

G0 - absence of a tangible morphological information (sometimes this could happen with textual Sources)

G1 - low, when the source gives us a schematic idea of an architectural element (From LoE I to LoE III)

G2 - medium, in this case the definition of information is related to an architectural element of the fourth level (LoE IV)

G3 - High, when information related to an



element of LoE IV goes through the geometrical definition of Mouldings.

The other parameter used to define the LoA is deducted from Measurements that are possible to assume from a documentary Source. Referring to "Type of Measurements" definition, the values are:

V0 Absence of indicated measure
V1 Indicated Measure
V2 Deducted Measure
V3 Interpreted Measure

To conclude, the code for LoA is made of both values separated by a dot.

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3. Methods and Criteria for Information Modeling

Data from virtual reconstruction processes are suitable for computerization and bring challenges of working with a lot of data, sometimes not clearly defined. The VRIM Abstract Reference Model tries to give an answer to some generical issues of create common standards regarding data modelling and information management.

The huge amount of collected data in VR projects must be processed and evaluated by project members: that is the reason why scholars focus on the need of experimenting new tools and strategies for interpretation and data analysis. As already explained ,meaning and significance within data are established on-process and afterwards the final hypothesis could be just one possible solution: all other solutions could be retrieved from other information already stored in the dataset and generate by personal cognitive process of the project member.

A common and powerful method for organizing data for computerization is the relational data model. Relational databases have a very well-known theory that makes possible automatic query optimization: that tool will be used in the scripting phase of the project.

Designing database means that the database is intended to provide a set of data: a database is a tool able to record and access on organized and stored set of information.

Resources stored in databases must be comprehensive within their "domain", could be maintained and updated and can include a wide variety of data which in turn requires a complex "data structure", or a way of information storage. This type of "data structure" provides great power and flexibility both for the retrieval and for the handling of the data, but also for future expansion of the database to include other information and materials over years.

Designing a database is a process made of the following steps (also according to traditional modelling theory):

- Analysis: this phase concerns the process of creating a **conceptual data model**: the result is an Entity-relationship (ER) model.
- Design: is the process that creates the **logical data model**
- Implementation: is the process of creating a **physical model** for a specific database system

The chapter will analyse these aspects related to creation of an entity-relationship DB

The creation of a DB corresponds to three design phases with a model as outcome for each phase:

- Conceptual Design
- Data Design
- Physical Design

In the Conceptual design phase, the Model is developed using a high level conceptual data model. According with the needs to use Standards, the Conceptual Model was developed using a CIDOC CRM ontology designed to document Virtual Reconstruction Processes and according with the aim to design a DB it concerns the design of a Conceptual E/R Model.

The Data design phase, also called data model mapping phase, is a relation scheme. The ER diagram or class diagram is the basis for this relation schema. The relation schema is also the basis for table definitions. The result of this phase is an UML class diagram that use the ConML notation. It is a high-level data model of the Classical Architecture application area. The ConML scheme describes how different entities (architectural elements) are related to each other (associations). It also describes what attributes (attributes) each entity has. It includes the definitions of all the concepts (entities, attributes) of the application area.

Once the logical design is finalized it is necessary to convert it into a physical design. The DBMS chosen at this stage was Microsoft Access.

Conceptual Reference Model for Virtual Reconstruction Purpose

The process of reconstruction of lost contexts follows the process explained in the workflow for VR. The result could be considered an "open" output because the virtual reconstruction can't be considered as a "definitive" result but can be modified in the future if new assumptions and sources become available.

At the same time the qualification of the provenance of the data (references) follows a completely different path: a set of procedures that create a system of relationships between the sources involved and the 3D output. The conceptual reference model for VR try to serve a small guide for good practice of conceptual modelling in VR.

Nowadays there are many models that propose to systematize concepts and relationship to handle the properties of tangible objects: the standard is CIDOC-CRM (Doerr, 2003)a high-level ontology to enable information integration for cultural heritage data and their correlation with library and archive information. The CIDOC CRM is now in the process to become an International Organization for Standardization (ISO.

CIDOC-CRM became a standard since 9/12/2006: ISO 21127:2006.

Even if the CIDOC-CRM provides definitions and a formal structure to describe the implicit and explicit concepts and relationships used in cultural heritage documentation (Aalberg et al., 2015), other ontologies were developed for more specific purposes over the years. The listed below are accreditated by the CIDOC-CRM community.

- CRMba (Ronzino, Niccolucci, Felicetti, & Doerr, 2016) is an extension of CIDOC CRM to support buildings archaeology documentation (Ronzino, 2015).
- CRMdig (Doerr, Stead, & Theodoridou, 2016) encodes metadata about the steps and methods of production ("provenance") of digitization products and synthetic digital representations such as 2D, 3D or even animated Models created by various technologies and can be used to create data paths to information provenance of digital elements from real world objects and it has been used also to annotate reasonings behind a reconstruction (Bruschke & Wacker, 2016).

In recent years, other tools and standards have been proposed with the specific purpose to annotate virtual reconstruction processes using the CIDOC-CRM as a semantic reference or without using it:

- Extended Matrix (EM) (Demetrescu, 2017) is a stratigraphic approach (Demetrescu, 2015) combined with visual tools Matrix. (Demetrescu & Fanini, 2017).
- Cultural Heritage Abstract Reference Model (CHARM) is a cultural heritage ontology structured to study, describe and communicate Heritage. CHARM combined to the visual representation of ConML language (Cesar Gonzalez-Perez, 2012), could be an alternative way for non-experts in

information technologies to express complex domains using ConML language symbols and diagrams.

The main need for scholars is to design tools and standards able to manage complex dataset. Even if many ontologies are available, many problems regarding the conceptual modelling of cognitive processes involved in VR are still open and the debate on integration of 3D virtual environments and rich semantic descriptions is still ongoing.

Because "An ontology is, in first approximation, a table of categories, in which every type of entity is captured by some node within a hierarchical tree." (Smith, 2002) in last decades many extensions of CIDOC-CRM have been developed but none of them is suitable to describe the data structure of VR processes.

A proposal for an extension of CIDOC-CRM to support virtual reconstruction documentation purpose (CRMvr)

Virtual Reconstruction processes are, in most cases, the result of a series of activities related to the definition of a representation of Cultural Heritage.

The identification of these processes, together with the analysis of different kind of source documentation, provides to scholars and people involved in 3d modelling different virtual representation of the same object.

All information contributes to produce a more detailed understanding of the development of a virtual reconstructed element that must be three-dimensionally defined to be modelled.

The three-dimensionally need, that involves metadata and paradata highlighted the necessity of adding more specialized concepts to describe the very complex structure of data provenance in VR, especially as concerns the description of a VR Elements and the relationship among its parts and with the whole and among its referenced sources.

Scope

The goal of the VR extension for CRM is an ontology to encode metadata and paradata related to VR processes and knowledge representation structure inside 3D models.
The goal of the concept model is to provide support to:

- Understand the VR process and its development
- Recognize the provenance of information used
- Identify the various version of the same element because of documentation used to model it
- Support the investigation and interpretation about digital representation of elements
- Understand the correlation between parts and whole
- Support the encoding process to identify each part/version of 3d model
- Support the assignment of classification to Reference Sources used in VR to depict uncertainty of the 3D representation
- Support the assignment of level of accuracy of VR elements that can be deducted from the Reference Source

The model is built on the same principle of CIDOC-CRM. The model reuses, when appropriate part of the CIDOC-CRM classes and properties, and refers to other CRM extensions that were developed to ensure the completeness of documentation.

Naming Convention

All the declared classes were given both a name and an identifier constructed according to the conventions used in the CIDOC CRM model. For classes that identifier consists of the letter V followed by a number. Resulting properties were also given a name and an identifier, constructed according to the same convention. That identifier consists of the letters VP followed by a number, which in turn is followed by the letter “i” every time the property is mentioned “backwards”, i.e., from target to domain (inverse link). “V” and “VP” do not have any other meaning. They correspond respectively to letters “E” and “P” in the CIDOC CRM naming conventions, where “E” originally meant “entity” (although the CIDOC CRM “entities” are now consistently called “classes”), and “P” means “property”. Whenever CIDOC CRM classes are used in our model, they are named by the name they have in the original CIDOC CRM.

Class and Property hierarchies

The CIDOC CRM model declares no “attributes” at all (except implicitly in its “scope notes” for classes), but regards any information element as a “property” (or “relationship”) between two classes.

The semantics are therefore rendered as properties, according to the same principles as the CIDOC CRM model. Although they do not provide comprehensive definitions, compact mono hierarchical presentations of the class and property IsA hierarchies have been found to significantly aid in the comprehension and navigation of the model, and are therefore provided below.

The class hierarchy presented below has the following format:

- Each line begins with an unique class identifier, consisting of a number preceded by the
appropriate letter “E”, “V”, “D”.
- A series of hyphens (“-”) follows the unique class identifier, indicating the hierarchical position of the class in the IsA hierarchy.
- The English name of the class appears to the right of the hyphens.
- The index is ordered by hierarchical level, in a “depth first” manner, from the smaller to the larger sub hierarchies.
- Classes that appear in more than one position in the class hierarchy as a result of multiple inheritance are shown in an *italic typeface*.

The property hierarchy presented below has the following format:

- Each line begins with an unique property identifier, consisting of a number preceded by the letter “VP”.
- A series of hyphens (“-”) follows the unique property identifier, indicating the hierarchical position of the property in the IsA hierarchy.
- The English name of the property appears to the right of the hyphens.
- The domain class for which the property is declared.

Virtual Reconstruction Class Declaration

The classes are comprehensively declared in this section using the following format:

- Class names are presented as headings in bold face, preceded by the class’s unique identifier;
- The line “Subclass of:” declares the superclass of the class from which it inherits properties;
- The line “Superclass of:” is a cross-reference to the subclasses of this class;
- The line “Scope note:” contains the textual definition of the concept the class represents;
- The line “Examples:” contains a bulleted list of examples of instances of this class.
- The line “Properties:” declares the list of the class’s properties;
- Each property is represented by its unique identifier, its forward name, and the range class that it links to, separated by columns;
- Inherited properties are not represented;
- Properties of properties, if they exist, are provided indented and in parentheses beneath their respective domain property.

Virtual Reconstruction Property Declaration

The properties are comprehensively declared in this section using the following format:

- Property names are presented as headings

in bold face, preceded by unique property identifiers;
- The line "Domain:" declares the class for which the property is defined;
- The line "Range:" declares the class to which the property points, or that provides the values for the property;
- The line "Superproperty of:" is a cross-reference to any Subproperties the property may have;
- The line "Scope note:" contains the textual definition of the concept the property represents;
- The line "Examples:" contains a bulleted list of examples of instances of this property.

Data e Paradata in Virtual Reconstruction Processes: The conceptual scheme

Using the yED tool, the Ontology designed in CIDOC-CRM is declared.

The Ontology represents the connections between the 3D output and the used sources. The first class declared is the (V1) Domain because the ontology was designed to be as more generic as possible. The Domain, correspond to the discipline of interest related to the piece of Heritage to virtually reconstruct.

Once the (V1) domain is stablished by the Author, the other relevant consideration to do is about the physical presence of the Object. Sometimes the need of a research team is to rebuild something that never existed or that it is partially documented, so it is necessary make distinguish between these two types of approach. It is common, especially in architectural context, to have sketches or drawings about a designed building never realized: in this case we can talk about (V11) Immaterial Heritage, as it could be the Tower of Babel described in the Holy Bible.

Another possibility is to decide to virtually reconstruct a (V3) Cultural Heritage element that could have some (V4) Finds or fragments to analyse and re-use for the virtual anastylosi.

The presence of (V4) finds sometimes allows to digitally acquire the evidences and to obtain a 3D object of the element. The (V6) 3D Find obtained by a digitalization process is only a copy, it is usually not use as it is, but it is commonly re-digitalized into a solid (V8) 3D object. Because in VR lots of assumptions can be generate deducted from the same set of data information, to each hypothesis a (V9) Version Identifier is assigned: the identifier assignment is necessary to transparency of process and to discern different hypothesis that could be done by different (V10) Authors. Once the criteria of analysis on (V17) sources and documents (E31) available is defined it is possible, to do all evaluations about Uncertainty (V19) and Accuracy (V20) of information derived from them. Sources in fact affect the 3D object because are the reference of information used to model the object. All evaluations procedures to assign to sources and 3D object an (V22) accuracy grade and an uncertainty grade (V21) are made during the analysis and the interpretation phases of the virtual reconstruction process according with the classification declared using the 3D model with the aim to trace the (V18) Transparency Inference between sources and the output of the reconstruction project.

A heritage artefact could be divided into its (V5) composing elements, that are related to each other according to a hierarchical structure. To identify the hierarchical level of each element, a hierarchy identifier (V7) is assigned to each component element.

The other important part of the scheme is about the 3D object and its components. According with the needs of software commonly used to model, it is possible to model an object using three primary information: the dimensions (E54), its geometrical representation (V11) and its morphological representation (V16). The geometrical representation of an

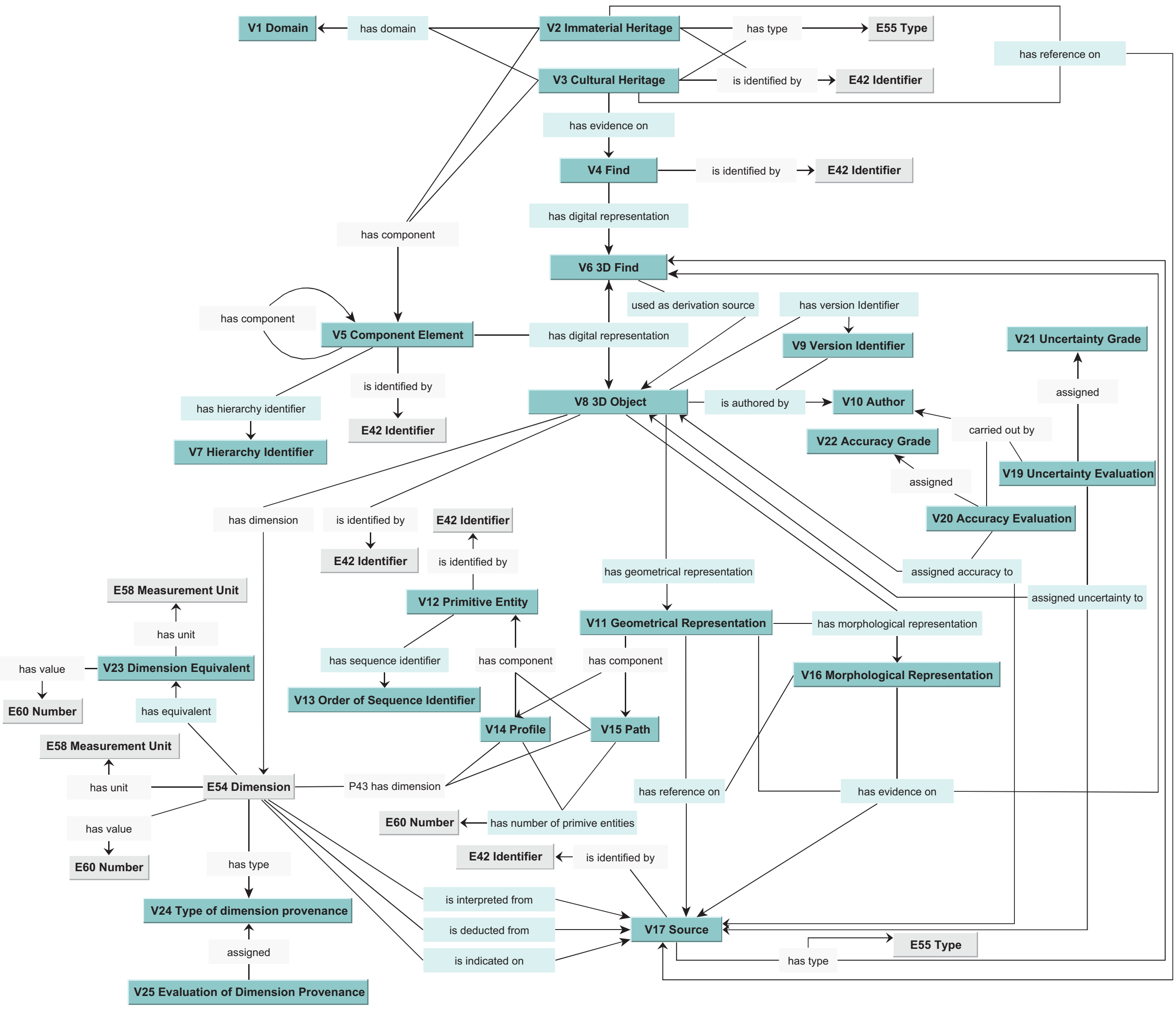

Fig 13: *Graphic view of Classes an Properties to define data and paradata structure in Virtual Reconstructions developed with yED*

object concerns its geometrical components: to generate a 3D solid model a profile (V14) and a path (V15) are necessary to recreate the three dimensions of the object. The morphological representation of an object regards its appearance that must be transferred into its geometrical representation. All these three elements are necessary to properly define a 3D object. Most of them can be interpreted or deducted from a set of sources: in this case, we can say that that information has reference on a source. Otherwise, if an information is indicated on a source, then it means that it has an evidence on it. The morphological representation can have evidence also on the digitalized representation of a find: the 3D find class is considered as a type instance of a reference source (V17).

Profile and Path are both composed by a series of Primitive entities (V12) that can be combined following a (V13) sequence order identifier. According with the different kind of sources the sequence order can change as the number of primitive entities that form the profile or path sequence. For each combination of primitive entities, a Version Identifier is assigned to generated 3D object.

Finally, the (E54) Dimension class maintain in the CRMvr proposal, the same properties listed on the CIDOC-CRM class with some additions: Dimension equivalent (V23) and Type of Dimension Provenance (V24). The dimension equivalent corresponds to the conversion value of a dimension: it is necessary for 3d modelling work with a standard measurement unit instead of the unit that had could been used in the past, at the date of the creation of the reference source. The Type of Dimension provenance is an attribute assigned to the Dimension that clarifies the relation between the dimension and the source reference used to assign that value.

Virtual Reconstruction classes

Classes
- V1 Domain
- V2 Immaterial Heritage
- V3 Cultural Heritage
- V4 Find
- V5 Component Element
- V6 3D Find
- V7 Hierarchy Identifier
- V8 3D Object
- V9 Version Identifier
- V10 Author
- V11 Geometrical Representation
- V12 Primitive Entity
- V13 Order of Sequence Identifier
- V14 Profile
- V15 Path
- V16 Morphological Representation
- V17 Source
- V18 Trasparency Inference Making
- V19 Uncertainty Evaluation
- V20 Accuracy Evaluation V21 Uncertainty Grade
- V22 Accuracy Grade
- V23 Dimension Equivalent
- V24 Type of Dimension Provenance
- V25 Evaluation of Dimension Provenance

Virtual Reconstruction properties

ID P.	*Property Name*	*Domain*	*Range*
VP1	has domain (is domain of)	V2	V1
VP2	has domain (is domain of)	V3	V1
VP3	has type (is type of)	V2	E55
VP4	has type (is type of)	V3	E55
VP5	is identified by (identifies)	V2	E42
VP6	is identified by (identifies)	V3	E42
VP7	has evidence on (is evidence of)	V4	V3
VP8	is identified by (identifies)	V4	E42
VP9	has digital representation (digitally represents)	V4	V3
VP10	has component (is component of)	V2	V4
VP11	has component (is component of)	V3	V4
VP12	ihas component (is component of)	V5	V5
VP13	is hierarchically identified (hierarchically identifies)	V5	V7
VP14	is identified by (identifies)	V5	E42
VP15	has digital representation (is digitally represented)	V5	V8
VP16	used as derivation source	V6	V8
VP17	has version identifier (is version identifier of)	V8	V9
VP18	is authored	V9	V10
VP19	is authored	V8	V10
VP20	carried out by (performed)	V19	V10
VP21	carried out by (performed)	V20	V10
VP22	assigned (was assigned by)	V19	V21
VP23	assigned (was assigned by)	V20	V22
VP24	assigned uncertainty to	V19	V8
VP25	assigned accuracy to	V20	V8
VP26	assigned uncertainty to	V19	V17
VP27	assigned accuracy to	V20	V17
VP28	has morphological representation (morphologically represents)	V8	V16
VP29	has morphological representation (morphologically represents)	V11	V16
VP30	has geometrical representation (geometrically represents)	V8	V11
VP31	has dimension (is dimension of)	V8	E54
VP32	is identified by on (identifies)	V8	E42
VP33	has reference on (is reference of)	V11	V17
VP34	has reference on (is reference of)	V16	V17
VP35	has evidence on (is evidence of)	V11	V17
VP36	has evidence on (is evidence of)	V16	V17
VP37	has component (is component of)	V11	V14
VP38	has component (is component of)	V11	V15
VP39	has component (is component of)	V14	V12
VP40	has evidence on (is evidence of)	V16	V6
VP41	is identified by (identifies)	V12	E42
VP42	has sequence identifier (is sequence identifier of)	V12	V13
VP43	has dimension (is dimension of)	V14	E54
VP44	has dimension (is dimension of)	V14	E60
VP45	has number of primitive entities	V15	E60
VP46	has number of primitive entities	V15	E54
VP47	has type (is type of)	V17	V6
VP48	is identified by (identifies)	V17	E42
VP49	has type (is type of)	V17	E55

VP50	is interpreted from	E55	V17
VP51	is deducted from	E55	V17
VP52	is indicated on (indicates)	E55	V17
VP53	has dimension equivalent (is equivalent dimension of)	E54	V23
VP54	has unit (is unit of)	V23	E58
VP55	has value (is value of)	V23	E60
VP56	has type (is type of)	E54	V24
VP57	assigned (was assigned by)	V25	V24
VP58	has type (is type of)	V17	V16
VP59	has type (is type of)	V17	E55
VP60	has reference on (is reference of)	V2	V17
VP61	has reference on (is reference of)	V3	V17
VP62	has component (is component of)	V15	V12

Virtual Reconstruction class hierarchy, aligned with portions from CIDOC CRM class hierarchies

E1	CRM Entity
E2	- Temporal Entity
E5	- - - Event
E7	- - - - Activity
E13	- - - - - Attribute Assignement
E17	- - - - - - Type Assignement
S5	- - - - - - - Inference Making
V18	- - - - - - - - Transparency Inference Making
V19	- - - - - - - - - Uncertainty Evaluation
V20	- - - - - - - - - Accuracy Evaluation
V25	- - - - - - - - - Evaluation of Dimension Provenance
E77	- Persistent Item
V1	- - Domain
E70	- - Thing
E72	- - - Legal Object
E90	- - - - Symbolic Object
E41	- - - - - Appellation
E42	- - - - - - Identifier
V7	- - - - - - - Hierarchy Identifier
V9	- - - - - - - Version Identifier
V13	- - - - - - - Order of Sequence Identifier
E71	- - - Man-Made Thing
E24	- - - - Physical Man-Made Thing
V3	- - - - - Cultural Heritage
V4	- - - - - - Find
E28	- - - - Conceptual Object
E90	- - - - - Symbolic Object
E73	- - - - - - Information Object
V17	- - - - - - - Source
E31	- - - - - - - - Document
V11	- - - - - - - Geometrical Representation
V14	- - - - - - - - Profile
V15	- - - - - - - - Path
V16	- - - - - - - Morphological Representation
D1	- - - - - - - - Digital Object
V8	- - - - - - - - - 3D Object

V6	- - - - - - - - - 3D Find
E89	- - - - - Propositional Object
V2	- - - - - - Immaterial Heritage
V5	- - - - - - Component Element
V12	- - - - - - Primitive Entity
E55	- - - - - Type
V21	- - - - - - Uncertainty Grade
V22	- - - - - - Accuracy Grade
V24	- - - - - - Type of Dimension Provenance
E39	- - Actor
E21	- - - Person
V10	- - - - Author
E54	- Dimension
V23	- - Dimension Equivalent

Virtual Reconstruction property hierarchy, aligned with portions from CIDOC CRM property hierarchies

ID p.	*Property Name*	*Entity-Domain*	*Entity-Range*
VP1	has domain	V2 Immaterial Heritage	V1 Domain
VP2	has domain	V3 Cultural Heritage	V1 Domain
VP18	is authored	V9 Version Identifier	V10 Author
VP19	is authored	V8 3D Object	V10 Author
P1	is identified by (identifies)	E1 CRM Entity	E41 Appellation
VP5	- is identified by (identifies)	V2 Immaterial Heritage	E42 Identifier
VP6	- is identified by (identifies)	V3 Cultural Heritage	E42 Identifier
VP8	- is identified by (identifies)	V4 Find	E42 Identifier
VP13	- is hierarchically identified (hierarchically identifies)	V5 Component Element	V7 Hierarchy Identifier
VP14	- is identified by (identifies)	V5 Component Element	E42 Identifier
VP32	- is identified by on (identifies)	V8 3D Object	E42 Identifier
VP41	- is identified by (identifies)	V12 Primitive Entity	E42 Identifier
VP42	- has sequence identifier (is sequence identifier of)	V12 Primitive Entity	V13 Order of Sequence Identifier
VP48	- is identified by (identifies)	V17 Source	E42 Identifier
P2	has type (is type of)	E1 CRM Entity	E55 Type
VP3	- has type (is type of)	V2 Immaterial Heritage	E55 Type
VP4	- has type (is type of)	V3 Cultural Heritage	E55 Type
VP47	- has type (is type of)	V17 Source	V6 3D Find
VP49	- has type (is type of)	V17 Source	E55 Type
VP56	- has type (is type of)	E54 Dimension	V24 Type of Dimension Provenance
VP58	- has type (is type of)	V17 Source	V16 Morphological Representation
VP59	- has type (is type of)	V17 Source	E55 Type
P12	occurred in the presence of (was present at)	E5 Event	E77 Persistent Item
P11	- had participant (participated in)	E5 Event	E39 Actor
P14	- - carried out by (performed)	E7 Activity	E39 Actor
VP20	- - - carried out by (performed)	V19 Uncertainty Evaluation	V10 Author
VP21	- - - carried out by (performed)	V20 Accuracy Evaluation	V10 Author
P43	has dimension (is dimension of)	E70 Thing	E54 Dimension
VP31	- has dimension (is dimension of)	V8 3D Object	E54 Dimension
VP43	- has dimension (is dimension of)	V14 Profile	E54 Dimension
VP44	- has dimension (is dimension of)	V15 Path	E54 Dimension

VP53	- has dimension equivalent (is equivalent dimension of)	E54 Dimension	V23 Dimension Equivalent
P57	has number of parts	E19 Physical Object	E60 Number
VP45	- has number of primitive entities	V14 Profile	E60 Number
VP46	- has number of primitive entities	V15 Path	E60 Number
P67	refers to (is reffered to by)	E89 Propositional Object	E1 CRM Entity
P70	- documents (is documented in)	E31 Document	E1 CRM Entity
VP7	- - has evidence on (is evidence of)	V4 Find	V3 Cultural Heritage
VP33	- - has reference on (is reference of)	V11 Geometrical Representation	V17 Source
VP34	- - has reference on (is reference of)	V16 Morphological Representation	V17 Source
VP35	- - has evidence on (is evidence of)	V11 Geometrical Representation	V17 Source
VP36	- - has evidence on (is evidence of)	V16 Morphological Representation	V17 Source
VP40	- - has evidence on (is evidence of)	V16 Morphological Representation	V6 3D Find
VP50	- - - is interpreted from	E54 Dimension	V17 Source
VP51	- - - is deducted from	E54 Dimension	V17 Source
VP52	- - - is indicated on (indicates)	E54 Dimension	V17 Source
VP60	- - has reference on (is reference of)	V2 Immaterial Heritage	V17 Source
VP61	- - has reference on (is reference of)	V3 Cultural Heritage	V17 Source
P90	has value	E54 Dimension	E60 Number
VP55	- has value (is value of)	V23 Dimension Equivalent	E60 Number
P91	has unit	E54 Dimension	E58 Measurement Unit
VP54	- has unit (is unit of)	V23 Dimension Equivalent	E58 Measurement Unit
P138	represents (has representation)	E36 Visual Item	E1 CRM Identity
VP9	- has digital representation (digitally represents)	V4 Find	V3 Cultural Heritage
VP15	- has digital representation (is digitally represented)	V5 Component Element	V8 3D Object
VP28	- has morphological representation (morphologically represents)	V8 3D Object	V16 Morphological Representation
VP29	- has morphological representation (morphologically represents)	V11 Geometrical Representation	V16 Morphological Representation
VP30	- has geometrical representation (geometrically represents)	V8 3D Object	V11 Geometrical Representation
P139	has alternativa form	E41 Appellation	E41 Appellation
VP17	- has version identifier (is version identifier of)	V8 3D Object	V9 Version Identifier
P140	assigned attribute to (was attributed by)	E13 Attribute Assignement	E1 CRM Entity
VP24	- assigned uncertainty to	V19 Uncertainty Evaluation	V8 3D Object
VP25	- assigned accuracy to	V20 Accuracy Evaluation	V8 3D Object
VP26	- assigned uncertainty to	V19 Uncertainty Evaluation	V17 Source
VP27	- assigned accuracy to	V20 Accuracy Evaluation	V17 Source
P141	assigned (was assigned by)	E13 Attribute Assignement	E1 CRM Entity
VP22	assigned (was assigned by)	V19 Uncertainty Evaluation	V21 Uncertainty Grade
VP23	assigned (was assigned by)	V20 Accuracy Evaluation	V22 Accuracy Grade
VP57	assigned (was assigned by)	V25 Evaluation of Dimension Provenance	V24 Type of Dimension Provenance
P148	has component (is component of)	E89 Propositional Object	E89 Propositional Object
VP10	- has component (is component of)	V2 Immaterial Heritage	V4 Find
VP11	- has component (is component of)	V3 Cultural Heritage	V4 Find
VP12	- has component (is component of)	V5 Component Element	V5 Component Element
VP37	- has component (is component of)	V11 Geometrical Representation	V14 Profile
VP38	- has component (is component of)	V11 Geometrical Representation	V15 Path
VP39	- has component (is component of)	V14 Profile	V12 Primitive Entity
VP62	- has component (is component of)	V15 Path	V12 Primitive Entity
L21	used as derivation source (was derivation source for)	D3 Formal Derivation	D1 Digital Object
VP16	- used as derivation source	V6 3D Find	V8 3D Object

Virtual Reconstruction Class Declarations

V1 Domain	
Subclass of:	E77 Persistent Item
Scope note:	This class includes all entities attributable to cultural heritage. Defines an area of interest or an area of which the object of reconstruction process is part of. Heritage includes buildings and historic places, monuments, artifacts, etc., including objects significant to the archaeology, architecture, science or technology of a specific culture.
Examples	Painting, Architecture

V2 Immaterial Heritage	
Subclass of:	E89 Propositional Object
Scope note:	This class comprises immaterial heritage that are documented in some way by any kind of source and that can be virtually reproduced.
Example	The background scene (V2) in "La flagellazione di cristo" The Doric Order (V2) in "I quattro libri dell'Architettura)
Properties:	VP1 has domain: V1 Domain
	VP3 has type (is type of): E55 Type
	VP5 is identified by (identifies): E42 Identifier
	VP10 has component (is component of): V4 Find
	VP60 has reference on (is reference of): V17 Source

V3 Cultural Heritage	
Subclass of:	E24 Man-Made Thing
Superclass of:	V4 Find
Scope note:	Cultural heritage includes buildings and historic places, monuments, artifacts, etc., including objects significant to the archaeology, architecture, science or technology of a specific culture that had a certain or documented physical existance.
Properties:	VP2 has domain: V1 Domain
	VP4 has type (is type of): E55 Type
	VP6 is identified by (identifies): E42 Identifier
	VP11 has component (is component of): V4 Find
	VP61 has reference on (is reference of): V17 Source

V4 Find	
Subclass of:	V3 Cultural Heritage
Scope note:	This class comprises physical evidence of the Heritage object that can be virtually reconstructed by SFM process (D2) or other methods.
Example	archeological evidences fragment of a ceramic plate
Properties:	VP7 has evidence on (is evidence of): V3 Cultural Heritage
	VP8 is identified by (identifies): E42 Identifier
	VP9 has digital representation (digitally represents): V3 Cultural Heritage

V5 Component Element	
Subclass of:	E89 Propositional Object
Scope note:	This class comprises instances that are considered functional units for the whole object, accordind with the declared domain. It comprise V5 component elements that are themselves instances of V5 components elements. The V5 component element could be further analyzed into sub-components creating a hierarchy of part decomposition that is declared by V7 Hierarchy Identifier.
Properties:	VP12 has component (is component of): V5 Component Element VP13 is hierarchically identified (hierarchically identifies): V7 Hierarchy Identifier VP14 is identified by (identifies): E42 Identifier VP15 has digital representation (is digitally represented): V8 3D Object

V6 3D Find	
Subclass of:	D1 Digital Object
Scope note:	This class comprise the immaterial representation of V4 Find that are represented as a 3D model obtained by a D2 Digitization process.
Properties:	VP16 used as derivation source: V8 3D Object

V7 Hierarchy Identifier	
Subclass of:	E42 Identifier
Scope note:	This class comprise the level of hierachical aggregation of the component in relation with the whole element. Depending on the domain, its classifications and its controlled vocabulary the sub-elements that compose the artifact could variate creating a hierarchy of part decomposition that is declared by V7 Hierarchy Identifier.

V8 3D Object	
Subclass of:	D1 Digital Object
Scope note:	Three-dimensional (3D) models represent an artefact, using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. A 3D digital object define the volume of the object that represent. In heritage virtual reconstructions is preferred the use of solid models that are usually built with constructive solid geometry.
Properties:	VP17 has version identifier (is version identifier of): V9 Version Identifier VP19 is authored: V10 Author VP28 has morphological representation (morphologically represents): V16 Morphological Representation VP30 has geometrical representation (geometrically represents): V11 Geometrical Representation VP31 has dimension (is dimension of): E54 Dimension VP32 is identified by on (identifies): E42 Identifier

V9 Version Identifier	
Subclass of:	E42 Identifier
Scope note:	This class comprise an identifier that declare the E42 Identifier assigned to each 3D modelled version of the same V8 3D Object based on different evidence/reference.
Properties:	VP18 is authored: V10 Author

V10 Author	
Subclass of:	E21 person
Scope note:	This class comprise instances of V10 author of the version of the 3D model of a V5 Component Element.

V11 Geometrical Representation	
Subclass of:	E73 Information Object
Scope note:	The class comprise the visual knowledge about the geometrical representation of a V5 Component Element.
Properties:	VP29 has morphological representation (morphologically represents): Morphological Representation
	VP33 has reference on (is reference of): V17 Source
	VP35 has evidence on (is evidence of): V17 Source
	VP37 has component (is component of): V14 Profile
	VP38 has component (is component of): V15 Path

V12 Primitive Entity	
Subclass of:	E89 Propositional Object
Scope note:	The class comprise the geometrical item that can be assumed as a geometrical primitive necessary for the construction of V14 Profile and V15 Path.
Properties:	VP41 is identified by (identifies): E42 Identifier
	VP42 has sequence identifier (is sequence identifier of): V13 Order of Sequence Identifier

V13 Order of Sequence Identifier	
Subclass of:	E42 Identifier
Scope note:	The class comprise an identifier that declare the E42 Identifier assigned to the V12 Primitive Entity and its position in the geometrical sequence of primitive elements that create V14 profile or V15 Path.

V14 Profile	
Subclass of:	V11 Geometrical Representation
Scope note:	The class comprise the geometrical representation of the physical features of a profile in the vertical plane containing both endpoints of the profile. The profile could be intended as a vertical section of the V11 Geometrical Representation
Properties:	VP39 has component (is component of): V12 Primitive Entity
	VP43 has dimension (is dimension of): E54 Dimension
	VP45 has number of primitive entities: E60 Number

V15Path	
Subclass of:	V11 Geometrical Representation
Scope note:	The class comprise the geometrical representation of the physical features of a path in the horizontal plane containing both endpoints of the path.
Properties:	VP44 has dimension (is dimension of): E54 Dimension
	VP46 has number of primitive entities: E60 Number
	VP62 has component (is component of): V12 Primitive Entity

V16 Morphological Representation	
Subclass of:	E73 Information Object
Scope note:	The class comprise immaterial items related to knoledge about the morphological representation of a V5 component element.
Properties:	VP34 has reference on (is reference of): V17 Source
	VP36: has evidence on (is evidence of): V17 Source
	VP40 has evidence on (is evidence of): V6 3D Find

V17 Source	
Subclass of:	E73 Information Object
Superclass of:	E31 Document
Scope note:	This class comprise instances of V17 Sources and E31 Documents used in the Virtual Reconstruction process as evidence of reference of 3D modelling.
Properties:	VP47 has type (is type of): V6 3D Find
	VP48 is identified by (identifies): E42 Identifier
	VP49 has type (is type of): E55 Type
	VP58 has type (is type of): V16 Morphological Representation
	VP59 has type (is type of): E55 Type

V18 Trasparency Inference Making	
Subclass of:	S5 Inference Making
Superclass of:	V19 Uncertainty Evaluation; V20 Accuracy Evaluation; V25 Evaluation of Dimension Provenance
Scope note:	This class comprises the action of making propositions and statements about particular geometrical or morphological representations of an V4 Find, its possible virtual representations (V6 3D Find), V17 sources and 3D objects. It includes evaluations and interpretations based on sources available for 3D reconstructions with the aim to fill the gap between documentation and 3D model obtained from them..

V19 Uncertainty Evaluation	
Subclass of:	V18 Trasparency Inference Making
Scope note:	This class comprises the action of make propositions on data observable from a V17 Source or E31 Document by making evaluations based on the V21 Uncertainty Grade of informations on morphological and geometrical representations of the Cultural Heritage or Immaterial Heritage that we want to digitally reproduce.
Properties:	VP20 carried out by (performed): V10 Author
	VP22 assigned (was assigned by): V21 Uncertainty Grade
	VP24 assigned uncertainty to: V8 3D Object
	VP26 assigned uncertainty to: V17 Source

V20 Accuracy Evaluation	
Subclass of:	V18 Trasparency Inference Making
Scope note:	This class comprises the action of make propositions on data observable from a V17 Source or E31 Document by making evaluations based on the V22 Accuracy Grade of informations on morphological and geometrical representations of the Cultural Heritage or Immaterial Heritage that it is possible to digitally reproduce.
Properties:	VP21 carried out by (performed): V10 Author
	VP23 assigned (was assigned by): V22 Accuracy Grade
	VP25 assigned accuracy to: V8 3D Object
	VP27 assigned accuracy to: V17 Source

V21 Uncertainty Grade	
Subclass of:	E55 Type
Scope note:	This class comprise instances of V21 Unvcertainty Grade that could be assigned to a V17 Source.

V22 Accuracy Grade	
Subclass of:	E55 Type
Scope note:	This class comprise instances of V22 Accuracy Grade that could be assigned to a V17 Source.

V23 Dimension Equivalent

Subclass of: E54 Dimension

Scope note: This class comprises equivalent value that can be attribute to an E54 Dimension according with the modelling software used. The 3D modelling software usually does not use the same E54 Dimension values and units indicated on a V17 source or E31 Document available.

Properties: VP54 has unit (is unit of): E58 Measurement Unit

VP55 has value (is value of): E60 Number

V24 Type of dimension provenance

Subclass of: E55 Type

Scope note: This class comprises Type of Dimensions in relation withw their reference V17 Sources or E31 Documents. In Virtual Reconstruction Processes are defined ony three enumerated Types of Dimension Provenance: Indicated, Deducted, Interpreted.

V25 Evaluation of Dimension Provenance

Subclass of: V18 Trasparency Inference Making

Scope note: This class comprises the action of make propositions about Dimension Provenance: connecting the E45 Dimension and its values with a V17 Source or E31 Document used for the Virtual Recontruction.

Properties: VP57 assigned (was assigned by): V24 Type of Dimension Provenance

E54 referred to CIDOC-CRM Class

E54 Dimension

Subclass of: E1 CRM Entity

Scope note: This class comprises quantifiable properties that can be measured by some calibrated means and can be approximated by values, i.e. points or regions in a mathematical or conceptual space, such as natural or real numbers, RGB values etc.
An instance of E54 Dimension represents the true quantity, independent from its numerical approximation, e.g. in inches or in cm. The properties of the class E54 Dimension allow for expressing the numerical approximation of the values of an instance of E54 Dimension. If the true values belong to a non-discrete space, such as spatial distances, it is recommended to record them as approximations by intervals or regions of indeterminacy enclosing the assumed true values. For instance, a length of 5 cm may be recorded as 4.5-5.5 cm, according to the precision of the respective observation. Note, that interoperability of values described in different units depends critically on the representation as value regions.
Numerical approximations in archaic instances of E58 Measurement Unit used in historical records should be preserved. Equivalents corresponding to current knowledge should be recorded as additional instances of E54 Dimension as appropriate.

Properties: P90 has value : E60 Number,

P91 has unit (is unit of) : E58 Measurement Unit

VP50 is interpreted from: V17 Source

VP51 is deducted from: V17 Source

VP52 is indicated on (indicates): V17 Source

VP53 has dimension equivalent (is equivalent dimension of): V23 Dimension Equivalent

VP56 has type (is type of): V24 Type of Dimension Provenance

Virtual Reconstruction Property Declarations

VP1 has domain (is domain of)

Domain: V2 Immaterial Heritage

Range: V1 Domain

Subproperty of:

Quantification:

VP2 has domain (is domain of)

Domain: V3 Cultural Heritage

Range: V1 Domain

Subproperty of:

Quantification:

VP3 has type (is type of)	
Domain:	V2 Immaterial Heritage
Range:	E55 Type
Subproperty of:	P2 has type (is type of)
Quantification:	

VP4 has type (is type of)	
Domain:	V3 Cultural Heritage
Range:	E55 Type
Subproperty of:	P2 has type (is type of)
Quantification:	

VP5 is identified by (identifies)	
Domain:	V2 Immaterial Heritage
Range:	E42 Identifier
Subproperty of:	P1 is identified by (identifies)
Quantification:	

VP6 is identified by (identifies)	
Domain:	V3 Cultural Heritage
Range:	E42 Identifier
Subproperty of:	P1 is identified by (identifies)
Quantification:	

VP7 has evidence on (is evidence of)	
Domain:	V4 Find
Range:	V3 Cultural Heritage
Subproperty of:	P70 documents (is documented in)
Quantification:	

VP8 is identified by (identifies)	
Domain:	V4 Find
Range:	E42 identifier
Subproperty of:	P1 is identified by (identifies)
Quantification:	

VP9 has digital representation (digitally represents)	
Domain:	V4 Find
Rang	V3 Cultural Heritage
Subproperty of:	P138 represents (has representation)
Quantification:	

VP10 has component (is component of)	
Domain:	V2 Immaterial Heritage
Range:	V4 Find
Subproperty of:	P148 has component (is component of)
Quantification:	

VP11 has component (is component of)	
Domain:	V3 Cultural Heritage
Range:	V4 Find
Subproperty of:	P148 has component (is component of)
Quantification:	

VP12 ihas component (is component of)	
Domain:	V5 Component Element
Range:	V5 Component Element
Subproperty of:	
Quantification:	

VP13 is hierarchically identified (hierarchically identifies)	
Domain:	V5 Component Element
Range:	V7 Hierarchy Identifier
Subproperty of:	P1 is identified by (identifies)
Quantification:	

VP14 is identified by (identifies)	
Domain:	V5 Component Element
Range:	E42 Identifier
Subproperty of:	P1 is identified by (identifies)
Quantification:	

VP15 has digital representation (is digitally represented)	
Domain:	V5 Component Element
Range:	V8 3D Ojbect
Subproperty of:	P138 represents (has representation)
Properties:	

VP16 used as derivation source	
Domain:	V6 3D Find
Range:	V8 3D Ojbect
Subproperty of:	
Quantification:	

VP17 has version identifier (is version identifier of)	
Domain:	V8 3D Object
Range:	V9 Version Identifier
Subproperty of:	P139 has alternativa form
Quantification:	

VP18 is authored	
Domain:	V9 Version Identifier
Range:	V10 Author
Subproperty of:	
Quantification:	

VP19 Version Identifier	
Domain:	V8 3D Object
Range:	V10 Author
Subproperty of:	
Quantification:	

VP20 carried out by (performed)	
Domain:	V19 Uncertainty Evaluation
Range:	V10 Author
Subproperty of:	P14 carried out by (performed)
Quantification:	

VP21 carried out by (performed)

Domain: V20 Accuracy Evaluation
Range: V10 Author
Subproperty of: P14 carried out by (performed)
Quantification:

VP22 assigned (was assigned by)

Domain: V19 Uncertainty Evaluation
Range: V21Uncertainty Grade
Subproperty of: P141 assigned (was assigned by)
Quantification:

VP23 assigned (was assigned by

Domain: V20 Accuracy valuation
Range: V22 Accuracy Grade
Subproperty of: P141 assigned (was assigned by)
Quantification:

VP24 assigned uncertainty to

Domain: V19 Uncertainty Evaluation
Range: V8 3D Object
Subproperty of: P 140 assigned attribute to (was attributed by)
Quantification:

VP25 assigned accuracy to

Domain: V20 Accuracy Evaluation
Range: V8 3D Object
Subproperty of: P 140 assigned attribute to (was attributed by)
Quantification:

VP26 assigned uncertainty to

Domain: V19 Uncertainty Evaluation
Range: V17 Type Assignement
Subproperty of: P 140 assigned attribute to (was attributed by)
Quantification:

VP27 assigned accuracy to

Domain: V20 Accuracy Evaluation
Range: V17 Source
Subproperty of: P 140 assigned attribute to (was attributed by)
Quantification:

VP28 has morphological representation (morphologically represents)

Domain: V8 3D Object
Range: V16 Morphological Rapresentation
Subproperty of: P138 represents (has representation)
Quantification:

VP29 has morphological representation (morphologically represents)

Domain: V11 Geometrical Rapresentation
Range: V16 Morphological Rapresentation
Subproperty of: P138 represents (has representation)
Quantification:

VP30 has geometrical representation (geometrically represents)

Domain: V8 3D Object
Range: V11 Geometrical Rapresentation
Subproperty of: P138 represents (has representation)
Quantification:

VP31 has dimension (is dimension of)

Domain: V8 3D Object
Range: E54 Dimension
Subproperty of: P43 has dimension (is dimension of)
Quantification:

VP32 is identified by on (identifies)

Domain: V8 3D Object
Range: E42Identifier
Subproperty of: P1 is identified by (identifies)
Quantification:

VP 33 is identified by on (identifies)

Domain: V11Geometrical Rapresentation
Range: V17 Source
Subproperty of: P70 documents (is documented in)
Quantification:

VP34 has reference on (is reference of)

Domain: V16 Morphological Rapresentaion
Range: V17 Source
Subproperty of: P70 documents (is documented in)
Quantification:

VP35 has reference on (is reference of)

Domain: V11 Geometrical Rapresentation
Range: V17 Source
Subproperty of: P70 documents (is documented in)
Quantification:

VP36 has reference on (is reference of)

Domain: V16 Morphological Representation
Range: V17 Source
Subproperty of:
Quantification:

VP37 has component (is component of)

Domain: V11 Geometrical Rapresentation
Range: V14 Profile
Subproperty of: P148 has component (is component of)
Quantification:

VP38 has component (is component of)

Domain: V11 Geometrical Rapresentation
Range: v15 Path

Subproperty of: P148 has component (is component of)
Quantification:

VP39 has component (is component of)

Domain: v14 Profile
Range: V12 Primitive Entity
Subproperty of:
Quantification:

VP40 has evidence on (is evidence of)

Domain: V16 Morphological Rapresentation
Range: V6 3D Find
Subproperty of: P70 documents (is documented in)
Quantification:

VP41 is identified by (identifies)

Domain: V12 Primitive Entity
Range: E42 Identifier
Subproperty of: P1 is identified by (identifies)
Quantification:

V42 has sequence identifier (is sequence identifier of)

Domain: V12 Primitive Entity
Range: V13 Attribute Assignement
Subproperty of: P1 is identified by (identifies)
Quantification:

VP43 has dimension (is dimension of)

Domain: V14 Profile
Range: E54 Dimension
Subproperty of: P43 has dimension (is dimension of)
Quantification:

VP44 has dimension (is dimension of)

Domain: V15 Path
Range: E54 Dimension
Subproperty of: P43 has dimension (is dimension of)
Quantification:

VP45 has number of primitive entities

Domain: V14 Profile
Range: E60 Number
Subproperty of: P57 has number of parts
Quantification:

VP46 has number of primitive entities

Domain: V15 Path
Range: E60 Number
Subproperty of: P57 has number of parts
Quantification:

VP47 has type (is type of)

Domain: V17 Source
Range: V6 3D Find
Subproperty of: P2 has type (is type of)
Quantification:

VP48 z is identified by (identifies

Domain: V17 Source
Range: E42 Identifier
Subproperty of: P1 is identified by (identifies)
Quantification:

VP49 is identified by (identifies

Domain: V17 Source
Range: E55 Type
Subproperty of: P2 has type (is type of)
Quantification:

VP50 is interpreted from

Domain: E54 Dimension
Range: V17 Source
Subproperty of: P70 documents (is documented in)
Quantification:

VP51 is deducted from

Domain: E54 Dimension
Range: V17 Source
Subproperty of:
Quantification:

VP52 s indicated on (indicates)

Domain: E54 Dimension
Range: V17 Source
Subproperty of:
Quantification:

VP53 s indicated on (indicates)

Domain: E54 Dimension
Range: V23 Dimension Equivalent
Subproperty of: P43 has dimension (is dimension of)
Quantification:

VP54 has unit (is unit of)

Domain: V23 Dimension Equivalent
Range: E58 Measurement Unit
Subproperty of: P91 has unit
Quantification:

VP55 has value (is value of)

Domain: V23 Dimension Equivalent
Range: E60 Number
Subproperty of: P90 has value
Quantification:

VP56 has type (is type of) has type (is type of)

Domain: E54 Dimension
Range: V24 Type of Dimension Prevenance

Subproperty of:	P2 has type (is type of)
Quantification:	

VP57 assigned was assigned By)

Domain:	V25 Evaluation of Dimension Provenance
Range:	V24 Type of Dimension Provenance
Subproperty of:	P141 assigned (was assigned by)
Quantification:	

VP58 **has type (is type of)**

Domain:	V17 Source
Range:	V16 Morphological Rapresentation
Subproperty of:	P2 has type (is type of)
Quantification:	

VP59 **has type (is type of)**

Domain:	V17 Source
Range:	E55 Type
Subproperty of:	P2 has type (is type of)
Quantification:	

VP60 **has reference on (is reference of)**

Domain:	V2 Immaterial Heritage
Range:	V17 Source
Subproperty of:	P70 documents (is documented in)
Quantification:	

VP61 **has reference on (is reference of)**

Domain:	V3 Cultural Heritage
Range:	V17 Source
Subproperty of:	P70 documents (is documented in)
Quantification:	

From the CIDOC-CRM for virtual reconstruction documentation to VRIM DB structure

The conceptual reference model for virtual reconstruction Purpose (CRMvr proposal) is a small ontology ready for use with an accessible language in which it is possible to express ideas, concepts and relationships on virtual reconstructed 3D objects and the knowledge-based documentation that create the 3D result. The presented model is not “finished”, and it is open to further processing. The proposed extension is made ad-hoc for those people who are going to virtually model the Entity of Cultural Heritage, even if it is an immaterial entity (where the traceability of the

Mapping Classes of “Architecture” Domain into CRMvr draft proposal Classes

CRMvr Classes	*“Architecture” Domain Classes*
V1 Domain	Architecture
V2 Immaterial Heritage	Immaterial Architecture
V3 Cultural Heritage	Built Architecture
V4 Find	Find
V5 Component Element	Architectural Element
V6 3D Find	3D Find
V7 Hierarchy Identifier	Level of Element
V8 3D Object	3D model of architectural element
V9 Version Identifier	Version of 3D model
V10 Author	Author
V11 Geometrical Representation	Geometrical Representation
V12 Primitive Entity	Geometrical Atom (GA)
V13 Order of Sequence Identifier	Sequence Identifier
V14 Profile	Profile
V15 Path	Path
V16 Morphological Representation	Morphological Representation
V17 Source	Reference Source
V18 Trasparency Inference Making	
V19 Uncertainty Evaluation	
V20 Accuracy Evaluation	
V21 Uncertainty Grade	Level of Uncertainty (LoU)
V22 Accuracy Grade	Level of Accuracy (LoA)
V23 Dimension Equivalent	Dimension Equivalent
V24 Type of Dimension Provenance	Type of Dimension Provenance
V25 Evaluation of Dimension Provenance	

decision-making process is more important).

From the general extension to a true application on the VRIM project it is necessary to define new Classes that correspond to Instances in the model: a Domain "Architecture" is declared and a Vocabulary of Taxonomy and Terminology for Classical Architecture Orders is defined.

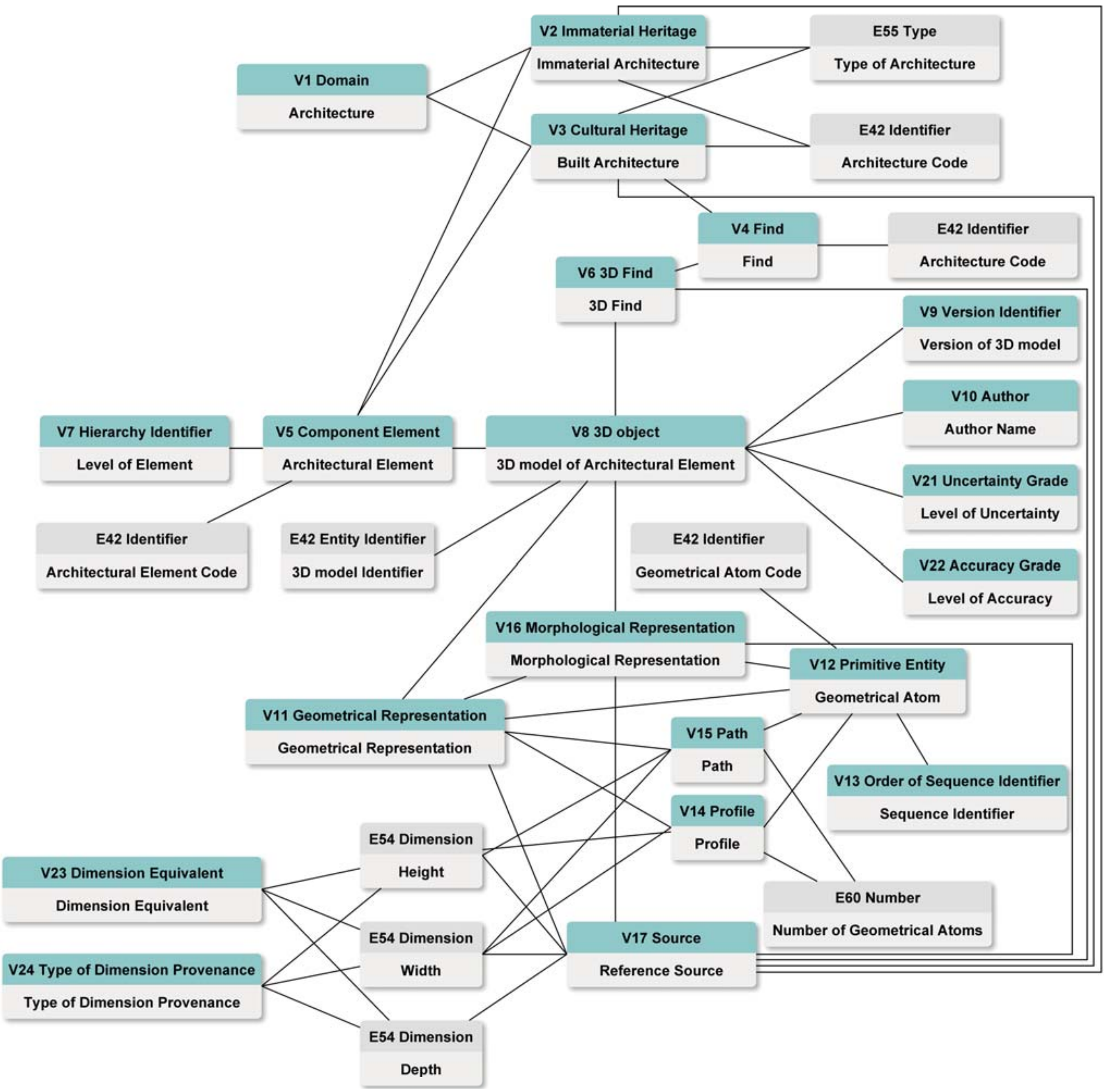

Fig 14: *Mapping Classes of "Architecture" Domain into CRMvr Classes with yED*

Assign a domain means mapping “Architecture” Domain Classes into CRMvr classes without considering the E7 Activity Classes.

Taxonomy and Terminology for a Controlled Vocabulary of Classical Orders of Architecture

Designing Data base structures from VR ontology needs to define a specific domain of interest: in this case Classical Architecture and more specifically buildings referred to Classic Orders of Architecture. This model aims at staying harmonized with the CIDOC CRM to guarantee the overall consistency, disciplinary adequacy and modularity of CRM-based ontology modules.

The VR extension ontology was used to define a VRIM conceptual schema using instances retrieved from the controlled vocabularies and notations for Classical Architecture (Chapter 2).

Conceptual Design

The realisation of the E / R conceptual model is the first phase of the design of a relational DB. The conceptual model describes the realities of the domain in an easy way. Use the ontology representing the organization and structure of the data with its entities and associations.

The final VRIM conceptual scheme was developed using ConML Technical Specification (César Gonzalez-Perez & Hug, 2016) that has some important requirements:

- It is used with an Object-oriented paradigm
- It is easily affordable to non-experts in information technologies
- It must be incrementally understandable and applicable

According with the ConML structure, also the VRIM conceptual model is composed by the following packages:

- Types. This package contains classes such as TypeModel, Class, Attribute and Association, which allow for the creation of type models, which represent reality in terms of categories of things.
- Instances. This package contains classes such as InstanceModel, Object and Link, which allow for the creation of instance models, which represent reality in terms of one-to-one representations of things. The Instance Model involves the Instance components where abstract classes become real entities and the list of attributes became a list of values.

ConML classes, attributes, associations (TypeModel) using vocabularies and notation for Classical Architecture and CRMvr ontology were use to create a conceptual model with ConML graphic notations: this schema is more affordable for non expert on CIDOC-CRM allowing to better understand relations and a first structure for the entity-relation database.

From the Conceptual Scheme to a Relational Data Management

Relational Database Management System is a database system made up of files with data elements in two-dimensional array (rows and columns). This database management system has the capability to recombine data elements to form different relations resulting in a great flexibility of data usage.

The SQL is used to manipulate relational databases and create VRIM sheets.

The relational model contains the following components:

- Collection of objects or relations
- Set of operations to act on the relations
- Data integrity for accuracy and consistency

The Data Base structure relations is a complex set of tables. From the Relational Database is possible to obtain information about single elements or a series of them and export data in single or multiple sheet of excel.

The possibility to extrapolate data is very important because by query it is possible to obtain compiled sheet that can be used for further applications. The sheets were the start point of the VRIM scripting workflow that can read data from excel and by the use of VRIM algorithm can use these information to create a 3D solid BIM family with semantic enrichment and structured data information, retrievable into Revit environment.

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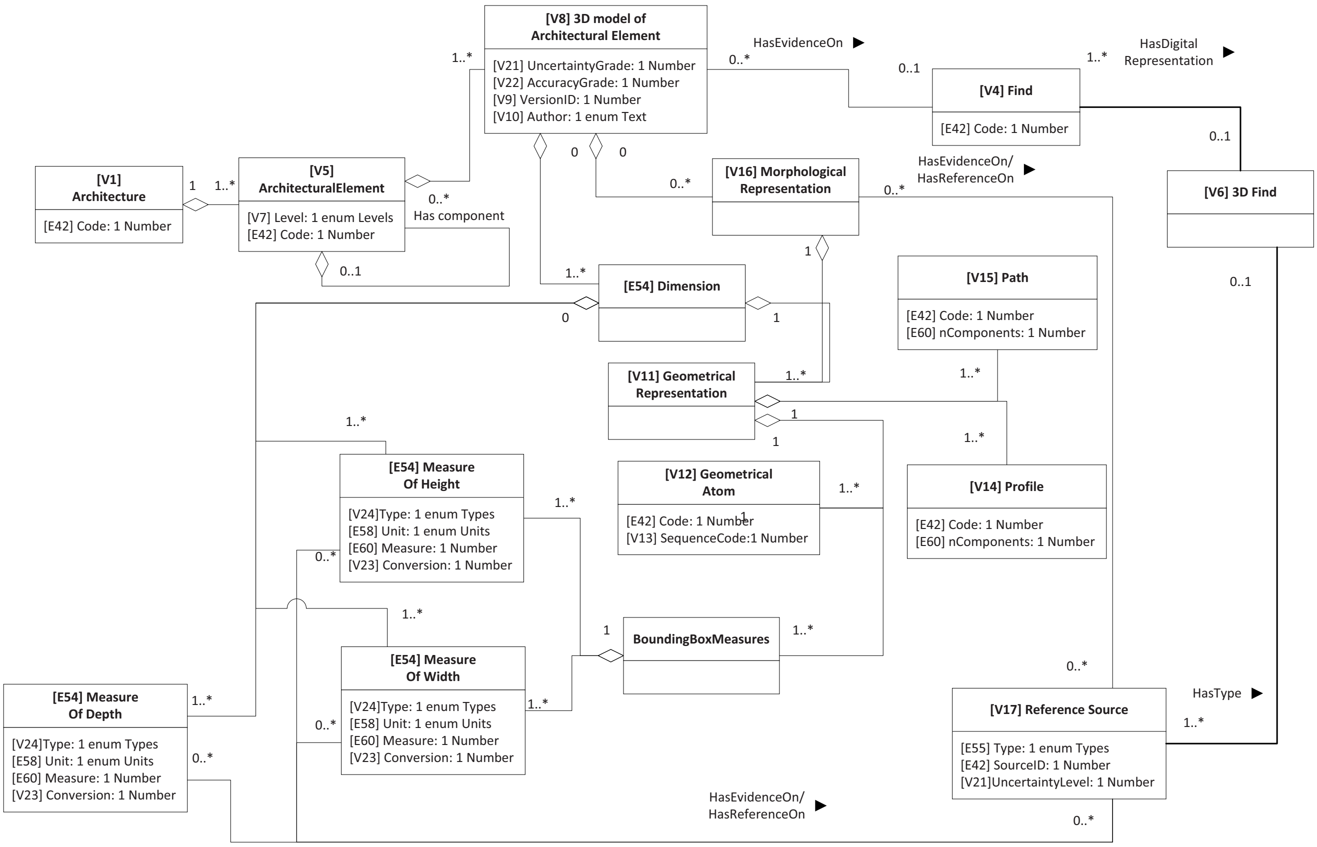


Fig 15: *"Architecture" domain based on CIDOC-CRMvr developed using ConML graphic notations*

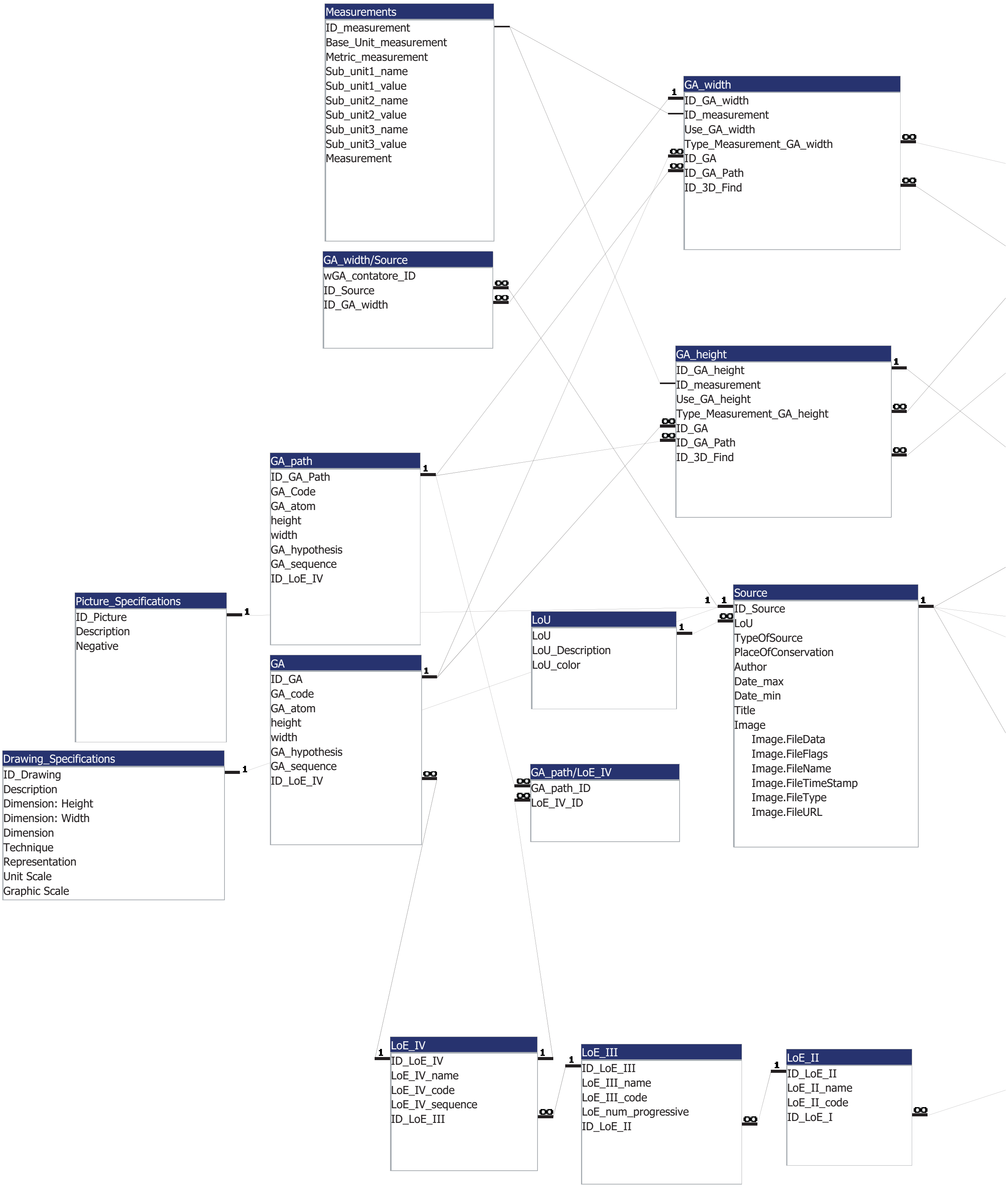
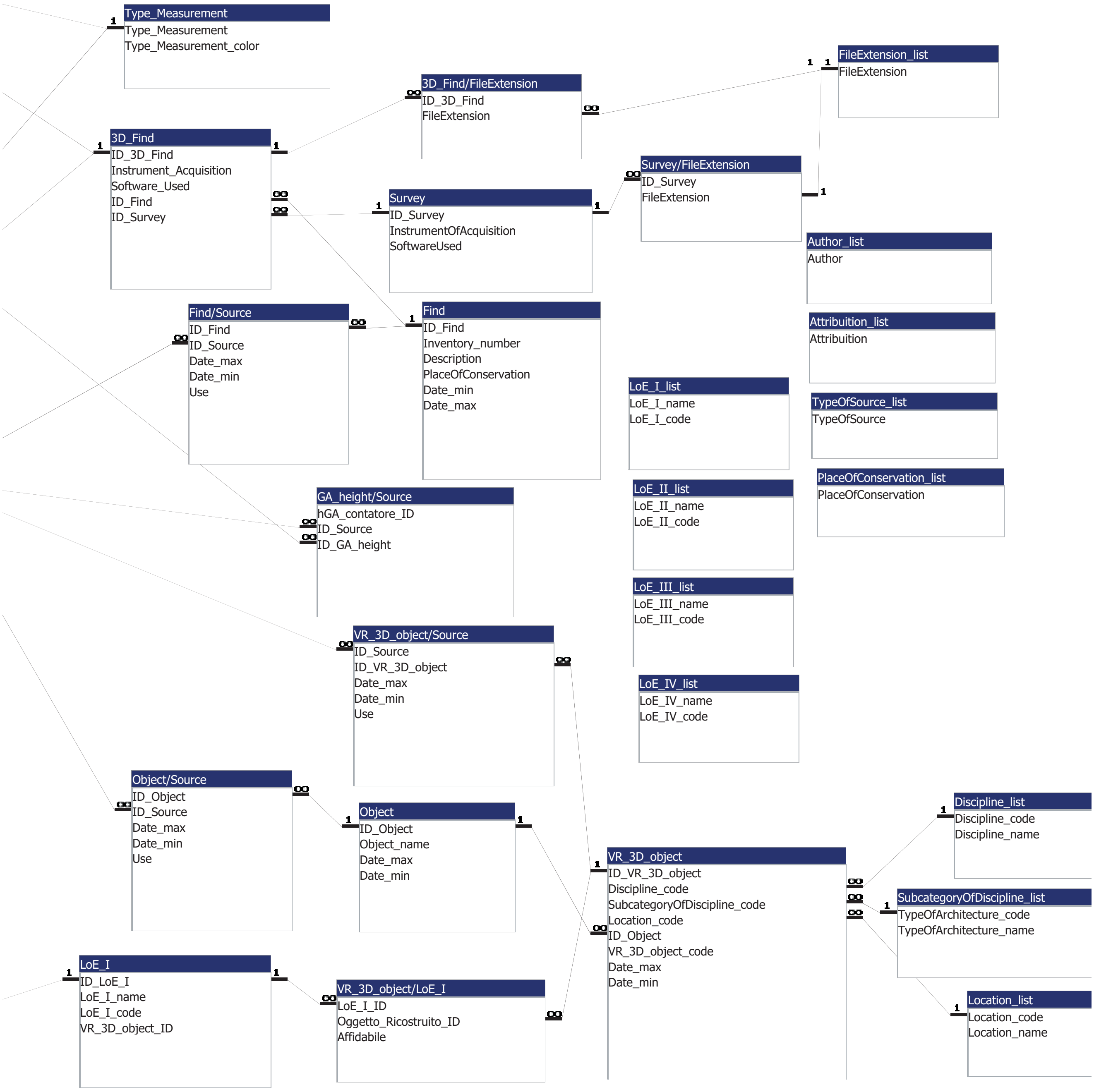

Measurements
ID_measurement
Base_Unit_measurement
Metric_measurement
Sub_unit1_name
Sub_unit1_value
Sub_unit2_name
Sub_unit2_value
Sub_unit3_name
Sub_unit3_value
Measurement
GA_width
ID_GA_width
ID_measurement
Use_GA_width
Type_Measurement_GA_width
ID_GA
ID_GA_Path
ID_3D_Find
GA_width/Source
wGA_contatore_ID
ID_Source
ID_GA_width
GA_height
ID_GA_height
ID_measurement
Use_GA_height
Type_Measurement_GA_height
ID_GA
ID_GA_Path
ID_3D_Find
GA_path
ID_GA_Path
GA_Code
GA_atom
height
width
GA_hypothesis
GA_sequence
ID_LoE_IV
Picture_Specifications
ID_Picture
Description
Negative
GA
ID_GA
GA_code
GA_atom
height
width
GA_hypothesis
GA_sequence
ID_LoE_IV
LoU
LoU
LoU_Description
LoU_color
Source
ID_Source
LoU
TypeOfSource
PlaceOfConservation
Author
Date_max
Date_min
Title
Image
Image.FileData
Image.FileFlags
Image.FileName
Image.FileTimeStamp
Image.FileType
Image.FileURL
Drawing_Specifications
ID_Drawing
Description
Dimension: Height
Dimension: Width
Dimension
Technique
Representation
Unit Scale
Graphic Scale
GA_path/LoE_IV
GA_path_ID
LoE_IV_ID
LoE_IV
ID_LoE_IV
LoE_IV_name
LoE_IV_code
LoE_IV_sequence
ID_LoE_III
LoE_III
ID_LoE_III
LoE_III_name
LoE_III_code
LoE_num_progressive
ID_LoE_II
LoE_II
ID_LoE_II
LoE_II_name
LoE_II_code
ID_LoE_I

Fig 16: *Relational DataBase Structure for manage Architectural virtual reconstruction data processes developed with Microsoft Access.*



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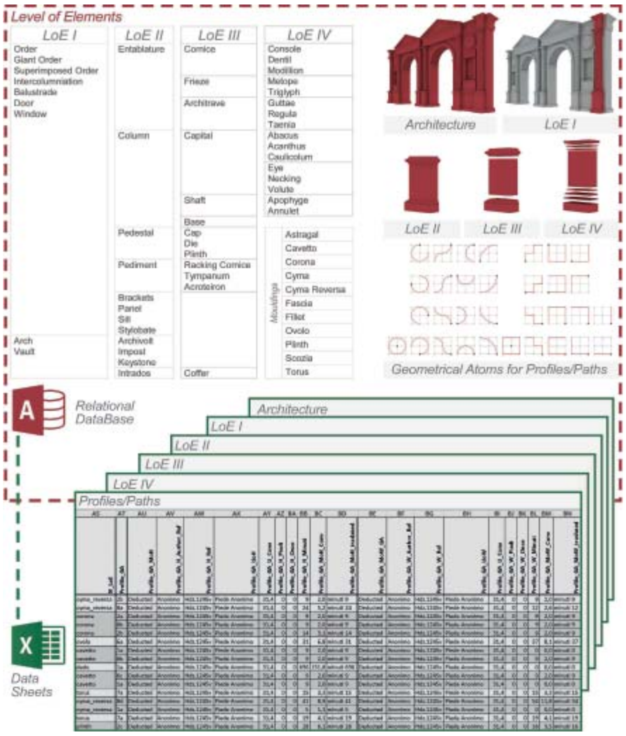
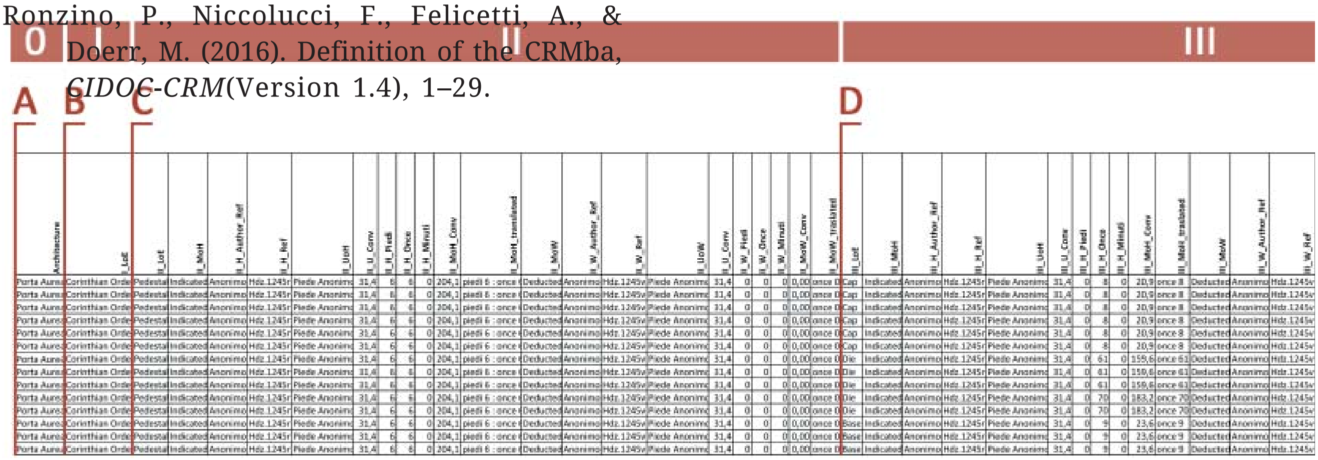
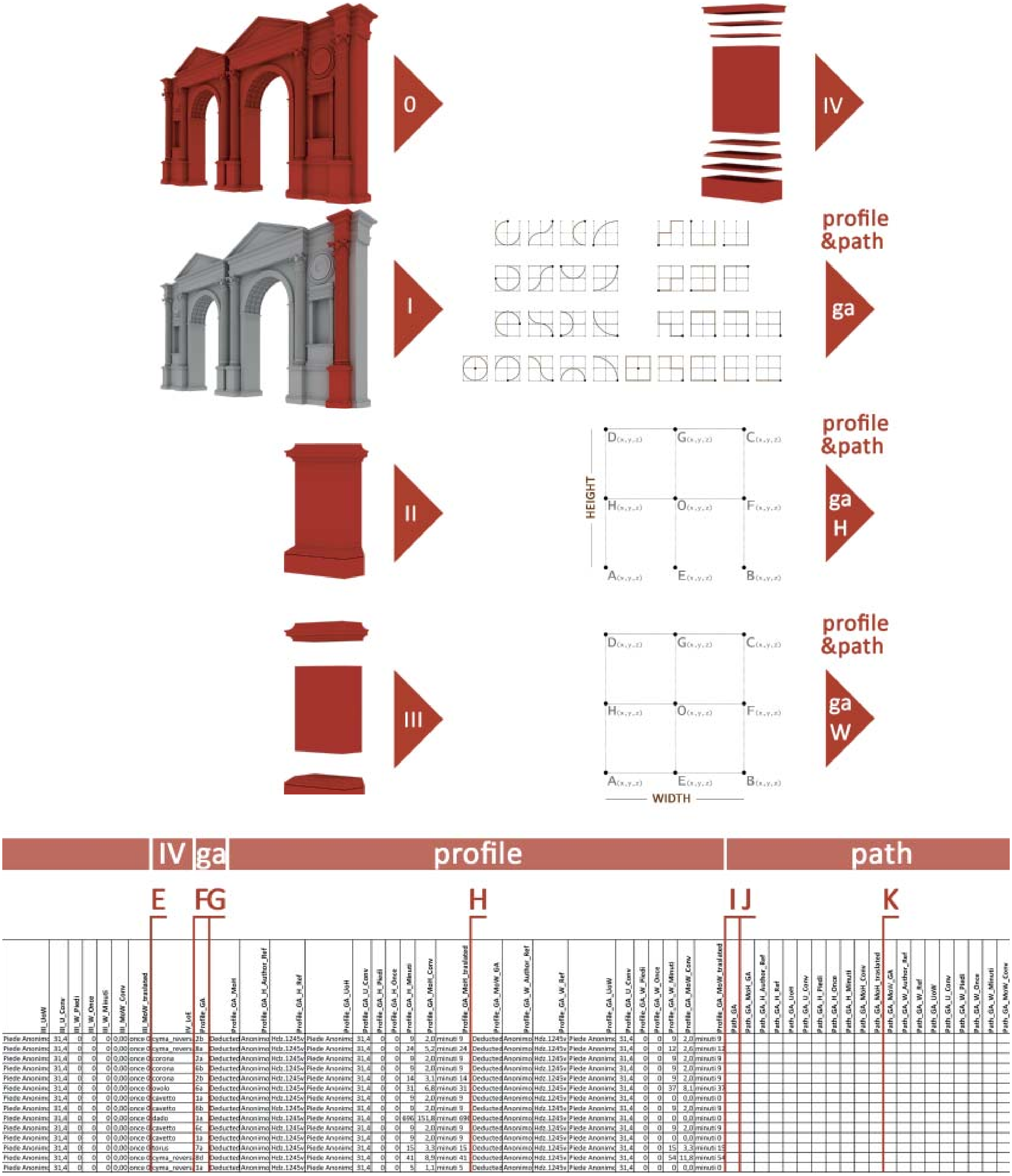


Fig 17:*Structure of Data Sheet comprehensive of all Level of Elements. Then the output of sheets from Query about profile and path.*




0
IV
I
profile
&path
ga
II
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K

4. Design Tools for parametric modeling

This chapter must be intended as a description of the automatic mouldings' profile generator from Excel to Revit via Dynamo Script.

The script can generate Classical Architecture Elements with a parametric approach that guarantees the possibility to re-use it for different 3d models and create built-in models.

Many scholars usually have a common approach to Classical Architecture based on making rules beyond the Orders definition as more straight as possible: as many famous and important architects did in the past. The role of teaching Classical Orders is used in Universities to teach a static and pre-determined method. But what happens when we need to approach to a real artefact? Model an existant piece or fragment of classical architecture is a difficult process where guidelines and workflows are still not really defined. To capture data is common to use laser or image based technology, then is also usual to create a mesh that could be more or less detailed.Finally, we can just have a copy of what was left from the past. Without any evidence, a 3d virtual reconstruction of buildings just designed or no longer existing, nor fully documented, the processes is still more complicated, and this is a reason why this script could help to create different and various 3d modelled hypothesis starting from the analysis of acquired data and focusing the modelling approach on mouldings dimensions.

The other purpose of the script is to reduce the time of modelling, using a limited set of algorithms in order to create multiple possibility of representation.

VRIM Scripting workflow

The general workflow that is used provides the following steps:

1. Exporting Datasheets from the VRIM database with information related mouldings and Geometrical Atoms that compose them.

2. Running the dynamo script. This with automatically create ad-hoc families of mouldings in Revit.

3. Adding Parameters and populate 3D model with information about virtual reconstructions processes

This script is created to automatize the creation of Profile Mouldings Families from an excel sheet (exported from VRIM Database created in excel) to Revit environment. The aim is creating Revit Families with the possibility to set the Virtual Reconstruction Information Management as parameters on Revit Parameter Tab. The script allows to create different designed hypothesis for virtual reconstructions and allows the re-use of families on different projects.

This script should be utilized first in a test environment and then on a live project. Then, the setting of the excel sheet should exactly follow the sequence described on VRIM Dataset Sheet.

VRIM scripting

According to the proposed workflow, Dynamo Studio is used to model profiles of mouldings of Classical Architecture. Office Excel is used to set the Dataset Sheet of different hypothetical reconstructions. The

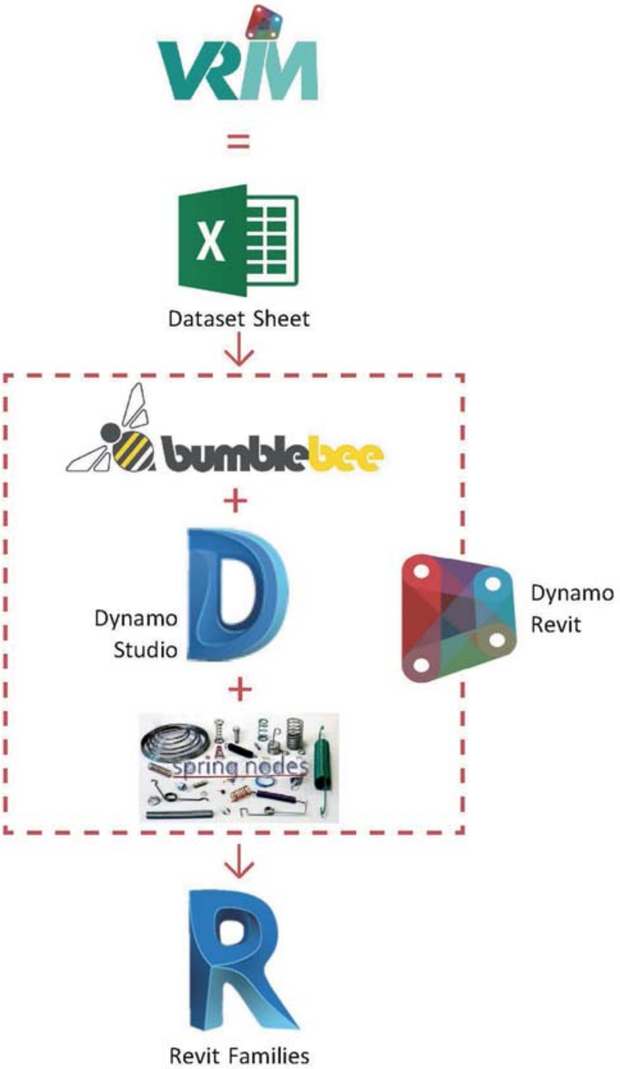


Fig 18: *VRIM Scripting flowchart with software involved in the developed of algorithms and scripts*

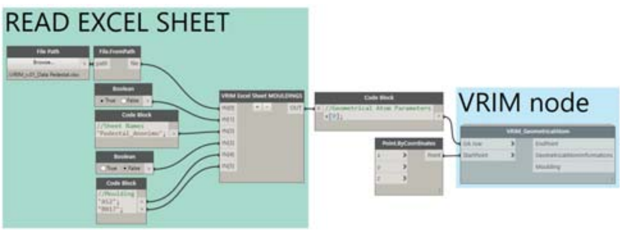


Fig 19: *VRIM FunctionNode (right) connected with a BumblebeeNode (left) used to read excel files*

Bumblebee package for Dynamo is used for interoperability between software below. The set of nodes developed for the VRIM Dynamo Package were designed using Code Blocks following Dynamo Language Manual.

The script consists of 3 parts:

- Input where is used BumbleBee Package
- VRIM nodes developed using Code Blocks
- Create Revit Families using Spring Nodes Package

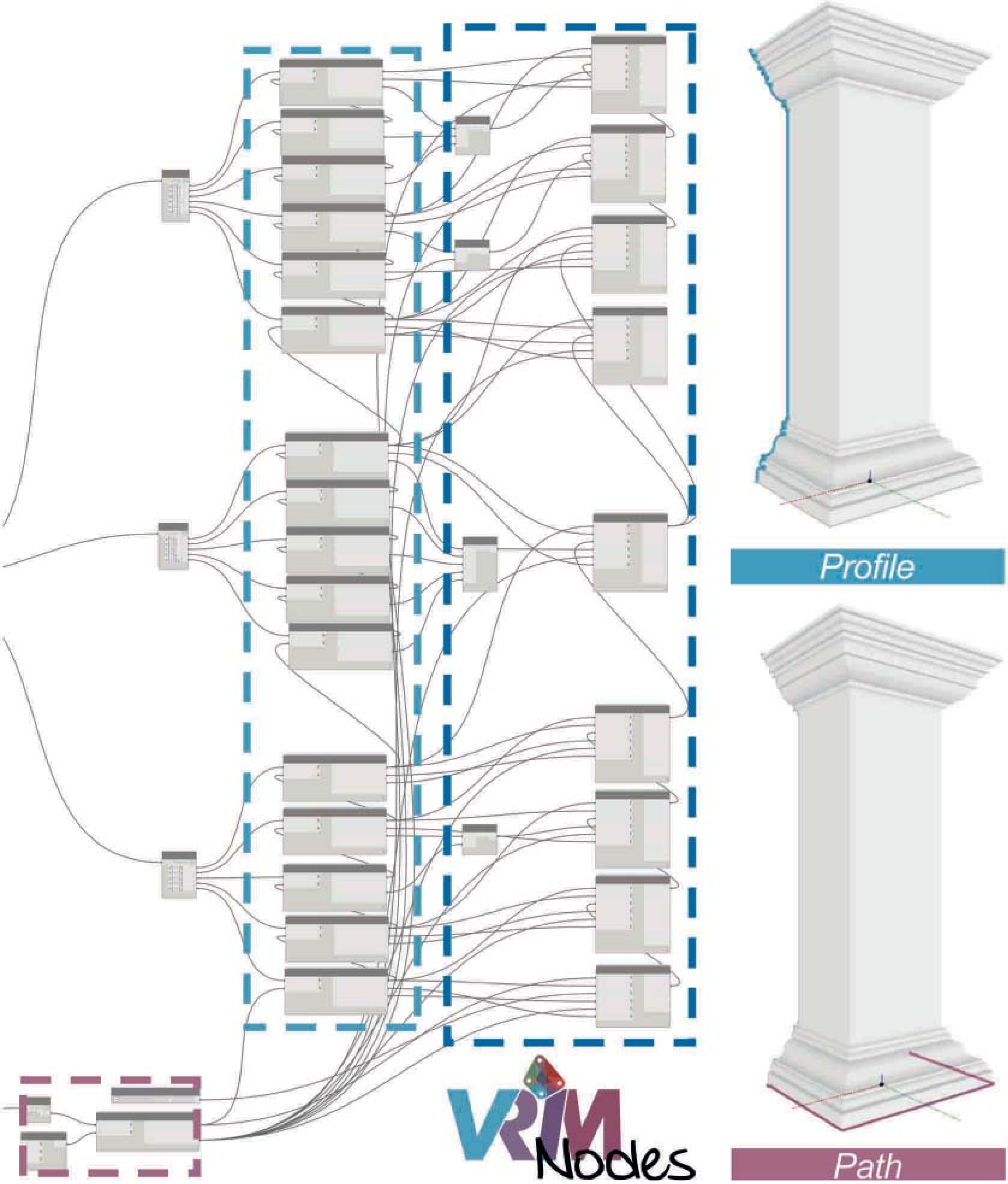
To summarize the process, it is possible to say that the dataset used is composed by a set of .xls files with Information related to geometric atoms, measurements of height and width and other levels of information. The Bumblebee “Read from File” node can read the datasheet into Dynamo platform where VRIM nodes create solid geometries of a sequence on mouldings. For each solid a Revit Family is created using of Spring Nodes series.

The script was entirely developed using the following version of software:

- Revit 2017 v. 17.0.416.0
- Dynamo Revit v. 1.1.1.2444
- Dynamo Studio 2017 v. 1.1.0.2093
- To develop the script the nodes used are the follows:
- “Read Excel” from BumbleBee package v. 2016.9.7
- “Springs.FamilyInstance.ByGeometry” from Spring Nodes package v. 100.0.1
- VRIM nodes

In Dynamo, Nodes are objects that can perform operations. Inside Code-Block nodes it is possible to store algorithms, instances that produce output from a given input.

Algorithms in VRIM nodes were created to automatize the generation of Profiles and Paths to generation of mouldings objects. The SQL queries in the database allow to extrapolate a set of data and create data sheets (.xls format) that can be used as input values of VRIM nodes.


VRIM Nodes
Profile
Path

Three different nodes were developed for the script such as the following:

- VRIM_xz
- VRIM_xy
- VRIM_solid

The algorithm inside VRIM zx/xy nodes was developed with the aim to create geometrical primitives that generate a moulding object.

The methodology follows a set of previous knowledges related to classical architecture and a generic formalism for the semantic modelling and representation of architectural elements. (De Luca, Véron, & Florenzano, 2007)

A set of 32 geometrical atoms was created using Dynamo textual programming and an alphanumerical code was associated to each one. Each geometrical atom is built on a deformable 9-point grid with a specified coordinate system orientation. The grid could be considered as a deformable bounding box ,where height and width are mutable. The profile and path of a solid 3D model of a moulding can be made by a single atom or by a sequence of atoms connected.

The necessity of working in different plans for profiles and paths is the reason why VRIM nodes are designed for both geometric definitions (profile/path).

The VRIM_solid node creates a solid by sweeping operation using Path and Profile. The sweep requires a close profile; for that reason the script included a code that close a series of geometrical atoms into unique profile or path.

Finally, the solid could be converted into a family using Dynamo Revit software interface and Spring Nodes, allowing to continue populating and managing information related to virtual reconstitution processes and others.

Dynamo visual programming environment

The Dynamo textual language (formerly DesignScript) has been created to express design intentions.

Text blocks inset in the SourceCode font should be pasted in a Code Block node, then, the output of the Code Block should be connected with a Watch node in order to see the result. Images are usually included in the right margin, illustrating the correct output of the program.

Every script is a series of written instructions that is usually first "commented" with two forward slashes, // that makes the node ignore everything written after the slashes.

The VRIM script for nodes is composed by a 9 points grid.

9 points grid

To create a deformable 9 points grid I assigned a letter for each point from A to H and i assumed the central one as O. The grid is the base of the constructions of Geometrical Atoms of Classical Architecture.

During this first steps, it was preferable to work into XZ System Workspace so It was assumed y=0. Because Dynamo allows to model directly on 3D Workspace and the Atoms correspond to geometrical parts of the profile of mouldings, profile is place on XZ plane instead of the rail profile (path) that is based on the XY plane. Assuming the point grid statement, the other important thing to define is the coordinate system for each element. The coordinate system for each Atoms also defined the anchor point called StartPt. The EndPt is the last point of the curve or Polycurve that defines the geometry. The profile is a succession of these Atoms, anchored by their Start Points and End Points.

The deformability of the points grid is defined by the coordinate system and how its works with Input Data.

The Input Data correspond to available information concerning the "Bounding Box" measures. In this way, each Atom is placed in the workspace with initial coordinate (x,z) called H0 and W0 and the others two measures

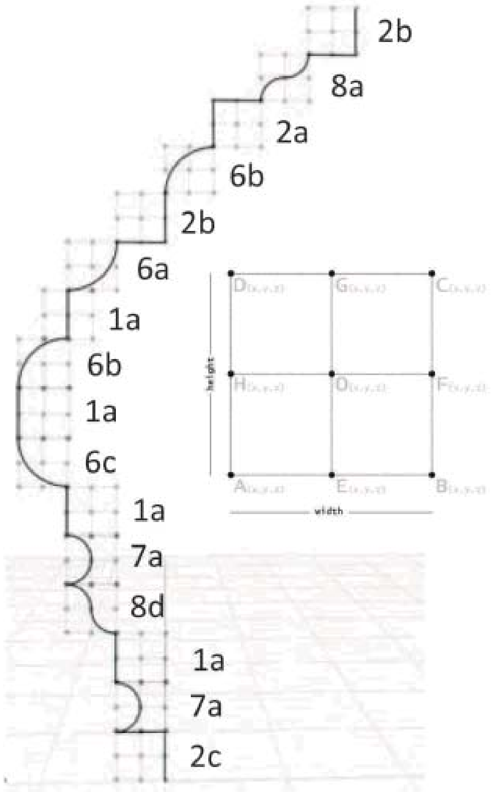


Fig 20: *Sequence of geometrical atoms with default values of height and width*

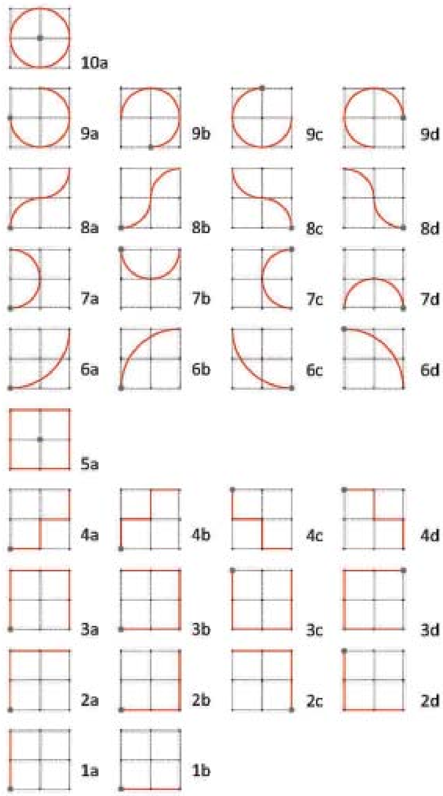
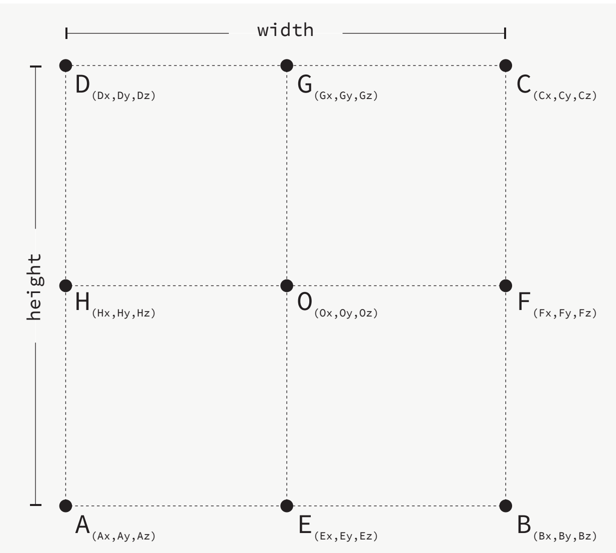


Fig 21: *List Of Geometrical Atoms according with De Luca et. al (2007)*



Code 1: *9 points grid and its points definitions*

```
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

Code 2: *9 points grid - Profile*

```
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

Code 3: *9 points grid - Path*

of Height and Width of the Bounding Box called H1 and W1.

To define the geometry of each Geometrical Atom is necessary to set a 9 point grid defining each three dimensional point specified by x, y, and z Cartesian coordinates, declaring the coordinate system and finally setting the input values.

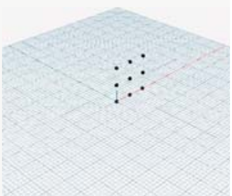
The possibility to view information about virtual reconstruction process levels is provided (LoE, LoM, LoU, LoR).

The VRIM_solid node creates a solid by sweep operation, using Path and Profile. The sweep requires a close profile; for that reason the script included a code that closes it.

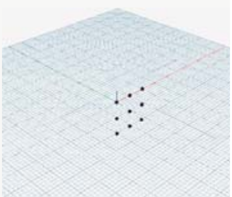
Finally the solid could be converted in a family using Dynamo Revit software interface and Spring Nodes.

To summarize the process, it is possible to say that the used dataset is composed by a set of .xls files with Information related to geometric atoms, measurements of height

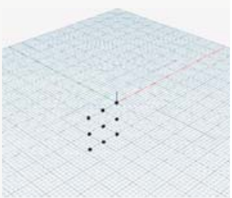
```
//Coordinate System (x,z)

Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;
```



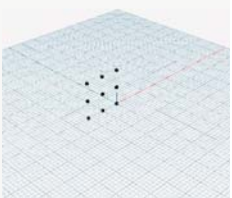
```
//Coordinate System (x,-z)

Ax = W0;
Az = H0-H1;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0-(H1/2);
Dz = H0;
```

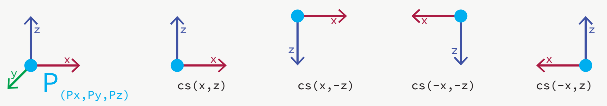


```
//Coordinate System (-x,-z)

Ax = W0-W1;
Az = H0-H1;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0-(H1/2);
Dz = H0;
```



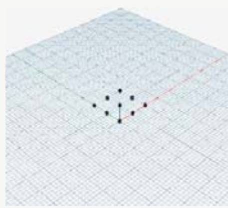
```
//Coordinate System(-x,z)

Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;
```



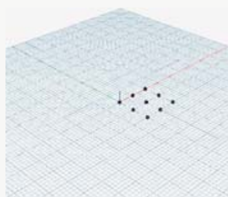


Code 4: *Coordinate Systems xz oriented*
a) cs (x, z); b) cs (x, -z); c) cs (-x, -z); d) cs (-x, z)

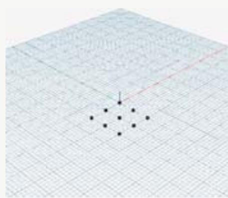
```
//Coordinate System (x,y)

Ax = W0;
Ay = H0;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0+(H1/2);
Cy = H0+H1;
```



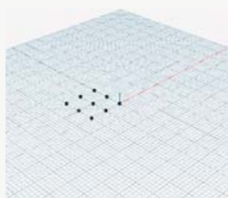
```
//Coordinate System (x,-y)

Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;
```

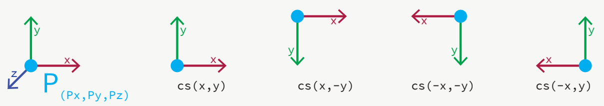


```
//Coordinate System (-x,-y)

Ax = W0-W1;
Ay = H0-H1;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0-(H1/2);
Cy = H0;
```



```
//Coordinate System (-x,y)

Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;
```





Code 5: *Coordinate Systems xy oriented*
a) cs (x, y); b) cs (x, -y); c) cs (-x, -y); d) cs (-x, y)

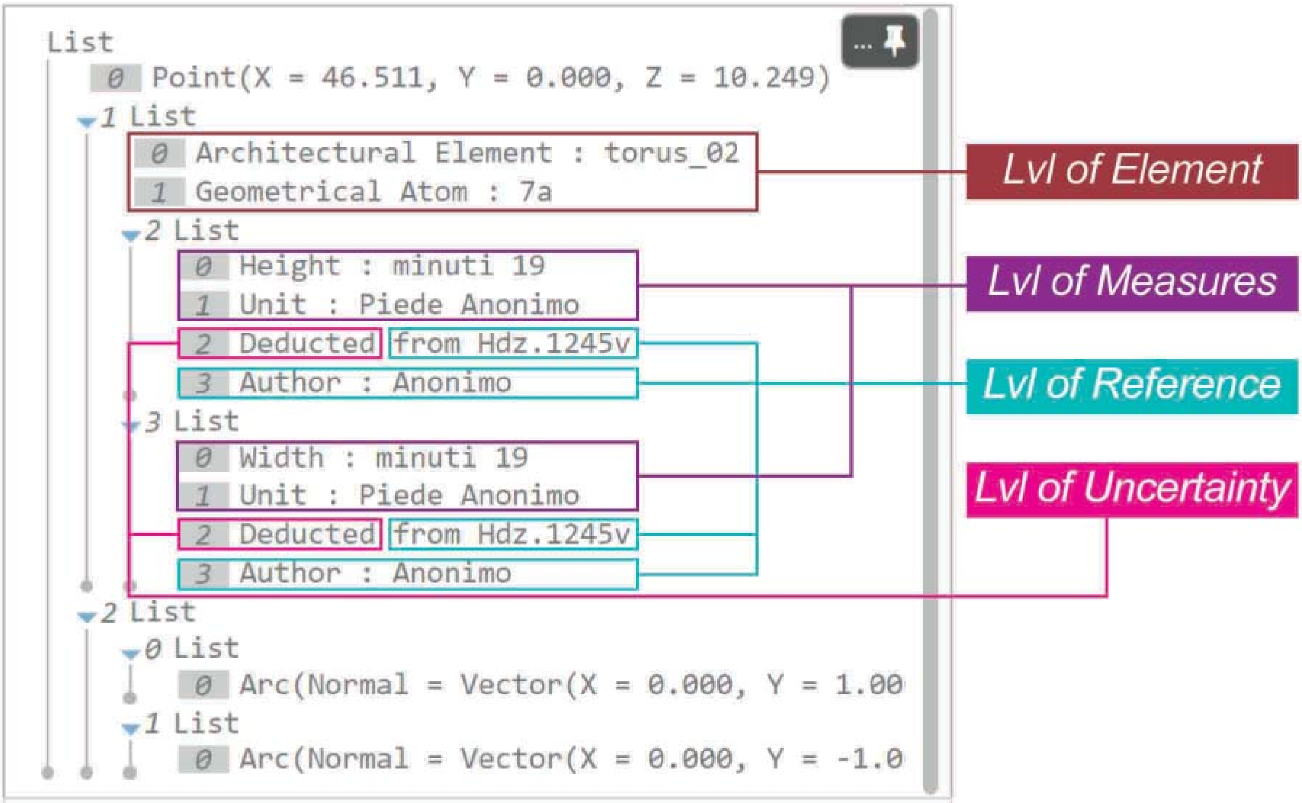


Fig 22: *Level of Knowledge Visualization inside the VRIM node*

and width and other levels of information.

- Experimental Results and future works

As first methodological tests were used data from reconstructive hypothesis of the Porta Aurea in Ravenna. For the test were considered the drawings produced by Anonymous Berlin taking as case study the pedestal of the Corinthian Order. The drawings were analysed individually and information concerning the interpretation of the form (moulding) and geometry (set of geometric primitives) have been entered in a VRIM Data Sheet. The sequence of internal instructions of the algorithm used data from VRIM Data Sheets as input data and it created families in BIM environment. The set of references and documentary sources will allow to test how effective the VRIM workflow work. The intention is to explore the theme of subjective processes and their management trying to bridge the gap between the source data and associated interpretations using BIM platform.

Bibliography

De Luca, L., Véron, P., & Florenzano, M. (2007). A generic formalism for the semantic modeling and representation of architectural elements. *Visual Computer*, *23*(3), 181–205. https://doi.org/10.1007/s00371-006-0092-5

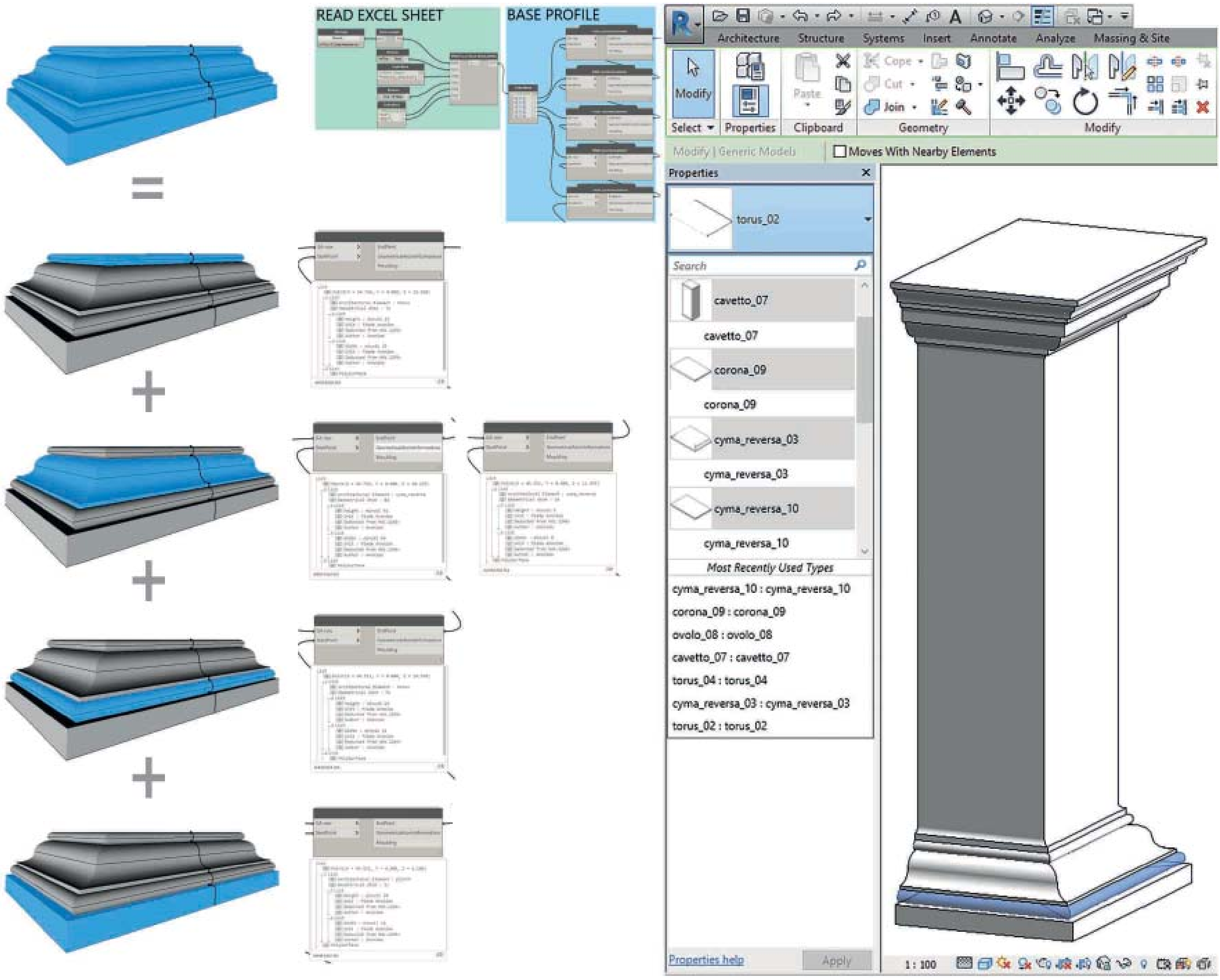


Fig 23: *Pedestal of Porta Aurea BIM families into Revit enviroment using Dynamo scripting*

3 Porta Aurea: a case study

Porta Aurea in Ravenna always aroused the interest of many scholars and archaeologists. Despite today the Roman gate is a no longer extant monument, many Renaissance representations -that handed down the original architectural appearance -,and which had also been the object of large studies by H. Kahler (1935) and G. Rosi (1939)-are still known. In 1986 G. Tosi made a deep examination of the metrological information of the Renaissance drawings by Andrea Palladio preserved at Royal Institute of British Architecture and that are unknown by previous scholars.

In the first Part of the Chapter the Case Study follows these steps:

- Data Collection & Data Acquisition
- Data Analysis

The Second Part of the Chapter is related to

- Data Interpretation
- Data Representation

The Second Part describes the evolution of process related to Interpretation and Representation of Porta Aurea in Ravenna.

At the beginning, the 3D model was firstly made using Rhinoceros, and all information related to the process are described for each Element.

In this case ,all information are not organized and not clear to understand without a critical approach. The use of 3D modelling software guarantees a fast modelling phase ,but it's not possible to use the same software to visualize or store data related to the reconstruction process.

To conclude, the use of the Dynamo package to model the Pedestal could be a better solution to model architectural elements and ,at the same time, to be able to store much more information, with a better transparency and with a visual approach too.

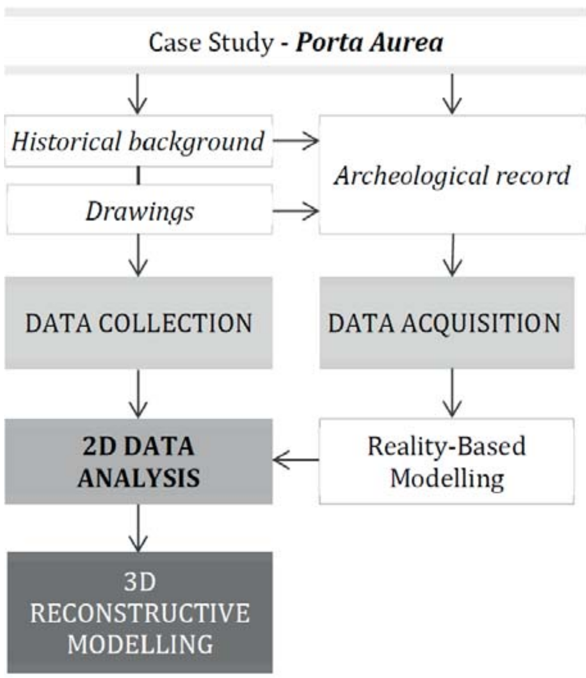


Fig 24: *Diagram of the reconstruction process for Porta Aurea in Ravenna*

1. Virtual Reconstruction processes

Collection & Acquisition

Collection

Historical Background

Porta Aurea is probably the most ancient Roman gate in the city of Ravenna. Nowadays, ruins are still evident on Via Porta Aurea ,where the gate once stood. Like other ancient oppida municipali (fortified cities) Ravenna had a quadrangular perimeter. The Decumano stretched from Porta Aurea along the Via Popilia, an ancient Roman road which started at the Roman settlement of Ariminum (Rimini), and led to the city of Aquileia, passing through Ravenna.

Throughout its history ,the gate has been known with various different names, such as Asiana, Aziana, Pinciana, Pinziana, Dè Pizzi, Dè Pizi, Dè Pici, Speciosa and Trionfale. (Zirardini, 1762)

During the early fifth century, the capital of the Western Roman Empire was transferred from Milan to Ravenna, following the decision of Honorius, who promoted a new urban growth. The gate was given the name of Aurea due to its magnificent ornamentation and use of marble.

As for the date of its original construction, one refers to an inscription bearing the words: "TI CLAUDIUS DRUSI FIL CAESAR AUGUSTUS GERMANICUS PONT MAX TRIB POT II COS II DESIG III P P DEDIT". The conclusion shared by scholars(Biondi, n.d.)(Rossi, 1572) is that Porta Aurea was built by Tiberius Claudius, the fourth Roman emperor, probably in the first century: they both believe it to be likely that not only Porta Aurea (but also the walls of Ravenna) were built or, instead, rebuilt by the same emperor. It is also believed that its construction is attributable to the commemoration of the victories in the Roman expedition against the British Isles, in the 796- 797 ab urbe condita (43 AD). Even if on a report Domenico Maioli quotes Regoli that says that the city gate was erected in the year 795 ab urbe condita (42 AD), the first date is the most accredited by historians. (Novara, 2002)

Porta Aurea was much afflicted by vicissitudes of misfortune throughout its history (Timeline). In 1241, it was deprived of stones and marble slabs by Frederick II, the Holy Roman Emperor, and thereafter passed into an increasingly ruinous state.(Rossi, 1572)

The City Council later expressed the will to restore it to its former brightness, as witnessed by various archival sources; proposing in 1522 to expose it from the ground which had, by now, rendered it partially hidden; eighteen years after the Prior of Canonica di Porto, Francesco of Vicenza, sought to have it dismantled piece by piece, and rebuilt elsewhere. The demolition of its ruins finally came about in 1582 at the hands of Cardinal Guido Ferreri who used the material to embellish other buildings (Kähler, 1935).

Drawings and Sketches

One of the earliest representations of Porta

Aurea appears in a seal dating back to the fifteenth century, which depicts the door inside of two circular towers , and reveals how the structure, crowned by pediments was most likely made up of three more levels above (Timeline – 1472).

Proof of its ruinous state in the early sixteenth century can be seen in the pictorial transposition make by Falconetto, to the "sign of Cancer" of the Zodiac Room at Palazzo d'Arco in Mantua (Timeline - 1520). The earliest representation of the raised structure and details were published by Giovanni Battista da Sangallo (Timeline - 1526).

Porta Aurea is described as a double-fronted structure characterized, on the front façade, by a double archway with pointed arches, each one framed by two columns with Corinthian capitals half-supporting the entablature. On both sides, always within half-columns, there are niches that are topped with medallions. Sangallo shows us the inscription (as quoted above) as it appears in the frieze of the entablature. The drawing shows a quite schematic layout, accompanied by some key measures, while the drawings provide details. The prospectus is full of important notes about the various parts as well as the state of preservation of the monument as a reference to the sign that indicates the water-level of the moat built in the Middle Ages around the city walls (Vasori, 1981).

On the way to Rome, in 1545 the convoy of Trissino stopped in Ravenna (Zorzi, 1959) and on this occasion Andrea Palladio measured and sketched the monument.

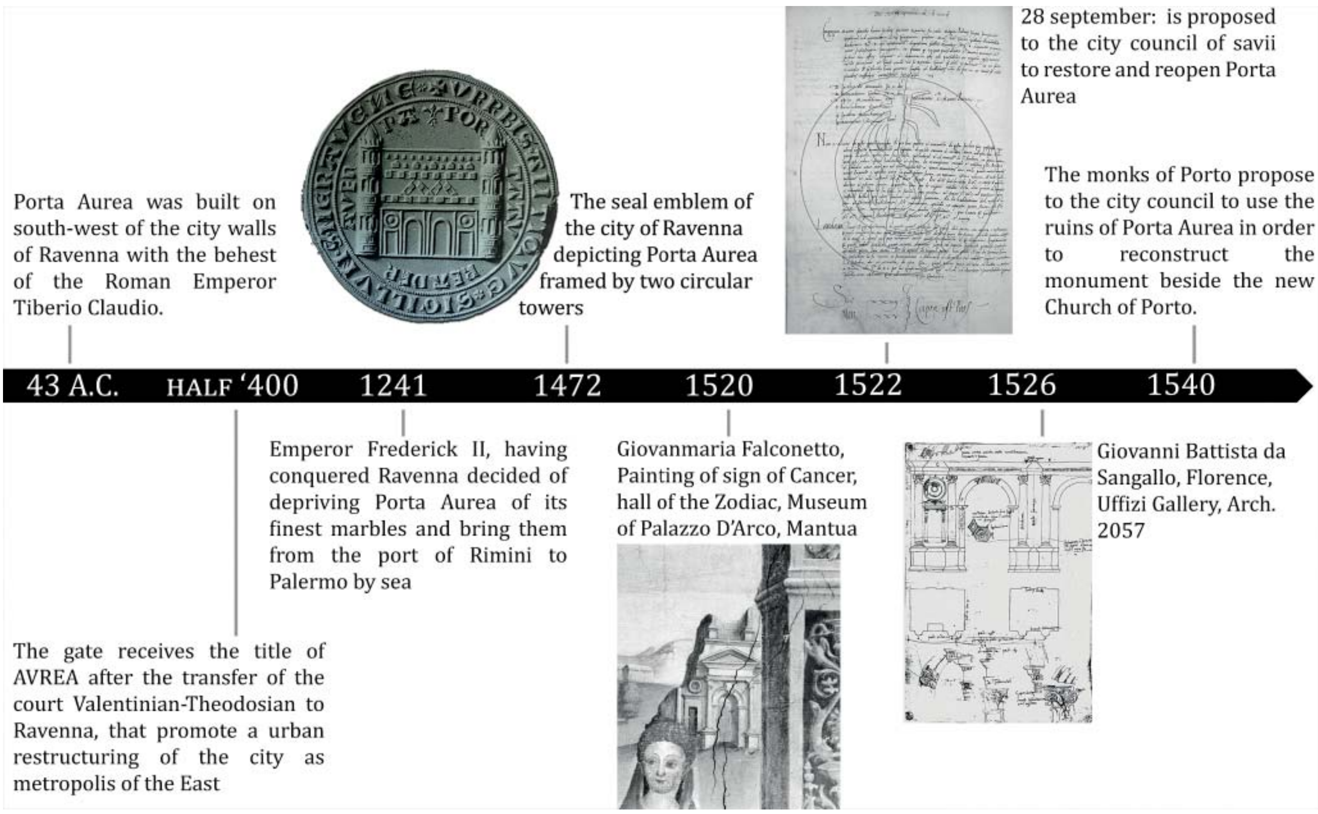
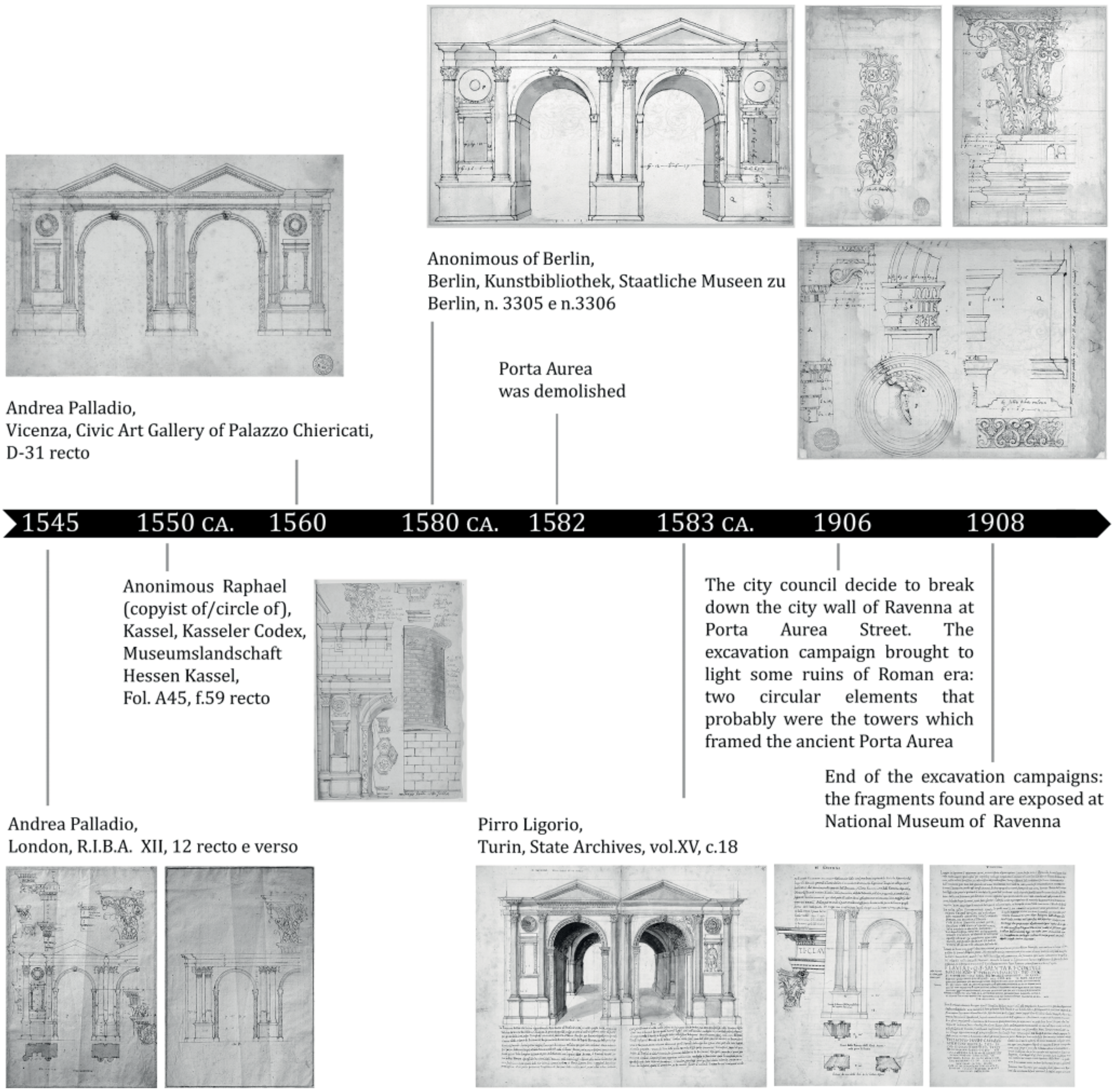
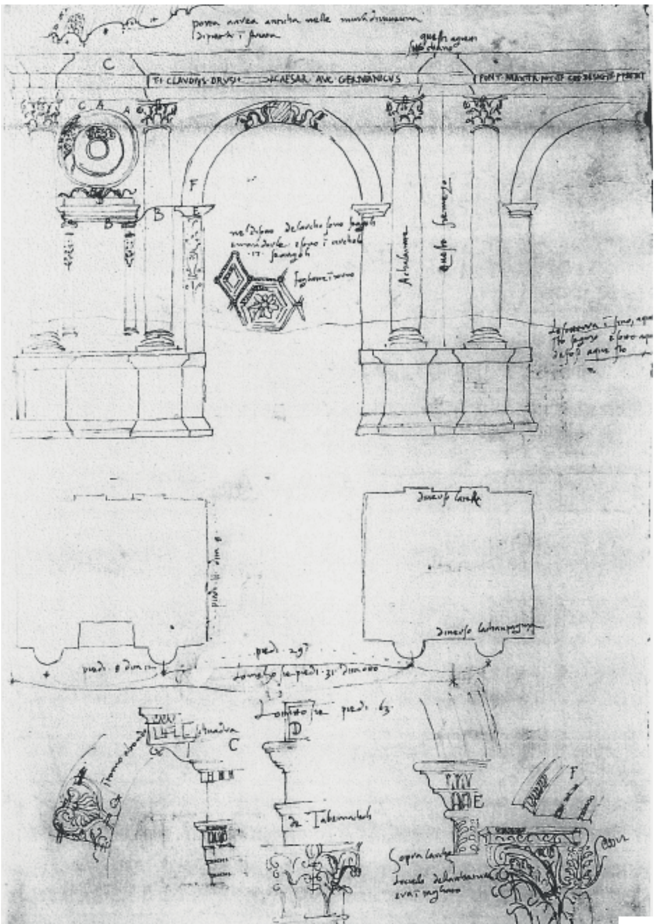


Fig 25: *Timeline about Porta Aurea*

In the drawings-that are now preserved in London- (Timeline - 1545) the two fronts and the layout with the main measurements are illustrated in detail as well as drawings of individual architectural details.

A second drawing, held at the Civic Museums of Vicenza (Timeline - 1560), considered to be the work of Palladio by Howard Burns (1973), only represents the side facing the city. According to Puppi , this drawing (1995) goes back to a more mature period of the author and was probably designed for translation





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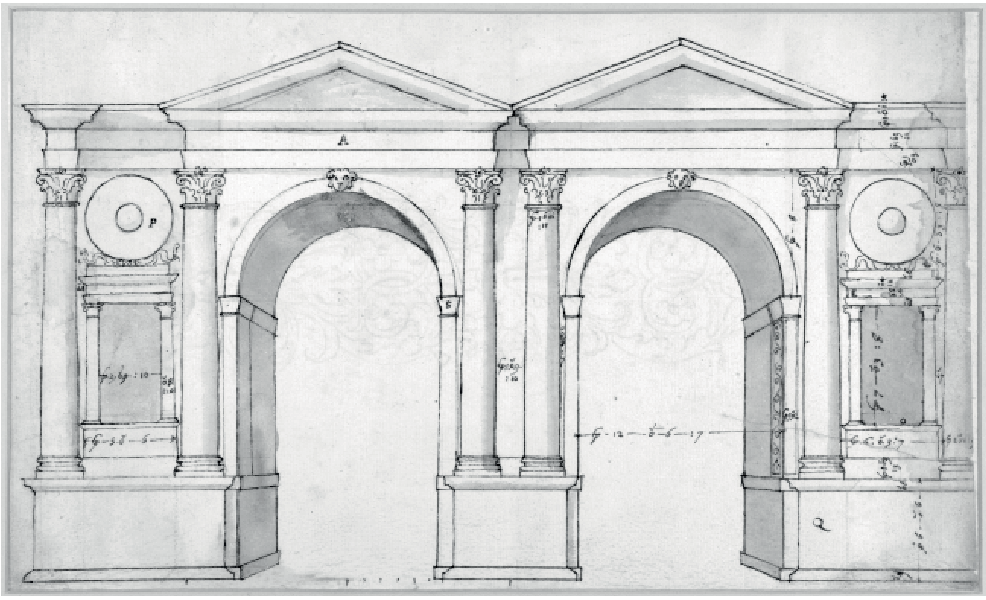

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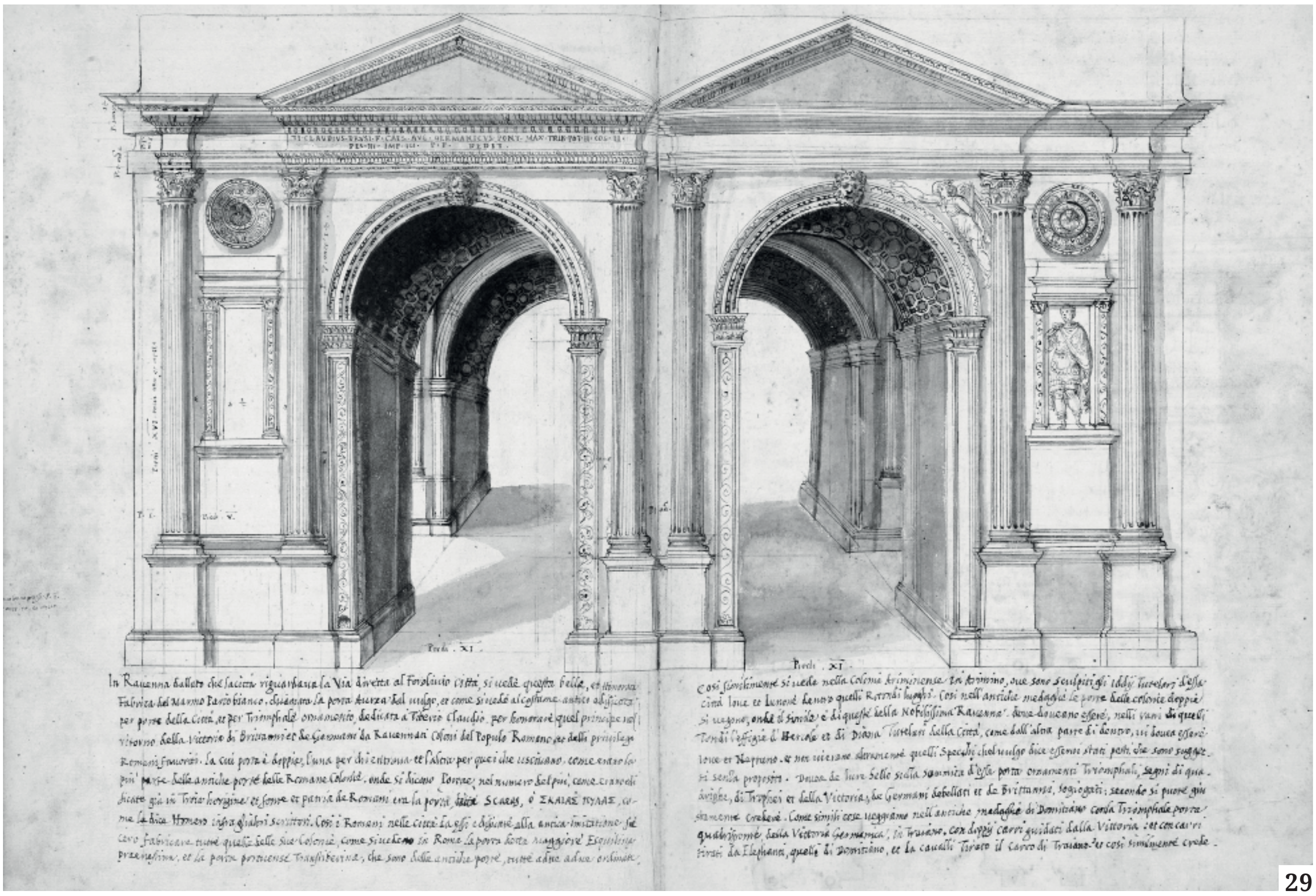

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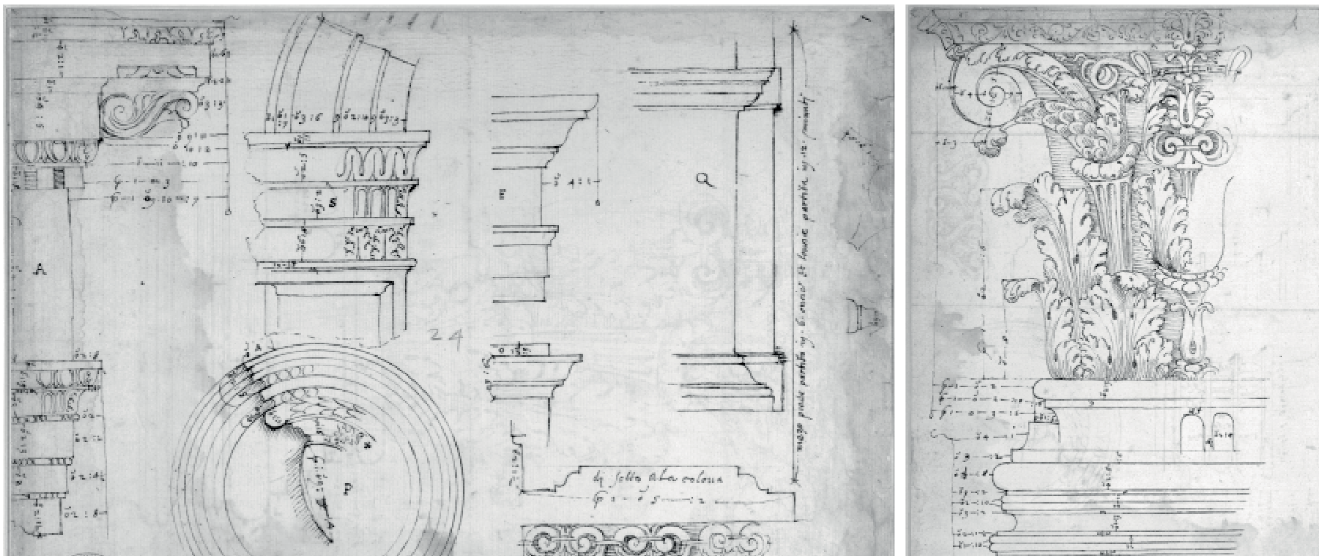

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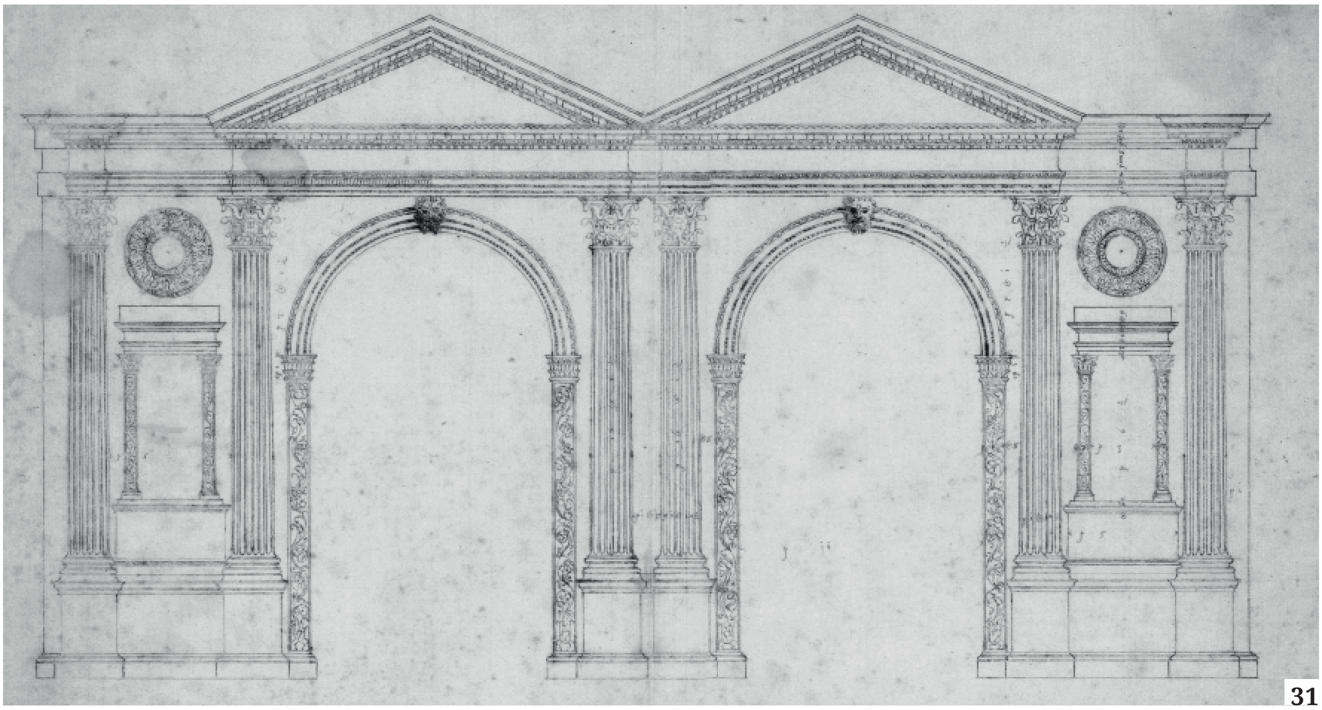
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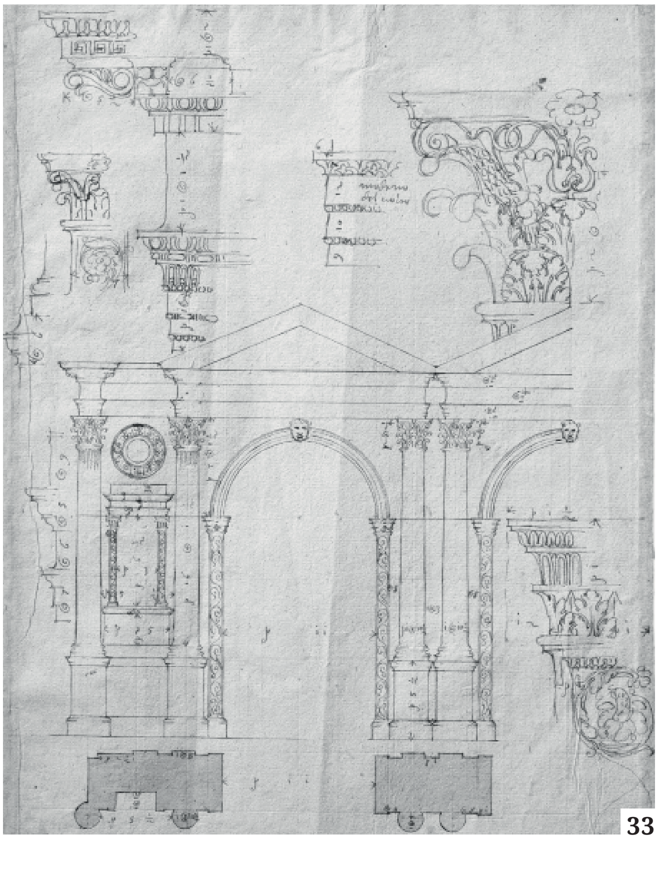
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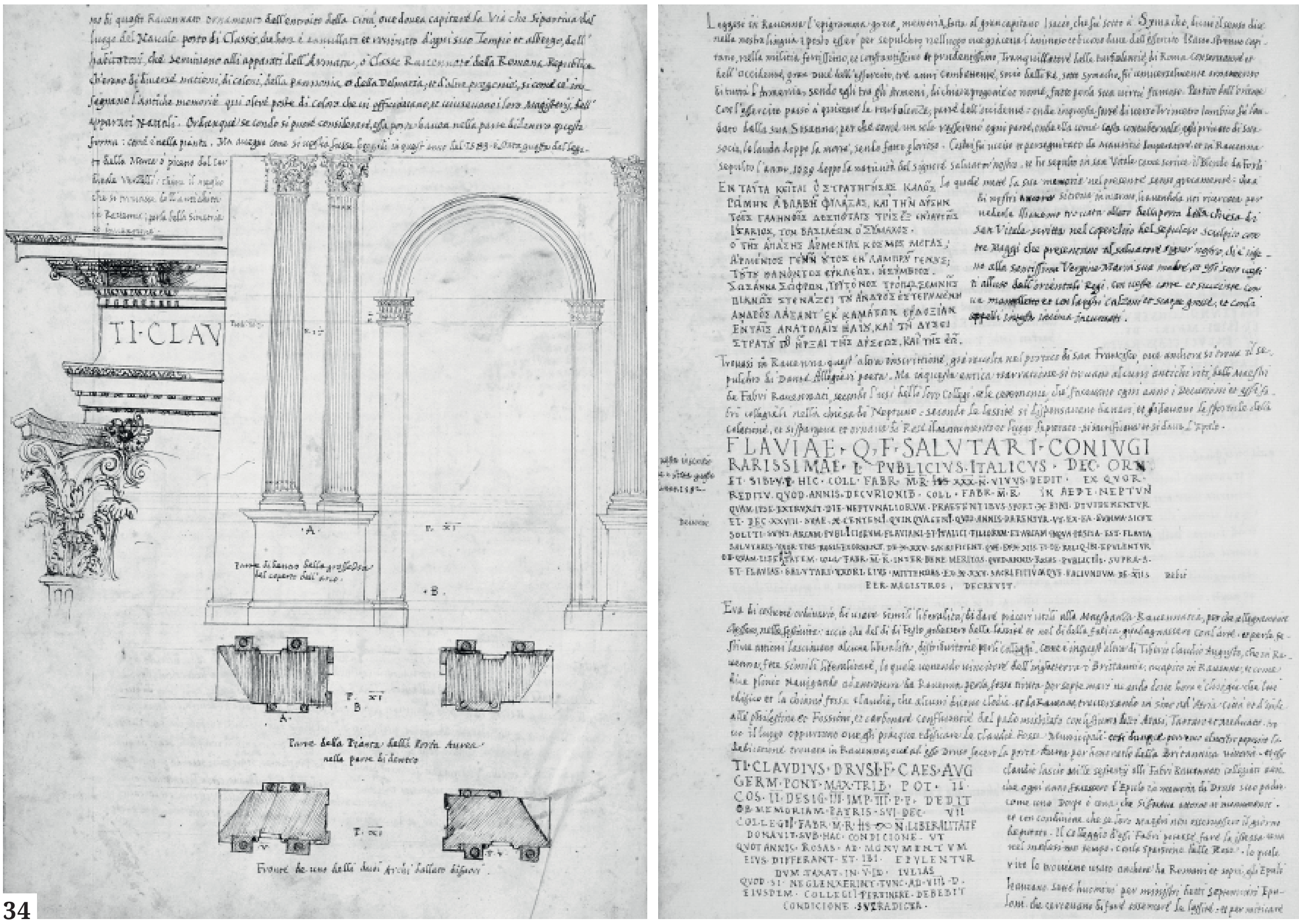

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Fig 26: *G.B. Da Sangallo, Inv. Arch. 2057, Florence, Uffizi Gallery*

Fig 27: *Anonimous Raphael (copyist of/circle of), Fol. 45 f.59 recto, Inv . Nr. GS 9638, Kassel, Kasseler Codex, Museumslandschaft Hessen Kassel,*

Fig 28: *Anonimous of Berlin - Hdz. 1245 r/v, Berlin, Kunstbibliothek - Staatliche Museen zu Berlin*

Fig 29: *Pirro Ligorio - ms. a.II.1 (vol.14) - [c. 14v - c. 15r] in "Roman Antiquities", Turin, State Archive*

Fig 30: *Anonimous of Berlin - Hdz. 1246 r/v, Berlin, Kunstbibliothek - Staatliche Museen zu Berlin*

Fig 31: *Andrea Palladio, Inv. D 31, Vicenza, Civic Art Gallery of Palazzo Chiericati*

Fig 32: *Andrea Palladio, Ref. No. RIBA31822: SC220/ XII/12v, London, R. I. B. A.*

Fig 33: *Andrea Palladio, Ref. No. RIBA31821: SC220/ XII/12r, London, R. I. B. A.*

Fig 34: *Pirro Ligorio - ms. a.II.1 (vol.14) - [c. 15v - c. 16r] in "Roman Antiquities", Turin, State Archive*

in print.

Another quite interesting sketch, never mentioned in previous studies on the Porta Aurea is located at Hessen Museumslandschaft Kassel, within the codex of Kassel, in turn, part of a book of fragmentary drawings by an unknown author. Arnold Nesselrath (2002) believes that the document can be attributed to a copyist of Raphael or a member of his circle is to be dated no earlier than the fourth decade of the 1500s. The special feature of this representation, albeit without any indicative metric, is the deliberate intention to describe the urban context (Timeline -1550 ca.). On the left-hand side, Porta Aurea is incorporated inside buildings, as for example, Porta dei

Borsari in Verona.

Of uncertain date -but probably contemporaneous with the previous drawings – there are 4 eidotypes by an unknown artist, better known as Anonymous of Berlin. These are stored at the Kunstbibliothek - Staatliche Museen zu Berlin, and represent meticulously listed architectural details, the capital and the decoration of the pillar (Timeline - 1580), in addition to the representation of the external front with letters in reference to details.

In “Roman Antiquities” (volume XV2) the author P. LigorioIV also writes about the city of Ravenna. In this case, an accurate description of Porta Aurea was given with an accompanying graphic of a perspective view of the external front of the Gate, the layout and the entire front facade (Timeline - 1583 ca.).

Scholars agree that Ligorio reworked the instructions contained in the drawings of the London Palladium. The only discrepancy is the representation of the plan where the author suggests a typical of cisalpine Roman city gates – monumental architectural construction that marked the entrance to the city, consisting of an inner and outer gate separated by a courtyard and flanked by symmetrical towers. Ligorio can be considered the last direct witness of the monument.

Archaeological excavation campaign in the IXX sec.

In May 1906, the city council decided to knock down the city walls of Ravenna at Via Porta Aurea, as the fee to enter the city had by then been abolished.

The excavation campaign (1906-1908) brought to light some ruins from the Roman era: two circular elements that were probably the towers which framed the ancient Porta Aurea and other marble architectural fragments.

Finally, there is an extensive collection of survey drawings of the walls, never


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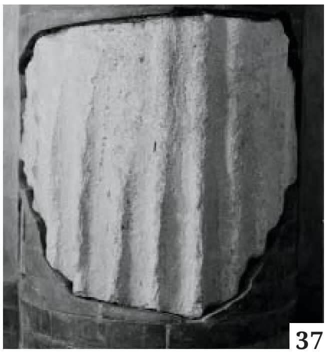
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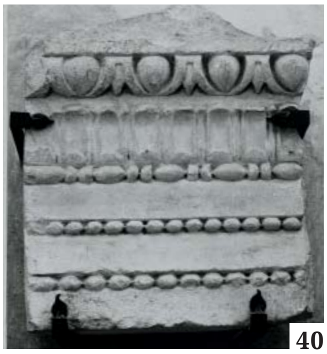
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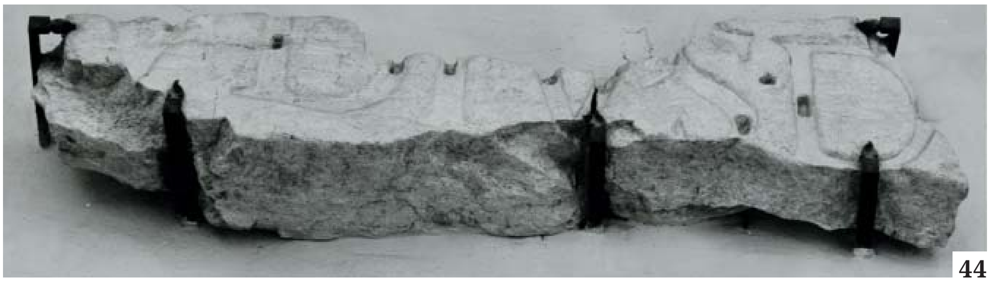
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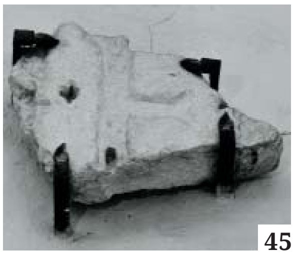
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Fig 35: *medallion, Inv.293*
Fig 36: *medallion, Inv.292*
Fig 37: *detail of half-column with grooves, Inv.295*
Fig 38: *corinthian capital of the half-column, Inv.296*
Fig 39: *part of the archivolt, Inv.297*
Fig 40: *part of the entablature, Inv.302*
Fig 41: *decorative element of a pillar, Inv.309*
Fig 42: *fragmentary portion of the Corinthian capital, Inv.307*
Fig 43: *element of the column of the recess, Inv.308*
Fig 44: *fragments of letters of inscription, Inv.299*
Fig 45: *fragments of letter "E" of inscription,Inv. 300*
Fig 46: *part of the column base of the recess, Inv.304*

All inventories numbers are referred to archaeological inventory held by Ravenna National Museum

Fig 47: *Archeological evidences of the east tower in "Ravenna: Piante panoramiche", G.Savini, Ravenna 1909, VIII, p.19*
Fig 48: *Archeological evidences of the west tower in "Ravenna: Piante panoramiche", G.Savini, Ravenna 1909, VIII, p.19*

published before then, in the archives of the Superintendence for Architectural Heritage and Landscape for the Province of Ravenna edited by Maioli in 1908 , including the first hypothetical reconstruction of the planimetric door within the walls based on the drawing of G. B. Sangallo.

Acquisition

Laser-Scan Campaign

The 3D data survey concerned two different places related to the monument. The first one is the "Porta Aurea Hall" at the National Museum of Ravenna, and the second one is the part of the city wall where ruins of the two round towers are found that most likely framed Porta Aurea. At both sites we used a ToF laser (Leyca C-10 all-in-one scan station) to acquire data.

Only a portion of the data acquired at the National Museum was processed. The

Fig 49: *Front view, Top view and axonometric view of the point cloud obtained from the survey at Via di Porta Aurea.*

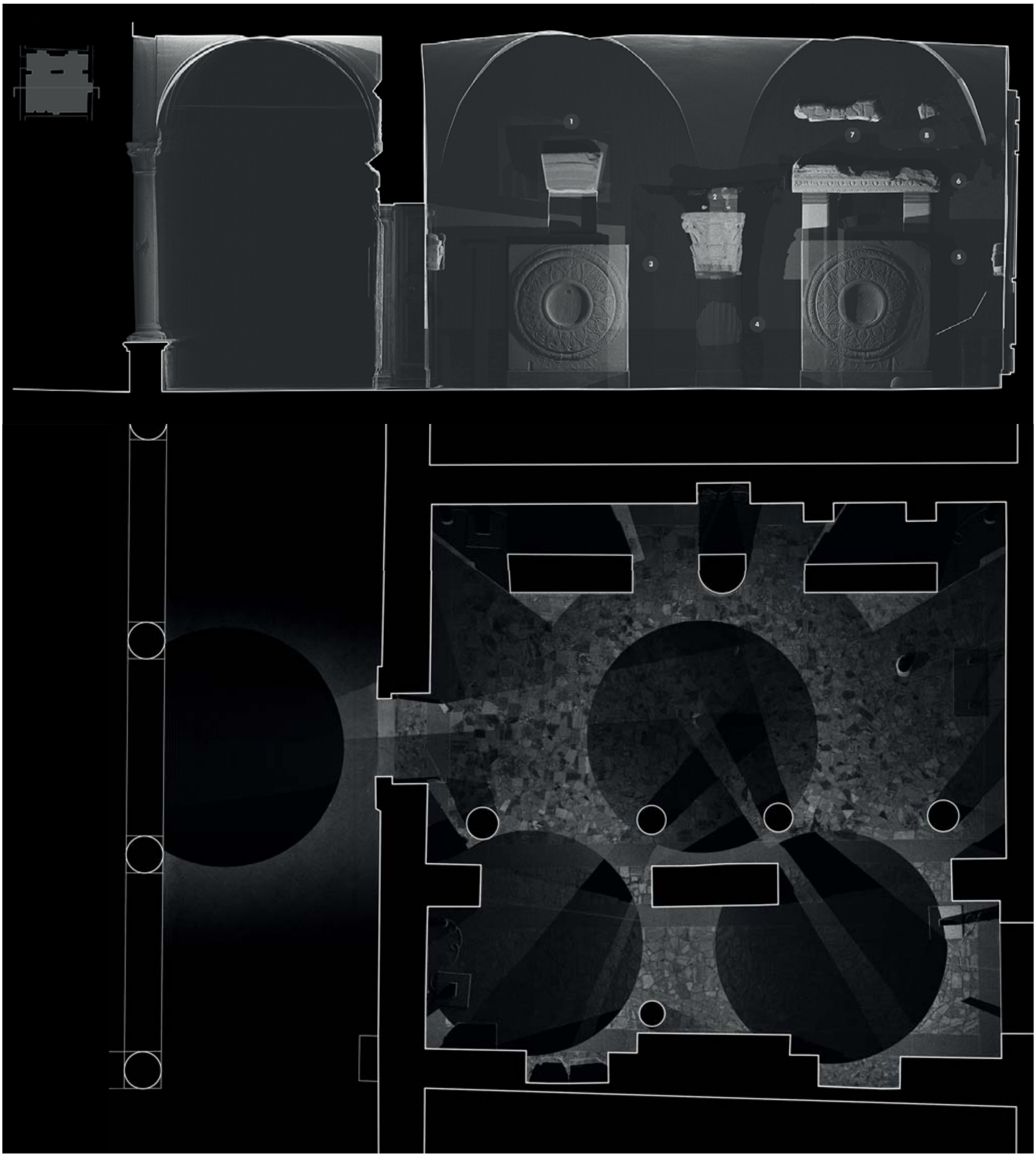


Fig 50: *Top view and longitudinal section of the point cloud obtained from the survey at National Archaeological Museum of Ravenna.*

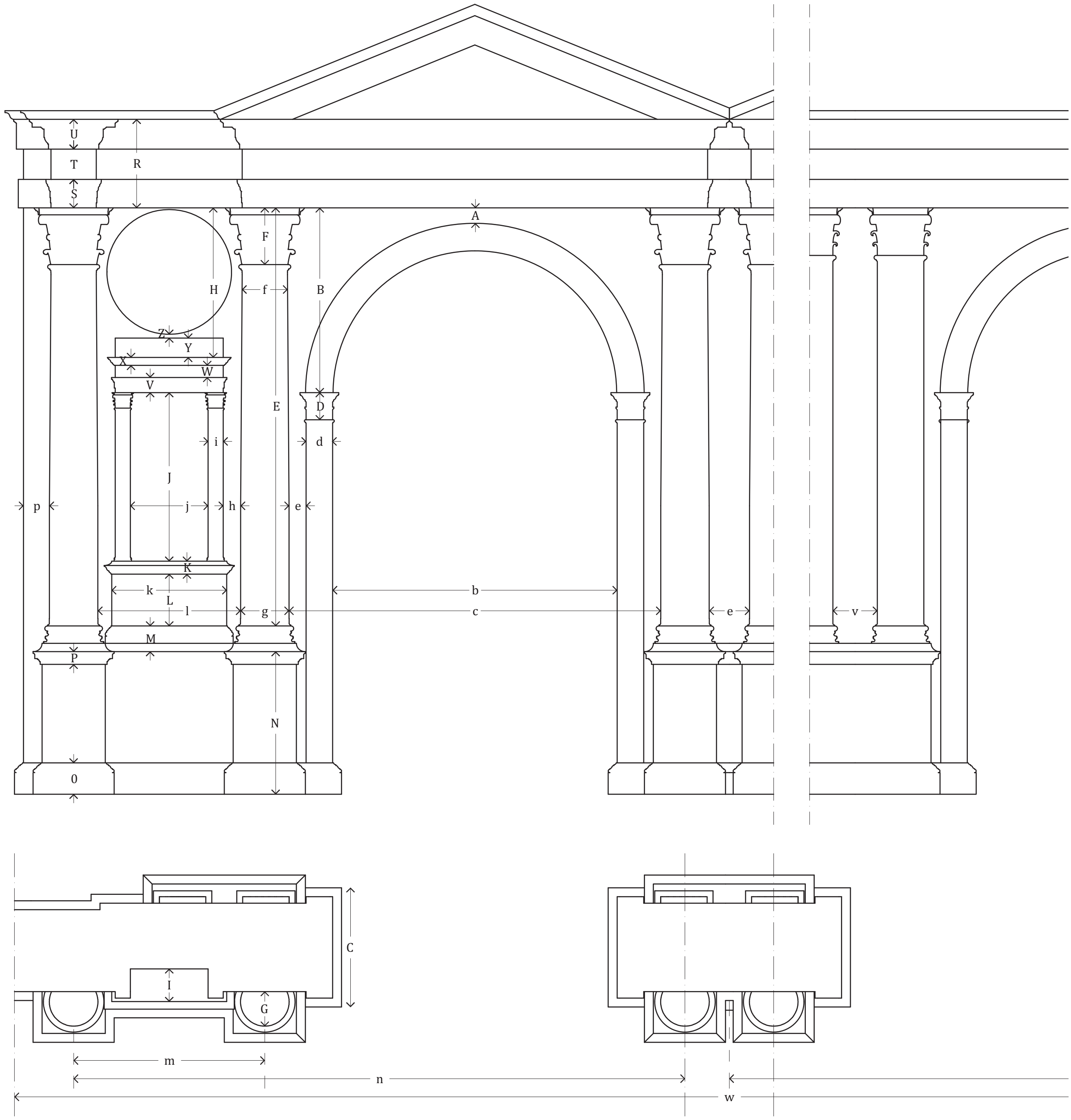
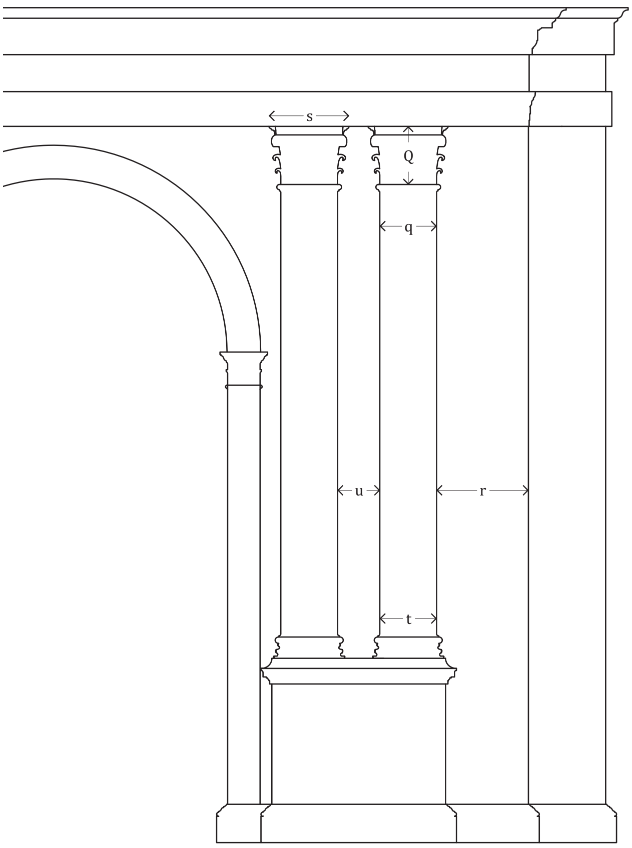
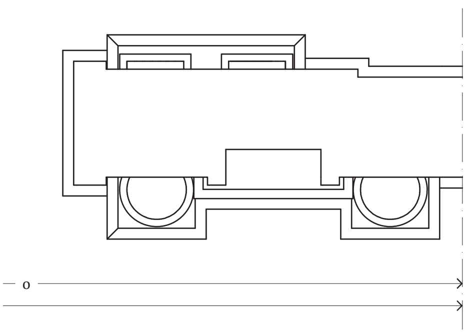


Fig 51: *Front view and back view of Porta Aurea with letters for dimensions used as reference to the transcript measurements (ToM) from drawings and sketches*

reality-based modelling process concerned only architectural fragments most probably related to the monument.





Analysis

Transcript of measurements (ToM)

In this phase of analysis, the drawings that represents façades and plans were analysed and their notation were transcripted.

In the table below ,the content of drawings are proposed with their specific unit. The measures of mouldings are not in the table because for them single considerations are required and explained later.

For each drawing or sketch the unit's specification table is indicated. All the measures were transcripted as it were indicated by Authors directly on the survey drawing.

Unit	***Sub-Unit***	***Sub-Sub-Unit***
Piede Romano	4 palmi	16 dita
Piede Vicentino	12 once	48 minuti
Graphic Scale	12 once	144 minuti

Tab 1: *Units specification table*

Author	***Unit***	***To cm***
G. B. da Sangallo	Piede Romano	29,7
Andrea Palladio	Piede Vicentino	35,7
Anonimous of Berlin	Graphic Scale	31,4

Tab 2: *Units conversions table*

Dimension letters	**Andrea Palladio**			**Andrea Palladio**			**Andrea Palladio**			**Anonimous of Berlin**			**Pirro Ligorio**			**Giovanbattista da Sangallo**		
	RIBA31821 SC220/XII/12r London R.I.B.A.			*RIBA31822 SC220/XII/12v London R.I.B.A.*			*Inv. D31 Vicenza Civic Art Gallery of Palazzo Chiericati*			*Hdz.1245r/1246r Berlin Kunstbibliothek Staatliche Museen zuBerlin*			*ms. a.II.1 vol.XIV c. 14v - 15r/v Roman Antiquities Turin State Archive*			*Inv. Arch. 2057 Florence Uffizi Gallery*		
	piedi	*once*	*minuti*	*piedi*	*once*	*minuti*	*piedi*	*once*	*minuti*	*piedi*	*once*	*minuti*	*piedi*	*once*	*minuti*	*piedi*	*palmi*	*diti*
A					6													
a		8						8			8	7		8				
B	7	1½		7	1½		7	1½		8			7	1½				
b	11			11			11			12	6	7	11					
C																11		8
c				14	9													
D	1			1			1						1					
d	1			1			1			1	2		1					
E	16	1½					16	1½					16	1½				
e	1	3					1	3		1	9	10	1	?				
F	2	2¼																
f										1	11	11						
G	1	4																
g	1	10½					1	10½		2	2	9	1	10½				
H										6	3	5						
h											7							
I	1	1½																
i		7						7			8	10						
J	6½						6½			7	3	8						
j	3						3			3	9	10						
K		6						6			3	6						

k	5						5			5	6		5					
L	2																	
l	5½						5½			6	3	7						
M										1	3	3						
m																8		12
N	5½			5½						6	6							
n																29		
O											9							
o																31		8
P											8							
p							1						1					
Q				1	10½									22				
q														22				
R				3	5													
r	2½			2½									2½					
S	1	2		1	2½		1	2		1	1		1	2				
s	2	5																
T	1	1¼		1	1½		1		5	1	3	1	1		5			
t	1	8		1	9½									22½				
U	1	1½		1	2		1	1¼		1	3		1	1½				
u				1									1½					
V			28					7			8							
v	1			1														
W			24					6			6	4						
w																63		
X			20					5			4	2						
Y			36					9						6				
Z												11						

Tab 3: *Transcript of Measurements (ToM) of most important sources according with drawing of "Dimension letters". The highlighted measures were used in the modeling process as "indicate measures"*

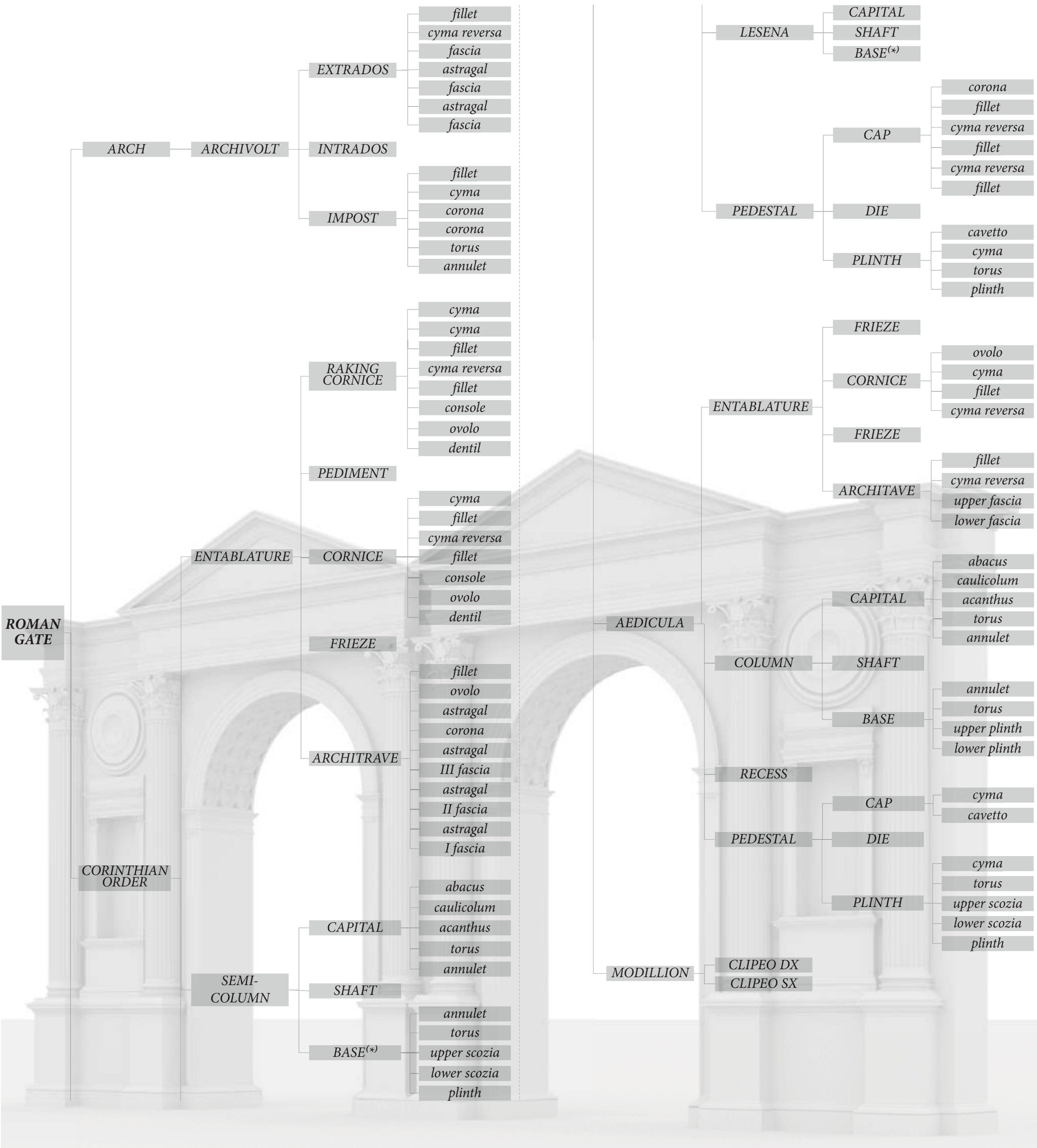


Fig 52: *Semantic Structure of Porta Aurea according with the Controlled Vocabulary for Classical Orders of Architecture*

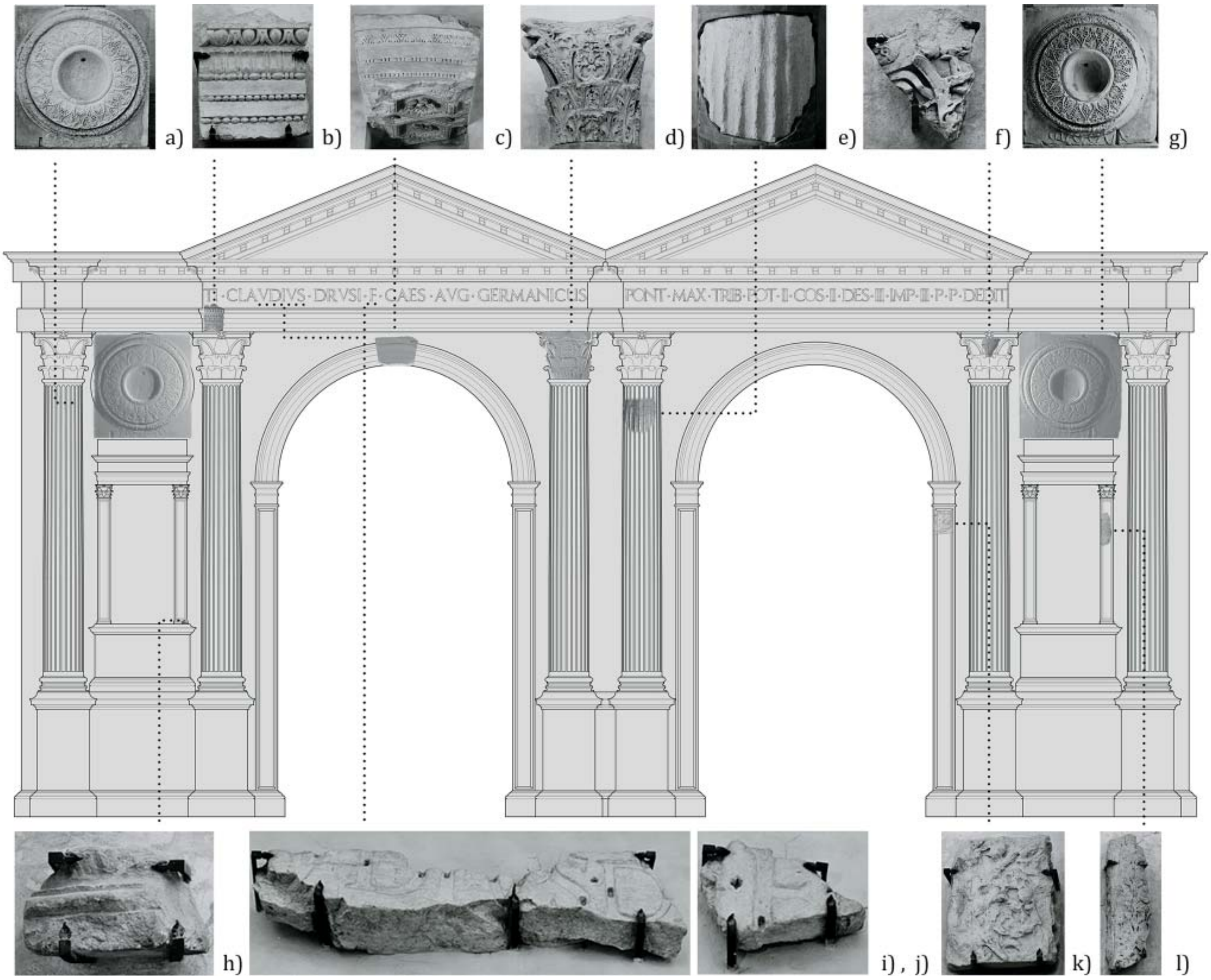


Fig 53: *Reconposition of Archaeological and Architectural Evidences*

According with different level of detail of sources and dimensions indicated were possible to design the letters for dimensions reference.Interpretation

Semantic Structure

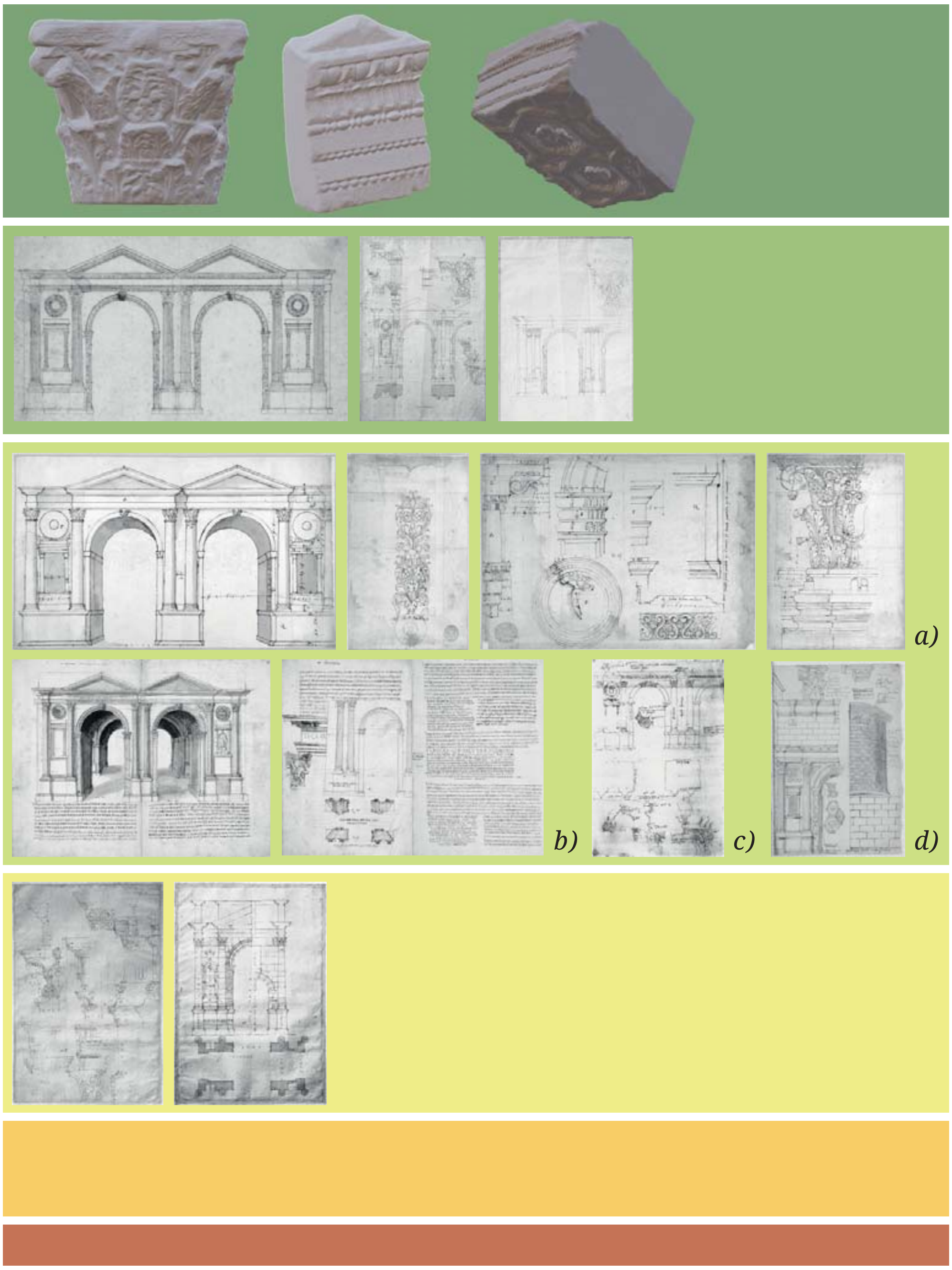
According to the taxonomy -and the controlled vocabulary for classical orders of architecture-, the structure was divided into its sub-elements.

The main artefact of Porta Aurea was analysed, and all components were encoded with their specific codes. in agree with the VRIM ontology proposed.

The domain specification for the project is “Architecture”, then the type of Architecture can be chosen from the list retrieved by the

Archaeological/Architectural Evidences

The identification of the fragments was made possible thanks to the interrelated study between the photographic archive



1_r.c. based on laser scanning survey of archaeological evidences and fragments

2_r.c. based on original survey drawings edited by Andrea Palladio

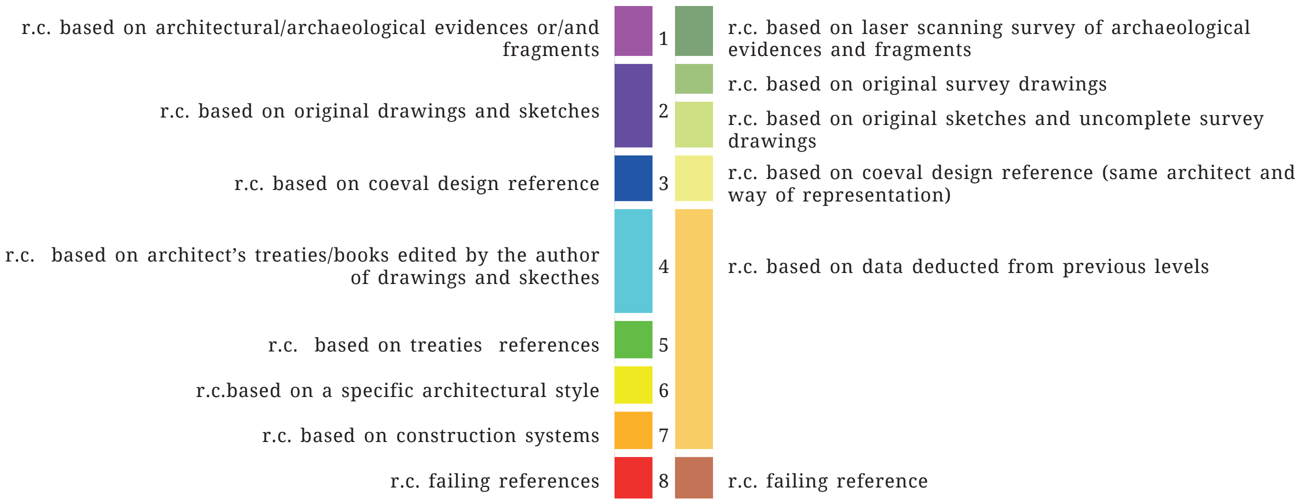
3_r.c. based on original sketches and uncomplete survey drawings edited by
a) anonimous of Berlin
b) Pirro Ligorio
c) G.B. da Sangallo
d) raphael (copyist of/ circle of)

4_r.c. based on coeval design reference (same architect and way of representation)
Arco dei Gavi (survey drawing edited by Andrea Palladio)

4_r.c. based on data deducted from previous levels

8_r.c. failing references

Fig 54: *Uncertainty grade assigned to set of reference sources available*



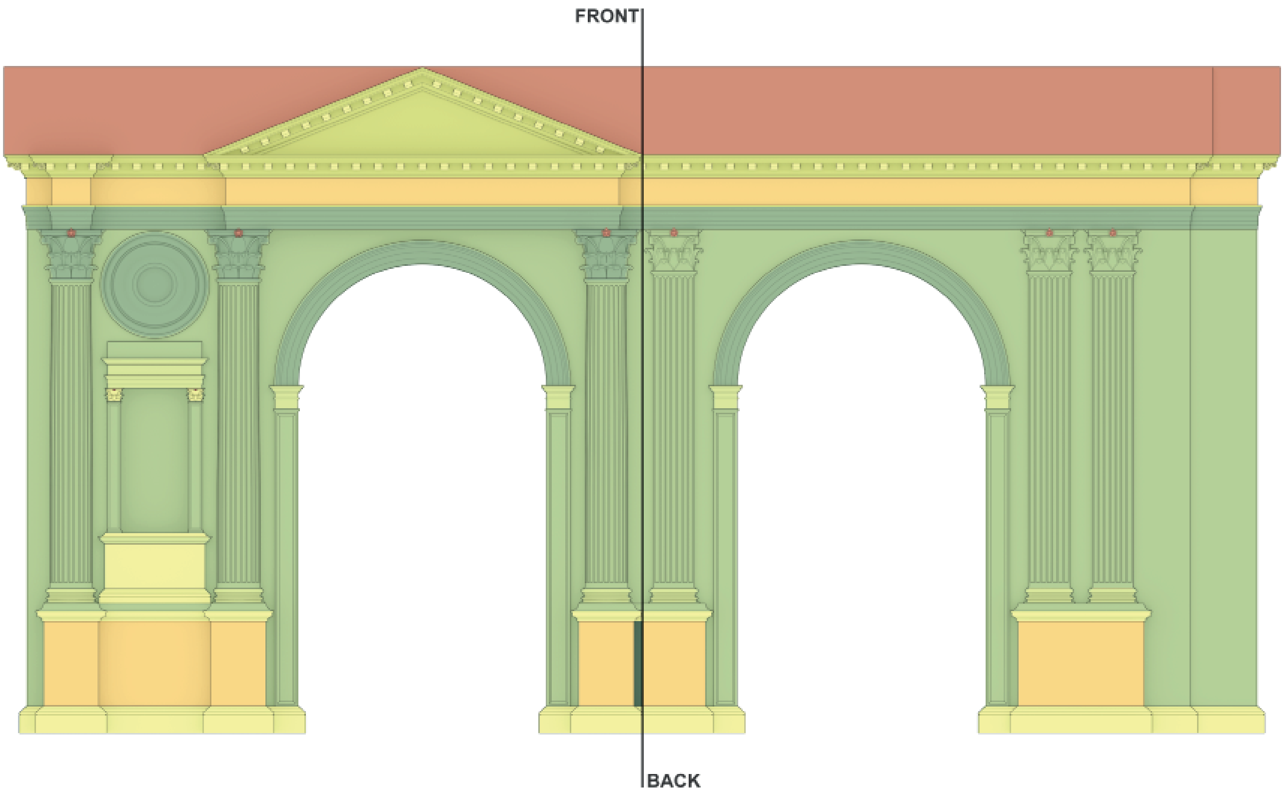


Fig 55: *Comparison between the VRIM uncertainty scale and colours assigned to Porta Aurea Project referred to source available.*

Fig 56: *Front and Back view of Porta Aurea labelled with colour gradient scale used to depict unceratinty of modelled architectural elements* and the inventory, both kept stored at the Superintendence for Architectural Heritage and Landscape for the Province of Ravenna. This study allowed us to return to those fragments – dating back mainly to the 1906-1908 excavations at the walls – which are congruent with the historical/documentary sources.

Gradient Colour Scale for Uncertainty

Referring to the case-study, the information derived from drawings has been classified according to the level of detail that they concern. The gradient colour scale start from the green colour to red and it refers to the Apollonio et. al. ones (Apollonio, Gaiani, & Sun, 2013). Some differences related to our case study are introduced.

The data from the laser scanner occupy the first level of the colour-scale and are more reliable as they are obtained from the architectural fragments acquisition.

At the second level of the scale , there are drawings by Andrea Palladio. The architect is the only one giving us information related to the layout and both sides of the Roman gate.

At the third level there are have eidotypes by different authors such as Anonymous Berlin, Sangallo, copyist Raphael and Ligorio. These authors are grouped together , due to a lack of information on each source. Despite the accuracy in describing ornamental details ,Anonymous Berlin doesn't show the oriented layout of the façade towards the city. Sangallo drew the plan and the façade oriented out of the city without pediments, as copyist Raphael did and both representations are of poor measurement. Despite having all the characteristics of Palladio's drawings,Pirro Ligorio shows us a gate with a completely different layout which leads us to believe his representation to be the least realistic.

Because survey drawings are usually lacking of information, the faithful reconstruction of the monument from its representations it is not quite easy, and that's why it is necessary to give a critical interpretation of the data: the fourth level instead refers to references with significant stylistic similarities. In this case we use the Gavi Arch in Verona- as an antecedent of Porta Aurea of about twenty years - and accredit it to the same architect Vitruvius Cedrone. As such, two eidotypes published by Andrea Palladio depicting the Gavi Arch are used. The use of information from eidotypes published for both monuments by the same author, allowed us to assume a formal-typological comparison among them , able to close the gaps in Porta Aurea drawings and to define some elements characterized by a low level of uncertainty.

The fifth level is a "new entry" and is occupied by that series of data that results from the 3D modelling-process based on data deducted from previous levels of the gradient colour scale.

At the end, the last colour (red) is related to reconstructive conjectures in the absence of reliable references.

Representation

3D modelling in VR : the solid modelling approach

The Arch

The arch was reconstructed starting from the analysis of the plan. The span of the opening located both in plan and elevation in Palladio (ToM - b) has been retained, as well as the height of the impost of the arch referred to the entablature (ToM - B)

Regarding the pillar, we used the data on both the general measurements of Anonymous (ToM - d) and the elements of the detail.

About the first belt, Anonymous describes

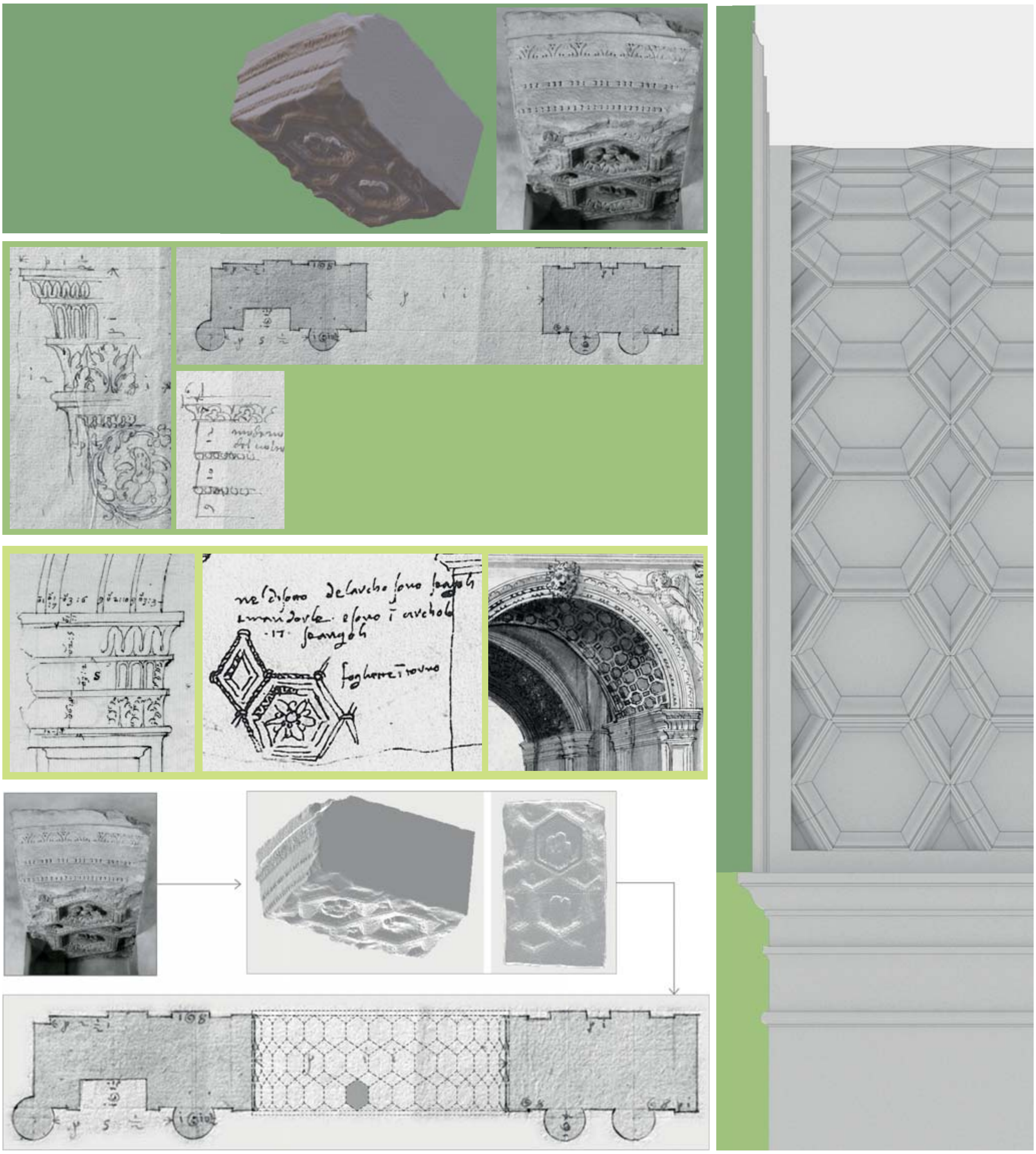


Fig 57: *From the architectural fragment to the definition of the arch and its hexagons*

all of it without subdividing the elements and, in this way the fillet was inferred from the proportion of the upper fascia, and set equal to 11 minutes (graphic scale).

The analysis of the arch and its reconstruction was involved also in the question of the size of the plan and of the thickness the monument may have had. Until now, it had always been assumed that the thickness of the gate would have been quite significant. The surviving excavation data, albeit in fragments, have always led historians (Kähler, 1959)(Tosi, 1986)(Rosi, 1939) to believe the planimetric drawing of Sangallo to be considered most appropriate.

According to our opinion, the thickness of the gate could have been proportionally like the plan as reported by Palladio. The reconstructive study of the vault was based on the analysis of the findings in the superintendence and reality-based measures of the hexagons. If the fragment of the archivolt belongs to the ancient monument, it is joined by a series of three hexagons to reconstruct the thickness. We identified a definite discrepancy between the 3.4 metres of Sangallo's drawing and the approximate1.6 metres of Palladio. In the drawing of Ligorio, in the face to the right one shows that the number of hexagons in succession is always three. As for the number of hexagons on the longitudinal side, it has remained the number as described by Sangallo "ne' di sotto de larcho sono seangoli e mandorle e sono ì archolo 17 seangoli" (under the arch there are coffered shaped hexagonal and quadrilateral, and on the whole vault there are 17 hexagons).

The entablature

Andrea Palladio provides different data in the three different manuscripts. In the first drawing the entablature shows its three main elements, but in the same paper the measures of the detail appear to be different. In the second drawing, depicting the front facing towards the city, the entablature is shown in its entireness. Finally, in the third drawing it resumes the subdivision adopted in the former one, but the information changes again. Considering the third drawing to likely be the least reliable and to all the versions differ in their partial representation of the entablature, it was decided to use the total height (ToM - R) while frame (ToM - U) and architrave (ToM - S) used data from Anonymous.

Starting from the top of the frame, the source did not provide the height of ovolo which then is considered equal to the height of the architrave level of ovolo and dentil considered as an addition to the space provided.

The architrave was considered as depicted by Anonymous that also shows us the section in rosettes.

Considering the alignment of the pediments and entablature compared to the column, it was clear that - as shown by Anonymous -the entablature would have significantly altered the distance between the half-column in the central pillar. It was therefore decided to use as a share of the overhang of the bracket, not the data from Anonymous but those of Palladio, which rendered the overhang less important and deter-mined a distance between the half-columns of 1 feet 7 ounces (Vicenzan feet), that is, 4 ounces greater compared to the London drawing (Tab. 3 - e).

Semi-columns and pillars

Data relating to a half-column examined for height (ToM - E), width (ToM - g) and depth (ToM - G) were taken from drawings by Palladio, while the tapering there was supplied by Anonymous (ToM - f) as well as the detail of the base and the Corinthian capital, for whose overall height (ToM - F) is referred to by Palladio.

Fig 58: *From the architectural fragment to the definition of the column and lesenas*

Fig 59: *Definition of the pedestal following indicated dimensions referenced by different sources*

As for the front facing towards the city, it presents the place of the half-columns, Corinthian pillars al-so being tapered.

In the drawings of Palladio, different measures are provided concerning the width of both plan and elevation.

So, in this case, the design of Pirro Ligorio is used to provide us with all of the information regarding its width (ToM - t) tapering (ToM - q) and height of capital (ToM - Q).

The height of the capital of the lesena is the only coincident measure to that is also reported by Palladio.

The Pedestal

As for the analysis of the base section, reference was made to the information in the sheets representing the Gavi Arch in Verona: an eidotype carefully detailed not only at the base section but also the niche above.

For aspects of form, the drawings of the Gavi Arch were brought into consideration,and those maintaining consistency with the available metric data on the Porta Aurea: the overall height of the pedestal was provided by Palladio (ToM - N), while the cap was considered as represented by Anonymous of Berlin (ToM - P). Regarding the plinth, reference is made only to RIBA 31820 even if the dado has not used the height to which it refers, but a height of 10 ounces (Vicenza's feet) which was more proportionate than redrawing Palladian gate.

The Aedicula

In the side pillars, framed by two half-columns, are niches (on the front facing out of the city).

The joint on the base was not described in Palladio for which in this case it has also been referred to the design of The Gavi Arch. From the geometrically formal point of view, again the same base is seen while, from the dimensional point of view, reference was made to the order of the base of the column that was proposed by Anonymous. The upper part remained the size proposed by Palladio to die (ToM -N) and cap (ToM - M).

Among the drawings of Anonymous and Palladio, one notices the difference between the base of the pillars, compared to the cube at the base of the pillar, which is considered the measure by Anonymous 2 ounces 3 minutes (graphic scale).

Regarding the recess, the information has been from Palladio for both height (ToM - J) and width (ToM - j) has been maintained.

The width of the pillar was considered as shown by Palladio (ToM - i), since the hypothesis of Palladio for the entire entablature would have been too high and would not permit the insertion of the fragment of the clipeo at the top. Anonymous Berlin is the source for the entablature above and for the architrave (ToM - V) frieze (ToM - W) and frame (ToM - X) with the addition of part of the frieze at the top, not recorded by Palladio (ToM - Y).

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2. Conclusions

Creating and editing 3D models are complex operations ,where the issue of transparency of processes and its traceability in visualization of Architectural Heritage could be partially solved with the use of BIM as methodological tool for communication and as methodology of research.

Building Information Modeling (BIM) can be used to manage 3D archives with considerable potential in terms of research and dissemination. Since BIM platforms were developed for commercial use and architectural design was necessary to understand the potential of BIM also for heritage buildings.

BIM platform allows the re-use of information by users that own a different background and integration of semantic meta-data for cultural heritage to enhancing interdisciplinary studies.

Effective virtual reconstruction of information management requires that both project managers and heritage recorders understand the technical possibilities and constraints associated with recording and documenting information. Information management dataset should reflect a clear and conscious agreement concerning desired levels of uncertainty, accuracy, degree of completeness and referenced source used to make hypothesis. It is equally important to ensure that standards are in place that encourage scholars carrying out virtual reconstruction project work, whether formally or informally, to integrate their records– sketches, photos, videos, or notes within an accessible, integrated central database for virtual reconstructions.

Appendix A

Other Classes and Properties referred CIDOC-CRM and extensions

Referred to CIDOC-CRM Classes | Version 6.2

E1 Entity CRM

Superclass of:	E2 TemporalEntity, E52 Time-Span, E53 Place, E54 Dimension, E77 Persistent Item, E92 Spacetime Volume
Scope note:	This class comprises all things in the universe of discourse of the CIDOC Conceptual Reference Model. It is an abstract concept providing for three general properties: 1. Identification by name or appellation, and in particular by a preferred identifier 2. Classification by type, allowing further refinement of the specific subclass an instance belongs to 3. Attachment of free text for the expression of anything not captured by formal properties. With the exception of E59 Primitive Value, all other classes within the CRM are directly or indirectly specialisations of E1 CRM Entity.
Examples:	the earthquake in Lisbon 1755 (E5)
Properties:	P1 is identified by (identifies) : E41 Appellation, P2 has type (is type of) : E55 Type, P3 has note : E62 String, P48 has preferred identifier (is preferred identifier of) : E42 Identifier, P137 exemplifies (is exemplified by) : E55 Type

E2 Temporal Entity

Subclass of:	E1 CRM Entity
Superclass of:	E3 Condition State, E4 Period
Scope note:	This class comprises all phenomena, such as the instances of E4 Periods, E5 Events and states, which happen over a limited extent in time.This extent in time must be contiguous, i.e., without gaps. In case the defining kinds of phenomena for an instance of E2 Temporal Entity cease to happen, and occur later again at another time, we regard that the former E2 Temporal Entity has ended and a new instance has come into existence. In more intuitive terms, the same event cannot happen twice. In some contexts, these are also called perdurants. This class is disjoint from E77 Persistent Item. This is an abstract class and has no direct instances. E2 Temporal Entity is specialized into E4 Period, which applies to a particular geographic area (defined with a greater or lesser degree of precision), and E3 Condition State, which applies to instances of E18 Physical Thing.
Examples:	Bronze Age (E4) the earthquake in Lisbon 1755 (E5) the Peterhof Palace near Saint Petersburg being in ruins from 1944 – 1946 (E3)
In first Order Logic	$E2(x) \supset E1(x)$
Properties:	P4 has time-span (is time-span of) : E52 Time-Span, P114 is equal in time to : E2 Temporal Entity, P115 finishes (is finished by) : E2 Temporal Entity, P116 starts (is started by) : E2 Temporal Entity, P117 occurs during (includes) : E2 Temporal Entity, P118 overlaps in time with (is overlapped in time by) : E2 Temporal Entity, P119 meets in time with (is met in time by) : E2 Temporal Entity, P120 occurs before (occurs after) : E2 Temporal Entity

E5 Event

Subclass of: E4 Period

Superclass of: E7 Activity, E63 Beginning of Existence, E64 End of Existence

Scope note: This class comprises changes of states in cultural, social or physical systems, regardless of scale, brought about by a series or group of coherent physical, cultural, technological or legal phenomena. Such changes of state will affect instances of E77 Persistent Item or its subclasses.
The distinction between an E5 Event and an E4 Period is partly a question of the scale of observation. Viewed at a coarse level of detail, an E5 Event is an 'instantaneous' change of state. At a fine level, the E5 Event can be analysed into its component phenomena within a space and time frame, and as such can be seen as an E4 Period. The reverse is not necessarily the case: not all instances of E4 Period give rise to a noteworthy change of state.

Examples:
the birth of Cleopatra (E67)
the destruction of Herculaneum by volcanic eruption in 79 AD (E6)
World War II (E7)
the Battle of Stalingrad (E7)
the Yalta Conference (E7)
my birthday celebration 28-6-1995 (E7)
the falling of a tile from my roof last Sunday
the CIDOC Conference 2003 (E7)

In first Order Logic E5(x) ⊃ E4(x)

Properties:
P11 had participant (participated in) : E39 Actor,
P12 occurred in the presence of (was present at) : E77 Persistent Item

E7 Activity

Subclass of: E5 Event

Superclass of: E8 Acquisition, E9 Move, E10 Transfer of Custody, E11 Modification, E13 Attribute Assignment, E65 Creation, E66 Formation, E85 Joining, E86 Leaving, E87 Curation Activity

Scope note: This class comprises actions intentionally carried out by instances of E39 Actor that result in changes of state in the cultural, social, or physical systems documented.
This notion includes complex, composite and long-lasting actions such as the building of a settlement or a war, as well as simple, short-lived actions such as the opening of a door.

Examples:
the Battle of Stalingrad
the Yalta Conference
my birthday celebration 28-6-1995
the writing of "Faust" by Goethe (E65)
the formation of the Bauhaus 1919 (E66)
calling the place identified by TGN '7017998' 'Quyunjig' by the people of Iraq
Kira Weber working in glass art from 1984 to 1993
Kira Weber working in oil and pastel painting from 1993

In first Order Logic E7(x) ⊃ E5(x)

Properties:
P14 carried out by (performed) : E39 Actor,
P15 was influenced by (influenced) : E1 CRM Entity,
P16 used specific object (was used for) : E70 Thing,
P17 was motivated by (motivated) : E1 CRM Entity,
P19 was intended use of (was made for) : E71 Man-Made Thing,
P20 had specific purpose (was purpose of) : E5 Event,
P21 had general purpose (was purpose of) : E55 Type,
P32 used general technique (was technique of) : E55 Type,
P33 used specific technique (was used by) : E29 Design or Procedure,
P125 used object of type (was type of object used in) : E55 Type,
P134 continued (was continued by) : E7 Activity

E13 Attribute Assignment

Subclass of:	E7 Activity
Superclass of:	E14 Condition Assessment, E15 Identifier Assignment, E16 Measurement, E17 Type Assignment
Scope note:	This class comprises the actions of making assertions about properties of an object or any relation between two items or concepts. This class allows the documentation of how the respective assignment came about, and whose opinion it was. All the attributes or properties assigned in such an action can also be seen as directly attached to the respective item or concept, possibly as a collection of contradictory values. All cases of properties in this model that are also described indirectly through an action are characterized as “short cuts” of this action. This redundant modelling of two alternative views is preferred because many implementations may have good reasons to model either the action or the short cut, and the relation between both alternatives can be captured by simple rules. In particular, the class describes the actions of people making propositions and statements during certain museum procedures, e.g. the person and date when a condition statement was made, an identifier was assigned, the museum object was measured, etc. Which kinds of such assignments and statements need to be documented explicitly in structures of a schema rather than free text, depends on if this information should be accessible by structured queries.
Examples:	the assessment of the current ownership of Martin Doerr’s silver cup in February 1997
In first Order Logic	E13(x) □ E7(x)
Properties:	P140 assigned attribute to (was attributed by) : E1 CRM Entity, P141 assigned (was assigned by) : E1 CRM Entity

E17 Type Assignment

Subclass of:	E13 Attribute Assignment
Superclass of:	
Scope note:	This class comprises the actions of classifying items of whatever kind. Such items include objects, specimens, people, actions and concepts. This class allows for the documentation of the context of classification acts in cases where the value of the classification depends on the personal opinion of the classifier, and the date that the classification was made. This class also encompasses the notion of “determination,” i.e. the systematic and molecular identification of a specimen in biology.
Examples:	the first classification of object GE34604 as Lament Cloth, October 2nd the determination of a cactus in Martin Doerr’s garden as ‘Cereus hildmannianus K.Schumann’, July 2003
In first Order Logic	E17(x) □ E13(x)
Properties:	P41 classified (was classified by) : E1 CRM Entity, P42 assigned (was assigned by) : E55 Type

E21 Person

Subclass of:	E20 Biological Object, E39 Actor.
Superclass of:	
Scope note:	This class comprises real persons who live or are assumed to have lived. Legendary figures that may have existed, such as Ulysses and King Arthur, fall into this class if the documentation refers to them as historical figures. In cases where doubt exists as to whether several persons are in fact identical, multiple instances can be created and linked to indicate their relationship. The CRM does not propose a specific form to support reasoning about possible identity
Examples:	Tut-Ankh-Amun Nelson Mandela
In first Order Logic	E21(x) □ E20(x), E21(x) □ E39(x)
Properties:	P152 has parent (is parent of) : E21 Person

E24 Physical Man-Made Thing

Subclass of: E18 Physical Thing, E71 Man-Made Thing

Superclass of: E22 Man-Made Object, E25 Man-Made Feature, E78 Collection

Scope note: This class comprises all persistent physical items that are purposely created by human activity.
This class comprises man-made objects, such as a swords, and man-made features, such as rock art. No assumptions are made as to the extent of modification required to justify regarding an object as man-made. For example, a “cup and ring” carving on bedrock is regarded as instance of E24 Physical Man-Made Thing.

Examples: the Forth Railway Bridge (E22)
the Channel Tunnel (E25)
the Historical Collection of the Museum Benaki in Athens (E78)

In first Order Logic E24(x) E18(x), E24(x) E71(x)

Properties: P62 depicts (is depicted by) : E1 CRM Entity,
P65 shows visual item (is shown by) : E36 Visual Item

E28 Conceptual Object

Subclass of: E71 Man-Made Thing

Superclass of: E55 Type, E89 Propositional Object, E90 Symbolic Object

Scope note: This class comprises non-material products of our minds and other human produced data that have become objects of a discourse about their identity, circumstances of creation or historical implication. The production of such information may have been supported by the use of technical devices such as cameras or computers.
Characteristically, instances of this class are created, invented or thought by someone, and then may be documented or communicated between persons. Instances of E28 Conceptual Object have the ability to exist on more than one particular carrier at the same time, such as paper, electronic signals, marks, audio media, paintings, photos, human memories, etc.
They cannot be destroyed. They exist as long as they can be found on at least one carrier or in at least one human memory. Their existence ends when the last carrier and the last memory are lost.

Examples: Beethoven’s “Ode an die Freude” (Ode to Joy) (E73)
the definition of “ontology” in the Oxford English Dictionary
the knowledge about the victory at Marathon carried by the famous runner
‘Maxwell equations’ [preferred subject access point from LCSH,http://lccn.loc.gov/sh85082387, as of 19 November 2012]
‘Equations, Maxwell’ [variant subject access point, from the same source]

In first Order Logic E28(x) E71(x)

Properties: P149 is identified by (identifies) : E75 Conceptual Object Appellation

E31 Document

Subclass of: E73 Information Object

Superclass of: E32 Authority Document

Scope note: This class comprises identifiable immaterial items that make propositions about reality.
These propositions may be expressed in text, graphics, images, audiograms, videograms or by other similar means. Documentation databases are regarded as a special case of E31 Document. This class should not be confused with the term “document” in Information Technology, which is compatible with E73 Information Object.

Examples: the Encyclopaedia Britannica (E32)
The image content of the photo of the Allied Leaders at Yalta published by UPI, 1945 (E38)
the Doomsday Book

In first Order Logic E31(x) E73(x)

Properties: P70 documents (is documented in) : E1 CRM Entity

E39 Actor	
Subclass of:	E77 Persistent Item
Superclass of:	E21 Person, E74 Group
Scope note:	This class comprises people, either individually or in groups, who have the potential to perform intentional actions of kinds for which someone may be held responsible. The CRM does not attempt to model the inadvertent actions of such actors. Individual people should be documented as instances of E21 Person, whereas groups should be documented as instances of either E74 Group or its subclass E40 Legal Body.
Examples:	London and Continental Railways (E40) the Governor of the Bank of England in 1975 (E21) Sir Ian McKellan (E21)
In first Order Logic	E39(x) E77(x)
Properties:	P74 has current or former residence (is current or former residence of) : E53 Place, P75 possesses (is possessed by) : E30 Right, P76 has contact point (provides access to) : E51 Contact Point, P131 is identified by (identifies) : E82 Actor Appellation

E41 Appellation	
Subclass of:	E90 Symbolic Object
Superclass of:	E35 Title, E42 Identifier, E44 Place Appellation, E49 Time Appellation, E51 Contact Point, E75 Conceptual Object Appellation, E82 Actor Appellation
Scope note:	This class comprises signs, either meaningful or not, or arrangements of signs following a specific syntax, that are used or can be used to refer to and identify a specific instance of some class or category within a certain context. Instances of E41 Appellation do not identify things by their meaning, even if they happen to have one, but instead by convention, tradition, or agreement. Instances of E41 Appellation are cultural constructs; as such, they have a context, a history, and a use in time and space by some group of users. A given instance of E41 Appellation can have alternative forms, i.e., other instances of E41 Appellation that are always regarded as equivalent independent from the thing it denotes. Specific subclasses of E41 Appellation should be used when instances of E41 Appellation of a characteristic form are used for particular objects. Instances of E49 Time Appellation, for example, which take the form of instances of E50 Date, can be easily recognised. E41 Appellation should not be confused with the act of naming something. Cf. E15 Identifier Assignment
Examples:	“Martin” “the Forth Bridge” “the Merchant of Venice” (E35) “Spigelia marilandica (L.) L.” [not the species, just the name] “information science” [not the science itself, but the name through which we refer to it in an English-speaking context] “” [Chinese “an”, meaning “peace”]
In first Order Logic	E41(x) E90(x)
Properties:	P139 has alternative form : E41 Appellation

E42 Identifier	
Subclass of:	E41 Appellation
Superclass of:	
Scope note:	This class comprises strings or codes assigned to instances of E1 CRM Entity in order to identify them uniquely and permanently within the context of one or more organisations. Such codes are often known as inventory numbers, registration codes, etc. and are typically composed of alphanumeric sequences. The class E42 Identifier is not normally used for machine-generated identifiers used for automated processing unless these are also used by human agents.
Examples:	“MM.GE.195” “13.45.1976” “OXCMS: 1997.4.1” ISSN “0041-5278” ISRC “FIFIN8900116” Shelf mark “Res 8 P 10” “Guillaume de Machaut (1300?-1377)” [a controlled personal name heading that follows the French rules]
In first Order Logic	E42(x) E41(x)

E55 Type

Subclass of:	E28 Conceptual Object
Superclass of:	E56 Language, E57 Material, E58 Measurement Unit
Scope note:	This class comprises concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify instances of CRM classes. Instances of E55 Type represent concepts in contrast to instances of E41 Appellation which are used to name instances of CRM classes. E55 Type is the CRM's interface to domain specific ontologies and thesauri. These can be represented in the CRM as subclasses of E55 Type, forming hierarchies of terms, i.e. instances of E55 Type linked via P127 has broader term (has narrower term). Such hierarchies may be extended with additional properties.
Examples:	weight, length, depth [types of E54] portrait, sketch, animation [types of E38] French, English, German [E56] excellent, good, poor [types of E3] Ford Model T, chop stick [types of E22] cave, doline, scratch [types of E26] poem, short story [types of E33] wedding, earthquake, skirmish [types of E5]
In first Order Logic	E55(x) ⊃ E28(x)
Properties:	P127 has broader term (has narrower term) : E55 Type, P150 defines typical parts of (defines typical wholes for) : E55 Type

E70 Thing

Subclass of:	E77 Persistent Item
Superclass of:	E71 Man-Made Thing, E72 Legal Object
Scope note:	This general class comprises discrete, identifiable, instances of E77 Persistent Item that are documented as single units, that either consist of matter or depend on being carried by matter and are characterized by relative stability. They may be intellectual products or physical things. They may for instance have a solid physical form, an electronic encoding, or they may be a logical concept or structure.
Examples:	my photograph collection (E78) the bottle of milk in my refrigerator (E22) the plan of the Strassburger Muenster (E29) the thing on the top of Otto Hahn's desk (E19) the form of the no-smoking sign (E36) the cave of Dirou, Mani, Greece (E27)
In first Order Logic	E70(x) ⊃ E77(x)
Properties:	P43 has dimension (is dimension of) : E54 Dimension, P101 had as general use (was use of) : E55 Type, P130 shows features of (features are also found on) : E70 Thing

E71 Man-Made Thing

Subclass of:	E70 Thing
Superclass of:	E24 Physical Man-Made Thing, E28 Conceptual Object
Scope note:	This class comprises discrete, identifiable man-made items that are documented as single units. These items are either intellectual products or man-made physical things, and are characterized by relative stability. They may for instance have a solid physical form, an electronic encoding, or they may be logical concepts or structures.
Examples:	Beethoven's 5th Symphony (E73) Michelangelo's David Einstein's Theory of General Relativity (E73) the taxon 'Fringilla coelebs Linnaeus,1758' (E55)
In first Order Logic	E71(x) ⊃ E70(x)
Properties:	P102 has title (is title of) : E35 Title, P103 was intended for (was intention of) : E55 Type

E72 Legal Object

Subclass of: E70 Thing

Superclass of: E18 Physical Thing, E90 Symbolic Object

Scope note: This class comprises those material or immaterial items to which instances of E30 Right, such as the right of ownership or use, can be applied.
This is true for all E18 Physical Thing. In the case of instances of E28 Conceptual Object, however, the identity of the E28 Conceptual Object or the method of its use may be too ambiguous to reliably establish instances of E30 Right, as in the case of taxa and inspirations. Ownership of corporations is currently regarded as out of scope of the CRM.

Examples: the Cullinan diamond (E19)
definition of the CIDOC Conceptual Reference Model Version 2.1 (E73)

In first Order Logic E72(x) ⊃ E70(x)

Properties: P104 is subject to (applies to) : E39 Actor,
P105 right held by (has right on) : E39 Actor

E73 Information Object

Subclass of: E89 Propositional Object, E90 Symbolic Object

Superclass of: E29 Design or Procedure, E31 Document, E33 Linguistic Object, E36 Visual Item

Scope note: This class comprises identifiable immaterial items, such as a poems, jokes, data sets, images, texts, multimedia objects, procedural prescriptions, computer program code, algorithm or mathematical formulae, that have an objectively recognizable structure and are documented as single units. The encoding structure known as a “named graph” also falls under this class, so that each “named graph” is an instance of an E73 Information Object.
An E73 Information Object does not depend on a specific physical carrier, which can include human memory, and it can exist on one or more carriers simultaneously.
Instances of E73 Information Object of a linguistic nature should be declared as instances of the E33 Linguistic Object subclass. Instances of E73 Information Object of a documentary nature should be declared as instances of the E31 Document subclass. Conceptual items such as types and classes are not instances of E73 Information Object, nor are ideas without a reproducible expression.

Examples: image BM000038850.JPG from the Clayton Herbarium in London
E. A. Poe’s “The Raven”
the movie “The Seven Samurai” by Akira Kurosawa
the Maxwell Equations
The Getty AAT as published as Linked Open Data, accessed 1/10/2014

In first Order Logic E73(x) ⊃ E89(x) , E73(x) ⊃ E90(x)

Properties: P165 incorporates (is incorporated in) : E90 Symbolic Object

E77 Persistent Item

Subclass of: E1 CRM Entity

Superclass of: E39 Actor, E70 Thing

Scope note: This class comprises items that have a persistent identity, sometimes known as “endurants” in philosophy.
They can be repeatedly recognized within the duration of their existence by identity criteria rather than by continuity or observation. Persistent Items can be either physical entities, such as people, animals or things, or conceptual entities such as ideas, concepts, products of the imagination or common names.
The criteria that determine the identity of an item are often difficult to establish -; the decision depends largely on the judgement of the observer. For example, a building is regarded as no longer existing if it is dismantled and the materials reused in a different configuration. On the other hand, human beings go through radical and profound changes during their life-span, affecting both material composition and form, yet preserve their identity by other criteria. Similarly, inanimate objects may be subject to exchange of parts and matter. The class E77 Persistent Item does not take any position about the nature of the applicable identity criteria and if actual knowledge about identity of an instance of this class exists. There may be cases, where the identity of an E77 Persistent Item is not decidable by a certain state of knowledge.
The main classes of objects that fall outside the scope the E77 Persistent Item class are temporal objects such as periods, events and acts, and descriptive properties.

Examples: Leonard da Vinci
Stonehenge
the hole in the ozone layer
the First Law of Thermodynamics
the Bermuda Triangle

In first Order Logic E77(x) ⊃ E1(x)

E89 Propositional Object	
Subclass of:	E28 Conceptual Object
Superclass of:	E30 Right, E73 Information Object
Scope note:	This class comprises immaterial items, including but not limited to stories, plots, procedural prescriptions, al-gorithms, laws of physics or images that are, or represent in some sense, sets of propositions about real or imaginary things and that are documented as single units or serve as topic of discourse. This class also comprises items that are “about” something in the sense of a subject. In the wider sense, this class includes expressions of psychological value such as non-figural art and musical themes. However, con-ceptual items such as types and classes are not instances of E89 Propositional Object. This should not be con-fused with the definition of a type, which is indeed an instance of E89 Propositional Object.
Examples:	Maxwell’s Equations The ideational contents of Aristotle’s book entitled ‘Metaphysics’ as rendered in the Greek texts translated in … Oxford edition… The underlying prototype of any “no-smoking” sign (E36) The common ideas of the plots of the movie “The Seven Samurai” by Akira Kurosawa and the movie “The Magnificent Seven” by John Sturges The image content of the photo of the Allied Leaders at Yalta 1945 (E38)
In first Order Logic	E89(x) □ E28(x)
Properties:	P67 refers to (is referred to by) : E1 CRM Entity, P129 is about (is subject of) : E1 CRM Entity, P148 has component (is component of) : E89 Propositional Object

E90 Symbolic Object	
Subclass of:	E28 Conceptual Object, E72 Legal Object
Superclass of:	E41 Appellation, E73 Information Object
Scope note:	This class comprises identifiable symbols and any aggregation of symbols, such as characters, identifiers, traffic signs, emblems, texts, data sets, images, musical scores, multimedia objects, computer program code or mathematical formulae that have an objectively recognizable structure and that are documented as single units. It includes sets of signs of any nature, which may serve to designate something, or to communicate some propositional content. An instance of E90 Symbolic Object does not depend on a specific physical carrier, which can include human memory, and it can exist on one or more carriers simultaneously. An instance of E90 Symbolic Object may or may not have a specific meaning, for example an arbitrary character string. In some cases, the content of an instance of E90 Symbolic Object may completely be represented by a serialized digital content model, such as a sequence of ASCII-encoded characters, an XML or HTML document, or a TIFF image. The property P3 has note allows for the description of this content model. In order to disambiguate which symbolic level is the carrier of the meaning, the property P3.1 has type can be used to specify the encoding (e.g. “bit”, “Latin character”, RGB pixel).
Examples:	‘ecognizabl’ The “no-smoking” sign (E36) “BM000038850.JPG” (E75) image BM000038850.JPG from the Clayton Herbarium in London (E38) The distribution of form, tone and colour found on Leonardo da Vinci’s painting named “Mona Lisa” in daylight (E38) The Italian text of Dante’s “Divina Commedia” as found in the authoritative critical edition La Commedia secondo l’antica vulgata a cura di Giorgio Petrocchi, Milano: Mondadori, 1966-67 (= Le Opere di Dante Alighieri, Edizione Nazionale a cura della Società Dantesca Italiana, VII, 1-4) (E33)
In first Order Logic	E90(x) □ E28(x), E90(x) □ E72(x)
Properties:	P106 is composed of (forms part of) : E90 Symbolic Object

Referred to CRMdig Classes | Version 3.2.1

D1 Digital Object

Subclass of:	E73 Information Object
Superclass of:	D9 Data Object, D14 Software, D35 Area
Scope note:	This class comprises identifiable immaterial items that can be represented as sets of bit sequences, such as data sets, e-texts, images, audio or video items, software, etc., and are documented as single units. Any aggregation of instances of D1 Digital Object into a whole treated as single unit is also regarded as an instance of D1 Digital Object. This means that for instance, the content of a DVD, an XML file on it, and an element of this file, are regarded as distinct instances of D1 Digital Object, mutually related by the P106 is composed of (forms part of) property. A D1 Digital Object does not depend on a specific physical carrier, and it can exist on one or more carriers simultaneously.

Referred to CRMsci Classes | Version 1.2.3

S5 Inference Making

Subclass of:	E13 Attribute Assignment
Superclass of:	S6 Data Evaluation, S7 Simulation or Prediction, S8 Categorical Hypothesis Building
Scope note:	This class comprises the action of making propositions and statements about particular states of affairs in reality or in possible realities or categorical descriptions of reality by using inferences from other statements based on hypotheses and any form of formal or informal logic. It includes evaluations, calculations, and interpretations based on mathematical formulations and propositions.
In first Order Logic	S5(x) □ E13(x)

Referred to CIDOC-CRM Properties | Version 6.2

P1 is identified by (identifies)	
Domain:	E1 CRM Entity
Range:	E41 Appellation
Subproperty of:	
Superproperty of:	E1 CRM Entity. P48 has preferred identifier (is preferred identifier of): E42 Identifier E52 Time-Span. P78 is identified by (identifies): E49 Time Appellation E53 Place. P87 is identified by (identifies): E44 Place Appellation, E71 Man-Made Thing. P102 has title (is title of): E35 Title E39 Actor. P131 is identified by (identifies): E82 Actor Appellation, E28 Conceptual Object. P149 is identified by (identifies): E75 Conceptual Object Appellation
Quantification	many to many (0,n:0,n)
Scope Note:	This property describes the naming or identification of any real world item by a name or any other identifier. This property is intended for identifiers in general use which form part of the world the model intends to describe and not merely for internal database identifiers which are specific to a technical system unless these latter also have a more general use outside the technical context. This property includes in particular identification by mathematical expressions such as coordinate systems used for the identification of instances of E53 Place. The property does not reveal anything about when where and by whom this identifier was used. A more detailed representation can be made using the fully developed (i.e. indirect) path through E15 Identifier Assignment.
Examples	the capital of Italy (E53) is identified by “Rome” (E48) text 25014–32 (E33) is identified by “The Decline and Fall of the Roman Empire” (E35)
In First Order Logic:	P1(x,y) E1(x) , P1(x,y) E41(y)

P2 has type (is type of)	
Domain:	E1 CRM Entity
Range:	E55 Type
Subproperty of:	
Superproperty of:	E1 CRM Entity. P137 exemplifies (is exemplified by): E55 Type
Quantification	many to many (0,n:0,n)
Scope Note:	This property allows sub typing of CRM entities - a form of specialisation – through the use of a terminological hierarchy or thesaurus. The CRM is intended to focus on the high-level entities and relationships needed to describe data structures. Consequently it does not specialise entities any further than is required for this immediate purpose. However entities in the isA hierarchy of the CRM may by specialised into any number of sub entities which can be defined in the E55 Type hierarchy. E51 Contact Point for example may be specialised into “e-mail address” “telephone number” “post office box” “URL” etc. none of which figures explicitly in the CRM hierarchy. Sub typing obviously requires consistency between the meaning of the terms assigned and the more general intent of the CRM entity in question.
Examples	“enquiries@cidoc-crm.org” (E51) has type e-mail address (E55)
In First Order Logic:	P2(x,y) E1(x) , P2(x,y) E55(y)

P12 occurred in the presence of (was present at)	
Domain:	E5 Event
Range:	E77 Persistent Item
Subproperty of:	
Superproperty of:	E5 Event. P11 had participant (participated in): E39 Actor E7 Activity. P16 used specific object (was used for): E70 Thing E9 Move. P25 moved (moved by): E19 Physical Object E11 Modification. P31 has modified (was modified by): E24 Physical Man-Made Thing E63 Beginning of Existence. P92 brought into existence (was brought into existence by): E77 Persistent Item E64 End of Existence. P93 took out of existence (was taken out of existence by): E77 Persistent Item E79 Part Addition. P111 added (was added by): E18 Physical Thing E80 Part Removal. P113 removed (was removed by): E18 Physical Thing
Quantification	many to many, necessary (1,n:0,n)
Scope Note:	This property describes the active or passive presence of an E77 Persistent Item in an E5 Event without implying any specific role. It connects the history of a thing with the E53 Place and E50 Date of an event. For example, an object may be the desk, now in a museum on which a treaty was signed. The presence of an immaterial thing implies the presence of at least one of its carriers.
Examples	Deckchair 42 (E19) was present at The sinking of the Titanic (E5)
In First Order Logic:	P12(x,y) □ E5(x) , P12(x,y) □ E77(y)

P11 had participant (participated in)	
Domain:	E5 Event
Range:	E39 Actor
Subproperty of:	E5 Event. P12 occurred in the presence of (was present at): E77 Persistent Item
Superproperty of:	E7 Activity. P14 carried out by (performed): E39 Actor, E67 Birth. P96 by mother (gave birth): E21 Person, E68 Dissolution. P99 dissolved (was dissolved by): E74 Group, E85 Joining. P143 joined (was joined by): E39 Actor, E85 Joining. P144 joined with (gained member by): E74 Group, E86 Leaving. P145 separated (left by): E39 Actor, E86 Leaving. P146 separated from (lost member by): E74 Group, E66 Formation. P151 was formed from (participated in): E74 Group
Quantification	many to many (0,n:0,n)
Scope Note:	This property describes the active or passive participation of instances of E39 Actors in an E5 Event. It connects the life-line of the related E39 Actor with the E53 Place and E50 Date of the event. The property implies that the Actor was involved in the event but does not imply any causal relationship. The subject of a portrait can be said to have participated in the creation of the portrait.
Examples	Napoleon (E21) participated in The Battle of Waterloo (E7) Maria (E21) participated in Photographing of Maria (E7)
In First Order Logic:	P11(x,y) □ E5(x), P11(x,y) □ E39(y), P11(x,y) □ P12(x,y)

P14 carried out by (performed)	
Domain:	E7 Activity
Range:	E39 Actor
Subproperty of:	E5 Event. P11 had participant (participated in): E39 Actor
Superproperty of:	E8 Acquisition. P22 transferred title to (acquired title through): E39 Actor, E8 Acquisition. P23 transferred title from (surrendered title through): E39 Actor, E10 Transfer of Custody. P28 custody surrendered by (surrendered custody through): E39 Actor, E10 Transfer of Custody. P29 custody received by (received custody through): E39 Actor
Quantification	many to many, necessary (1,n:0,n)
Scope Note:	This property describes the active participation of an E39 Actor in an E7 Activity. It implies causal or legal responsibility. The P14.1 in the role of property of the property allows the nature of an Actor's participation to be specified.
Examples	the painting of the Sistine Chapel (E7) carried out by Michaelangelo Buonaroti (E21) in the role of master craftsman (E55)
In First Order Logic:	P14 (x,y) □ E7(x), P14 (x,y)□ E39(y), P14 (x,y) □ P11(x,y), P14(x,y,z) □ [P14(x,y) □ E55(z)]

P43 has dimension (is dimension of)

Domain:	E70 Thing
Range:	E54 Dimension
Subproperty of:	No subproperties found
Superproperty of:	No superproperties found
Quantification	one to many, dependent (0,n:1,1)
Scope Note:	This property records a E54 Dimension of some E70 Thing. It is a shortcut of the more fully developed path from E70 Thing through P39 measured (was measured by), E16 Measurement P40 observed dimension (was observed in) to E54 Dimension. It offers no information about how and when an E54 Dimension was established, nor by whom. An instance of E54 Dimension is specific to an instance of E70 Thing.
Examples	silver cup 232 (E22) has dimension height of silver cup 232 (E54) has unit (P91) mm (E58), has value (P90) 224 (E60)
In First Order Logic:	P43(x,y) □ E70(x) , P43(x,y) □ E54(y)

P57 has number of parts

Domain:	E19 Physical Object
Range:	E60 Number
Subproperty of:	No subproperties found
Superproperty of:	No superproperties found
Quantification	many to one (0,1:0,n)
Scope Note:	This property documents the E60 Number of parts of which an instance of E19 Physical Object is composed. This may be used as a method of checking inventory counts with regard to aggregate or collective objects. What constitutes a part or component depends on the context and requirements of the documentation. Normally, the parts documented in this way would not be considered as worthy of individual attention For a more complete description, objects may be decomposed into their components and constituents using P46 is composed of (forms parts of) and P45 consists of (is incorporated in). This allows each element to be described individually.
Examples	chess set 233 (E22) has number of parts 33 (E60)
In First Order Logic:	P57(x,y) □ E19(x), P57(x,y) □ E60(y)

P67 refers to (is referred to by)

Domain:	E89 Propositional Object
Range:	E1 CRM Entity
Subproperty of:	No subproperties found
Superproperty of:	E29 Design or Procedure. P68 foresees use of (use foreseen by): E57 Material, E31 Document. P70 documents (is documented in): E1 CRM Entity, E32 Authority Document. P71 lists (is listed in): E1 CRM Entity, E89 Propositional Object. P129 is about (is subject of): E1 CRM Entity, E36 Visual Item. P138 represents (has representation): E1 CRM Entity
Quantification	many to many (0,n:0,n)
Scope Note:	This property documents that an E89 Propositional Object makes a statement about an instance of E1 CRM Entity. P67 refers to (is referred to by) has the P67.1 has type link to an instance of E55 Type. This is intended to allow a more detailed description of the type of reference. This differs from P129 is about (is subject of), which describes the primary subject or subjects of the E89 Propositional Object.
Examples	the eBay auction listing of 4 July 2002 (E73) refers to silver cup 232 (E22) has type item for sale (E55)
In First Order Logic:	P67(x,y) □ E89(x), P67(x,y) □ E1(y) , P67(x,y,z) □ [P67(x,y) □ E55(z)]

P70 documents (is documented in)	
Domain:	E31 Document
Range:	E1 CRM Entity
Subproperty of:	E89 Propositional Object. P67 refers to (is referred to by): E1 CRM Entity
Superproperty of:	No superproperties found
Quantification	many to many, necessary (1,n:0,n)
Scope Note:	This property documents a source E32 Authority Document for an instance of an E1 CRM Entity.
Examples	the Art & Architecture Thesaurus (E32) lists alcazars (E55)
In First Order Logic:	P70 (x,y) □ E31(x) , P70 (x,y) □ E1(y), P70(x,y) □ P67(x,y)

P90 has value	
Domain:	E54 Dimension
Range:	E60 Number
Subproperty of:	No subproperties found
Superproperty of:	No superproperties found
Quantification	many to one, necessary (1,1:0,n)
Scope Note:	This property allows an E54 Dimension to be approximated by an E60 Number primitive.
Examples	height of silver cup 232 (E54) has value 226 (E60)
In First Order Logic:	P90(x,y) □ E54(x) , P90(x,y) □ E60(y)

P91 has unit (is unit of)	
Domain:	E54 Dimension
Range:	E58 Measurement Unit
Subproperty of:	No subproperties found
Superproperty of:	No superproperties found
Quantification	many to one, necessary (1,1:0,n)
Scope Note:	This property shows the type of unit an E54 Dimension was expressed in.
Examples	height of silver cup 232 (E54) has unit mm (E58)
In First Order Logic:	P91(x,y) □ E54(x) ,P91(x,y) □ E58(y)

P138 represents (has representation)	
Domain:	E36 Visual Item
Range:	E1 CRM Entity
Subproperty of:	E89 Propositional Object. P67 refers to (is referred to by): E1 CRM Entity
Superproperty of:	No superproperties found
Quantification	many to many (0,n:0,n)
Scope Note:	This property establishes the relationship between an E36 Visual Item and the entity that it visually represents. Any entity may be represented visually. This property is part of the fully developed path from E24 Physical Man-Made Thing through P65 shows visual item (is shown by), E36 Visual Item, P138 represents (has representation) to E1 CRM Entity, which is shortcut by P62depicts (is depicted by). P138.1 mode of representation allows the nature of the representation to be refined. This property is also used for the relationship between an original and a digitisation of the original by the use of techniques such as digital photography, flatbed or infrared scanning. Digitisation is here seen as a process with a mechanical, causal component rendering the spatial distribution of structural and optical properties of the original and does not necessarily include any visual similarity identifiable by human observation.
Examples	the digital file found at http://www.emunch.no/N/full/No-MM_N0001-01.jpg (E73) represents page 1 of Edward Munch's manuscript MM N 1, Munch-museet (E73) mode of representation Digitisation(E55) The 3D model VAM_A.200-1946_trace_1M.ply (E73) represents Victoria & Albert Museum's Madonna and child sculpture (visual work) A.200-1946 (E22) mode of representation 3D surface (E55)
In First Order Logic:	P138(x,y) □ E36(x) , P138(x,y) □ E1(y) , P138(x,y,z) □ [P138(x,y) □ E55(z)] , P138(x,y) □ P67(x,y)

P139 has alternative form	
Domain:	E41 Appellation
Range:	E41 Appellation
Subproperty of:	No subproperties found
Superproperty of:	No superproperties found
Quantification	many to many (0,n:0,n)
Scope Note:	This property establishes a relationship of equivalence between two instances of E41 Appellation independent from any item identified by them. It is a dynamic asymmetric relationship, where the range expresses the derivative, if such a direction can be established. Otherwise, the relationship is symmetric. The relationship is not transitive. The equivalence applies to all cases of use of an instance of E41 Appellation. Multiple names assigned to an object, which are not equivalent for all things identified with a specific instance of E41 Appellation, should be modelled as repeated values of P1 is identified by (identifies). P139.1 has type allows the type of derivation, such as “transliteration from Latin 1 to ASCII” be refined..
Examples	“Martin Doerr” (E41) has alternative form “Martin Dörr” (E41) has type Alternate spelling (E55) “Гончарова, Наталья Сергеевна” (E41) has alternative form “Gončarova, Natal´â Sergeevna” (E41) has type ISO 9:1995 transliteration (E55) “Αθήνα” has alternative form “Athina” has type transcription.
In First Order Logic:	P139(x,y) E41(x) , P139 (x,y) E41(y) , P139(x,y,z) [P139(x,y) E55(z)] , P139(x,y) P139(y,x)

P140 assigned attribute to (was attributed by)	
Domain:	E13 Attribute Assignment
Range:	E1 CRM Entity
Subproperty of:	No subproperties found
Superproperty of:	E14 Condition Assessment. P34 concerned (was assessed by): E18 Physical Thing, E16 Measurement. P39 measured (was measured by): E1 CRM Entity, E17 Type Assignment. P41 classified (was classified by): E1 CRM Entity
Quantification	many to many (0,n:0,n)
Scope Note:	This property indicates the item to which an attribute or relation is assigned.
Examples	February 1997 Current Ownership Assessment of Martin Doerr’s silver cup (E13) assigned attribute to Martin Doerr’s silver cup (E19) 01 June 1997 Identifier Assignment of the silver cup donated by Martin Doerr (E15) assigned attribute to silver cup 232 (E19)
In First Order Logic:	P140(x,y) E13(x), P140(x,y) E1(y)

P141 assigned (was assigned by)	
Domain:	E13 Attribute Assignment
Range:	E1 CRM Entity
Subproperty of:	No subproperties found
Superproperty of:	E14 Condition Assessment. P35 has identified (was identified by): E3 Condition State, E15 Identifier Assignment. P37 assigned (was assigned by): E42 Identifier, E15 Identifier Assignment. P38 deassigned (was deassigned by): E42 Identifier, E16 Measurement. P40 observed dimension (was observed in): E54 Dimension, E17 Type Assignment. P42 assigned (was assigned by): E55 Type
Quantification	many to many (0,n:0,n)
Scope Note:	This property indicates the attribute that was assigned or the item that was related to the item denoted by a property P140 assigned attribute to in an Attribute assignment action.
Examples	February 1997 Current Ownership Assessment of Martin Doerr’s silver cup (E13) assigned Martin Doerr (E21) 01 June 1997 Identifier Assignment of the silver cup donated by Martin Doerr (E15) assigned object identifier 232
In First Order Logic:	P141(x,y) E13(x) , P141(x,y) E1(y)

P148 has component (is component of)	
Domain:	E89 Propositional Object
Range:	E89 Propositional Object
Subproperty of:	No subproperties found
Superproperty of:	No superproperties found
Quantification	many to many (0,n:0,n)
Scope Note:	This property associates an instance of E89 Propositional Object with a structural part of it that is by itself an instance of E89 Propositional Object.
Examples	Dante’s “Divine Comedy” (E89) has component Dante’s “Hell” (E89)
In First Order Logic:	P148(x,y) □ E89(x), P148(x,y) □ E89(y)

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L21 used as derivation source (was derivation source for)	
Domain:	D3 Formal Derivation
Range:	D1 Digital Object
Subproperty of:	D10 Software Execution: L2 used as source (was source for): D1 Digital Object
Scope Note:	This property associates an instance of a D3 Formal Derivation with the instance of D1 Digital Object that is used as a derivation source

Appendix B

Code Script for Geometrical Atoms

The VRIM package can be found in Dynamo , by performing the next steps:
1. In Dynamo go to packages > Search for a package
2. In the next dialog find the appropriate package and install it using the “arrow” button
Once you have installed VRIM, it is possible to find following sections in your Dynamo Library:
Function: with these functions it is possible to automatically create a Moulding Profile using input data of an external .xls file that contain LoI (related to parameters information) and LoG (referred to dimensions of each geometry). The Function sections is composed by two nodes that have the same output but in different coordinate systems based on plane XY or plane XZ.
Solid: provides nodes to create solid and a series of solids
Geometry: offers a series of nodes defined for both coordinate systems based on plane XY or plane XZ to define the profile of a moulding. Each node defined by the grid of 9 points has “default value” of height and width as 10 unit.
The following list of codes were designed using DesignScript code in Dynamo. All the codes were developed inside “code block” nodes and could have further implementation into IronPhyton.
The function node is not declared here, because of the redundancy of the script: in the function node an “Imperative Function” works and choose, according with the input declarations, witch GeometryNode is suitable to use. The VRIM package it was developed using Dynamo and it is free to use to all Dynamo Members community.
Even if the final Output could be create into Revit environment, the methodology proposed is aware from Revit and it was in fact developed with Dynamo that is an Open Source Software.

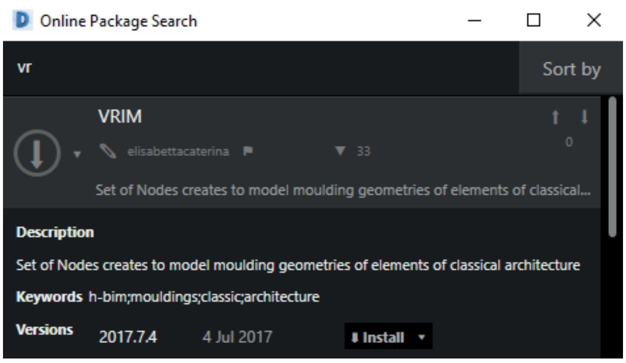


Fig 61: *VRIM package available Online*

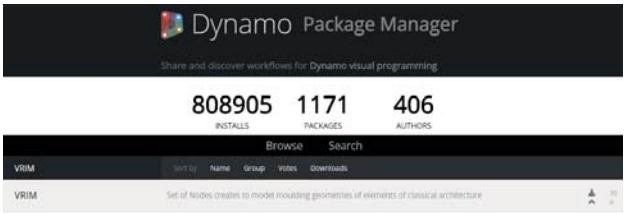
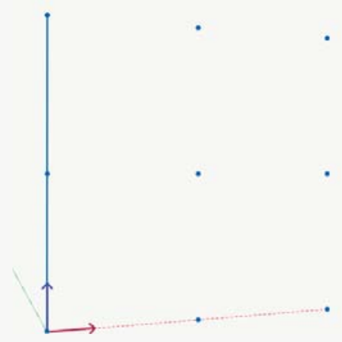


Fig 60: *DynamoPackage webpage at http://dynamopackages.com/*



Geometrical Atom: ***1a***

Coordinate System: ***(x,y)***
Number of object type: ***1***

```
//Measurements - Profile 1a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

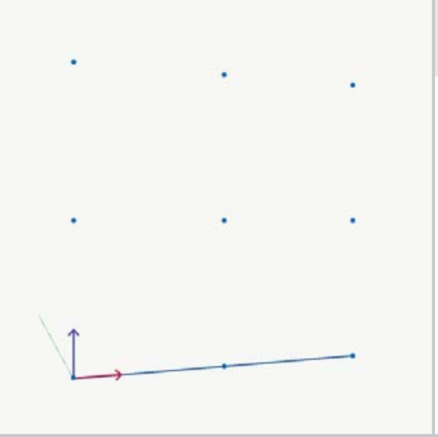
```
//Measurements - Path 1a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometryOutput =Line.ByStartPointEndPoint(A, D);
```

Code 6: *Geometrical Atom - 1a*



Geometrical Atom: ***1b***

Coordinate System: ***(x,y)***
Number of object type: ***1***

```
//Measurements - Profile 1b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

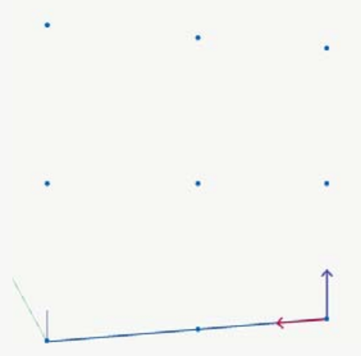
```
//Measurements - Path 1b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometryOutput =Line.ByStartPointEndPoint(A, B);
```

Code 7: *Geometrical Atom - 1b*



Geometrical Atom: ***1c***

Coordinate System: ***(x,y)***
Number of object type: ***1***

```
//Measurements - Profile 1c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

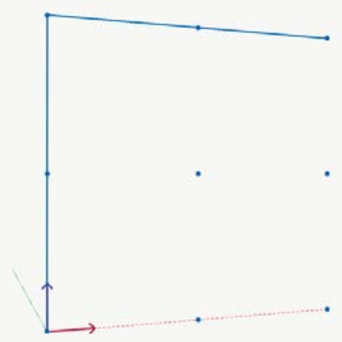
```
//Measurements - Path 1c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometryOutput =Line.ByStartPointEndPoint(B, A);
```

Code 8: *Geometrical Atom - 1c*



Geometrical Atom: ***2a***

Coordinate System: ***(x,y)***
Number of object type: ***2***

```
//Measurements - Profile 2a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

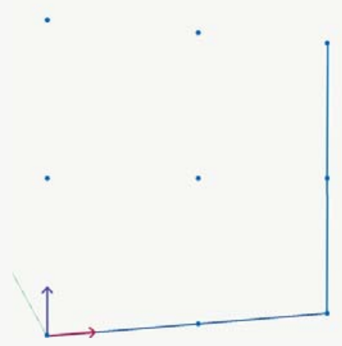
```
//Measurements - Path 2a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {A, D, C};
geometryOutput = PolyCurve.ByPoints(t1, false);
```

Code 9: *Geometrical Atom - 2a*



Geometrical Atom: ***2b***

Coordinate System: ***(x,y)***
Number of object type: ***2***

```
//Measurements - Profile 2b
H1;
W1;
W0= StartPt.X;
H0= StartPt.Z;

//Local System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

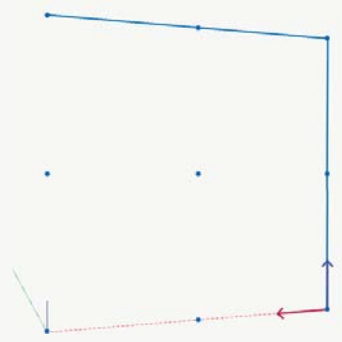
```
//Measurements - Path 2b
H1;
W1;
W0= StartPt.X;
H0= StartPt.Y;

//Local System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry 2b
t1 = {A, B, C};
geometry2b = PolyCurve.ByPoints(t1, false);
```

Code 10: *Geometrical Atom - 2b*



Geometrical Atom: ***2c***

Coordinate System: ***(-x,y)***
Number of object type: ***2***

```
//Measurements - 2c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Local System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

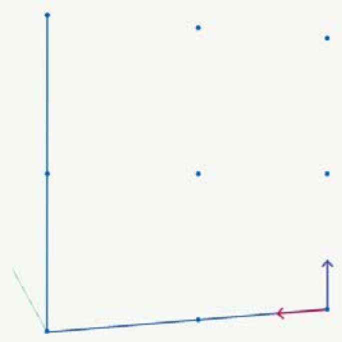
```
//Measurements - 2c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Local System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry 2c
t1 = {B, C, D};
geometry2c = PolyCurve.ByPoints(t1, false);
```

Code 11: *Geometrical Atom - 2c*



Geometrical Atom: ***2d***

Coordinate System: ***(-x,y)***
Number of object type: ***2***

```
//Measurements - 2d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Local System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

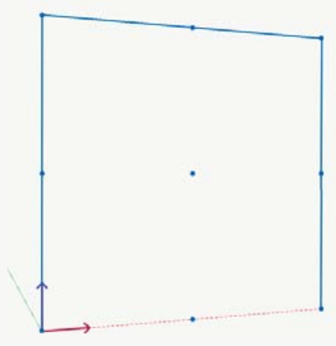
```
//Measurements - 2d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Local System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry 2d
t1 = {B, A, D};
geometry2d = PolyCurve.ByPoints(t1, false);
```

Code 12: *Geometrical Atom - 2d*



Geometrical Atom: *3a*

Coordinate System: ***(x,y)***
Number of object type: ***2***

```
//Measurements - 3a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

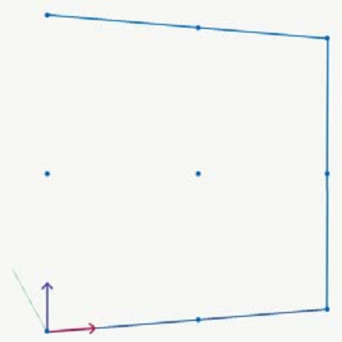
```
//Measurements - 3a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry 3a
t1 = {A, D, C, B};
geometryOutput = PolyCurve.ByPoints(t1, false);
```

Code 13: *Geometrical Atom - 3a*



Geometrical Atom: ***3b***

Coordinate System: ***(x,y)***
Number of object type: ***2***

```
//Measurements - Profile 3b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

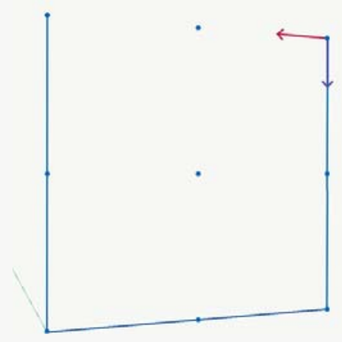
```
//Measurements - Path 3b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {A, B, C, D};
geometryOutput = PolyCurve.ByPoints(t1, false);
```

Code 14: *Geometrical Atom - 3b*



Geometrical Atom: ***3c***

Coordinate System: ***(-x,-y)***
Number of object type: ***2***

```
//Measurements - Profile 3c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,-z)
Ax = W0-W1;
Az = H0-H1;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0-(H1/2);
Dz = H0;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

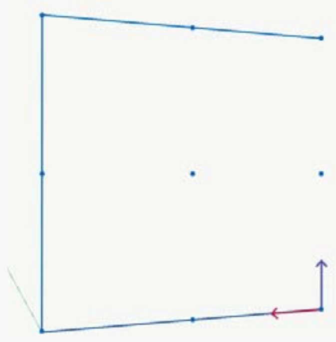
```
//Measurements - Path 3c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,-y)
Ax = W0-W1;
Ay = H0-H1;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {C, B, A, D};
geometryOutput = PolyCurve.ByPoints(t1, false);
```

Code 15: *Geometrical Atom - 3c*



Geometrical Atom: ***3d***

Coordinate System: ***(-x,y)***
Number of object type: ***2***

```
//Measurements - Profile 3d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

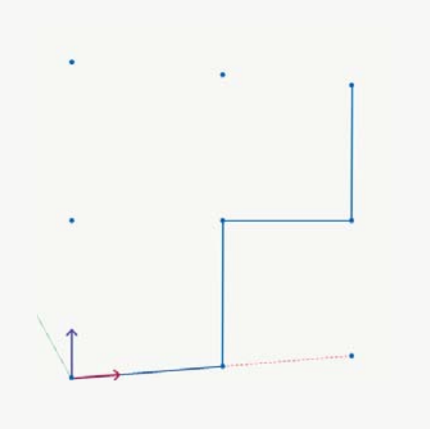
```
//Measurements - Path 3d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {B, A, D, C};
geometryOutput = PolyCurve.ByPoints(t1, false);
```

Code 16: *Geometrical Atom - 3d*



Geometrical Atom: ***4a***

Coordinate System: ***(x,y)***
Number of object type: ***5***

```
//Measurements - 4a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

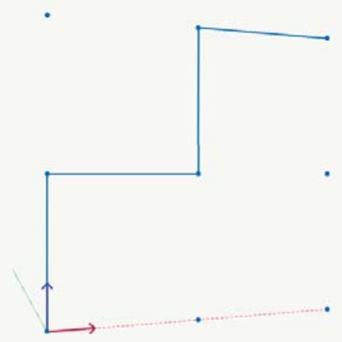
```
//Measurements - Path 4a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {O, E, A};
t2 = {O, F, C};
polyCurve1 = PolyCurve.ByPoints(t1, false);
polyCurve2 = PolyCurve.ByPoints(t2, false);
geometryOutput = {polyCurve1, polyCurve2};
```

Code 17: *Geometrical Atom - 4a*



Geometrical Atom: ***4b***

Coordinate System: ***(x,y)***
Number of object type: ***5***

```
//Measurements - 4b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

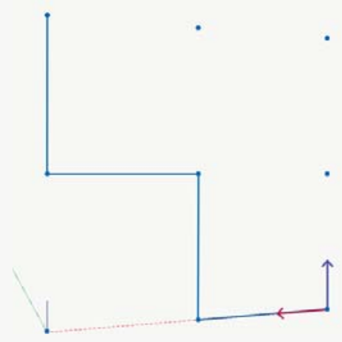
```
//Measurements - Path 4b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {O, H, A};
t2 = {O, G, C};
polyCurve1 = PolyCurve.ByPoints(t1, false);
polyCurve2 = PolyCurve.ByPoints(t2, false);
geometryOutput = {polyCurve1, polyCurve2};
```

Code 18: *Geometrical Atom - 4b*



Geometrical Atom: ***4c***

Coordinate System: ***(-x,y)***
Number of object type: ***5***

```
//Measurements - Profile 4c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

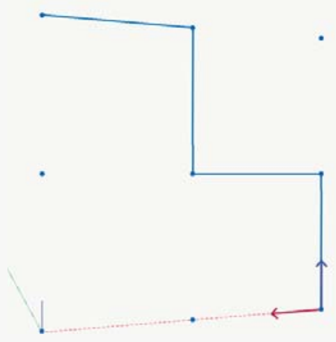
```
//Measurements - Path 4c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {D, H, O};
t2 = {B, E, O};
polyCurve1 = PolyCurve.ByPoints(t1, false);
polyCurve2 = PolyCurve.ByPoints(t2, false);
geometryOutput = {polyCurve1, polyCurve2};
```

Code 19: *Geometrical Atom - 4c*



Geometrical Atom: ***4d***

Coordinate System: ***(-x,y)***
Number of object type: ***5***

```
//Measurements - Profile 4d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

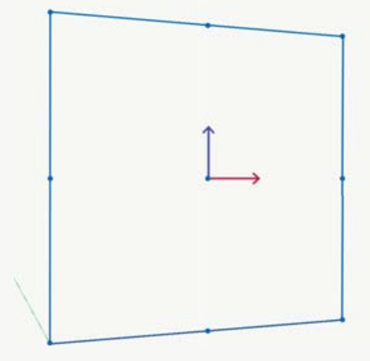
```
//Measurements - Path 4d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {B, F, O};
t2 = {D, G, O};
polyCurve1 = PolyCurve.ByPoints(t1, false);
polyCurve2 = PolyCurve.ByPoints(t2, false);
geometryOutput = {polyCurve1, polyCurve2};
```

Code 20: *Geometrical Atom - 4d*



Geometrical Atom: ***5a***

Coordinate System: ***(x,y)***
Number of object type: ***5***

```
//Measurements - Profile 5a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
centered in O grid point
Ax = W0-(W1/2);
Az = H0-(H1/2);
Ex = W0;
Bx = H0+(H1/2);
Hz = H0;
Dz = H0+(H1/2);

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

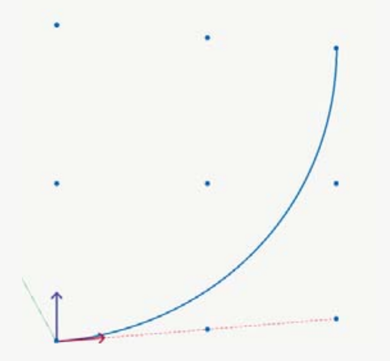
```
//Measurements - Path 5a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
centered in O grid point
Ax = W0-(W1/2);
Ay = H0-(H1/2);
Ox = W0;
Bx = H0+(H1/2);
Oy = H0;
Cy = H0+(H1/2);

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
t1 = {C, B, A};
t2 = {C, D, A};
polyCurve1 = PolyCurve.ByPoints(t1, false);
polyCurve2 = PolyCurve.ByPoints(t2, false);
geometryOutput = {polyCurve1, polyCurve2};
```

Code 21: *Geometrical Atom - 5a*



Geometrical Atom: ***6a***

Coordinate System: ***(x,y)***
Number of object type: ***20***

```
//Measurements - Profile 6a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

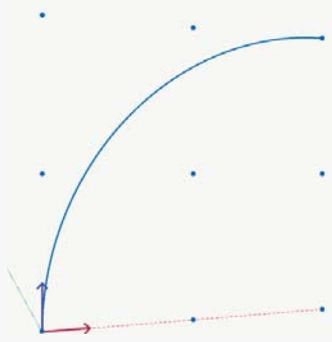
```
//Measurements - Path 6a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry6a = [Imperative]
{
if(H1>W1)
{
//Geometry by arc
plane1 = Plane.ByThreePoints(C, G, F);
plane2 = Plane.ByThreePoints(A, E, H);
x1 = A.DistanceTo(C);
circle1 = Circle.ByPlaneRadius(plane1, x1);
circle2 = Circle.ByPlaneRadius(plane2, x1);
ip1 = circle1.Intersect(circle2);
p1 = ip1[0];
p2 = ip1[1];
v1 = Vector.ByTwoPoints(p1, p2);
v2 = Vector.ByTwoPoints(C, D);
l1 = Line.ByStartPointDirectionLength(p1, v1, 3000);
l2 = Line.ByStartPointDirectionLength(C, v2, 3000);
intP = l1.Intersect(l2);
geometry6a = Arc.ByCenterPointStartPointEndPoint(intP, C, A);
InfOutput = {geometry6a, H1, W1};
return= {InfOutput, C};
}
else
{//Geometry by ellipse
r1 = W1;
r2 = H1;
plane = Plane.ByThreePoints(D, H, G);
geometry6a = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 0, 90);
InfOutput = {geometry6a, H1, W1};
return= {InfOutput, C};
}
};
```

Code 22: *Geometrical Atom - 6a*



Geometrical Atom: ***6b***

Coordinate System: ***(x,y)***
Number of object type: ***20***

```
//Measurements - Profile 6b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

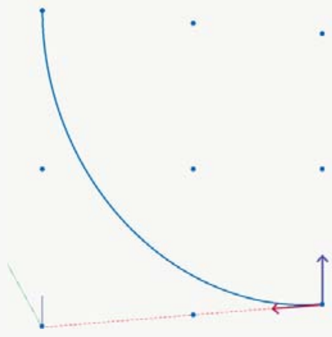
```
//Measurements - Path 6b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry6b = [Imperative]
{
if(H1>W1)
{
//Geometry
plane1 = Plane.ByThreePoints(C, G, F);
plane2 = Plane.ByThreePoints(A, E, H);
x1 = A.DistanceTo(C);
circle1 = Circle.ByPlaneRadius(plane1, x1);
circle2 = Circle.ByPlaneRadius(plane2, x1);
ip1 = circle1.Intersect(circle2);
p1 = ip1[0];
p2 = ip1[1];
v1 = Vector.ByTwoPoints(p2, p1);
v2 = Vector.ByTwoPoints(A, B);
l1 = Line.ByStartPointDirectionLength(p2, v1, 3000);
l2 = Line.ByStartPointDirectionLength(A, v2, 3000);
intP = l1.Intersect(l2);
geometry6b = Arc.ByCenterPointStartPointEndPoint(intP, A, C);
InfOutput = {geometry6b, H1, W1};
return= {InfOutput, C};
}
else
{
//Geometry
r1 = W1;
r2 = H1;
plane = Plane.ByThreePoints(B, F, E);
geometry6b = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 90, -90);
InfOutput = {geometry6b, H1, W1};
return= {InfOutput, C};
}
};
```

Code 23: *Geometrical Atom - 6b*



Geometrical Atom: ***6c***

Coordinate System: ***(-x,y)***
Number of object type: ***20***

```
//Measurements - Profile 6c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

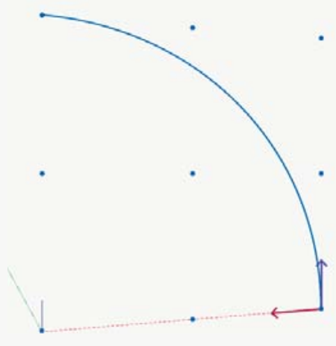
```
//Measurements - Path 6c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry6c = [Imperative]
{
if(H1>W1)
{
//Geometry 6c arc
plane1 = Plane.ByThreePoints(B, F, E);
plane2 = Plane.ByThreePoints(D, F, G);
x1 = B.DistanceTo(D);
circle1 = Circle.ByPlaneRadius(plane1, x1);
circle2 = Circle.ByPlaneRadius(plane2, x1);
ip1 = circle1.Intersect(circle2);
p1 = ip1[0];
p2 = ip1[1];
v1 = Vector.ByTwoPoints(p1, p2);
v2 = Vector.ByTwoPoints(D, C);
l1 = Line.ByStartPointDirectionLength(p1, v1, 3000);
l2 = Line.ByStartPointDirectionLength(D, v2, 3000);
intP = l1.Intersect(l2);
geometry6c = Arc.ByCenterPointStartPointEndPoint(intP, B, D);
InfOutput = {geometry6c, H1, W1};
return= {InfOutput, D};
}
else
{
//Geometry 6c ellipse
r1 = W1;
r2 = H1;
plane = Plane.ByThreePoints(C, G, F);
geometry6c = EllipseArc.ByPlaneRadiiAngles(plane, r2, r1, 90, -90);
InfOutput = {geometry6c, H1, W1};
return= {InfOutput, D};
}
};
```

Code 24: *Geometrical Atom - 6c*



Geometrical Atom: ***6d***

Coordinate System: ***(-x,y)***
Number of object type: ***20***

```
//Measurements - Profile 6d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

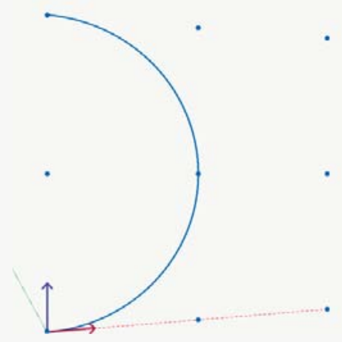
```
//Measurements - Path 6d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry6d = [Imperative]
{
if(H1>W1)
{
//Geometry 6d arc
plane1 = Plane.ByThreePoints(B, F, E);
plane2 = Plane.ByThreePoints(D, F, G);
x1 = B.DistanceTo(D);
circle1 = Circle.ByPlaneRadius(plane1, x1);
circle2 = Circle.ByPlaneRadius(plane2, x1);
ip1 = circle1.Intersect(circle2);
p1 = ip1[0];
p2 = ip1[1];
v1 = Vector.ByTwoPoints(p2, p1);
v2 = Vector.ByTwoPoints(B, A);
l1 = Line.ByStartPointDirectionLength(p2, v1, 3000);
l2 = Line.ByStartPointDirectionLength(B, v2, 3000);
intP = l1.Intersect(l2);
geometry6d = Arc.ByCenterPointStartPointEndPoint(intP, D, B);
InfOutput = {geometry6d, H1, W1};
return= {InfOutput, D};
}
else
{
//Geometry 6d ellipse
r1 = W1;
r2 = H1;
plane = Plane.ByThreePoints(A, B, D);
geometry6d = EllipseArc.ByPlaneRadiiAngles(plane, r2, r1, 90, -90);
InfOutput = {geometry6d, H1, W1};
return= {InfOutput, D};
}
};
```

Code 25: *Geometrical Atom - 6d*



Geometrical Atom: ***7a***

Coordinate System: ***(x,y)***
Number of object type: ***6***

```
//Measurements - Profile 7a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

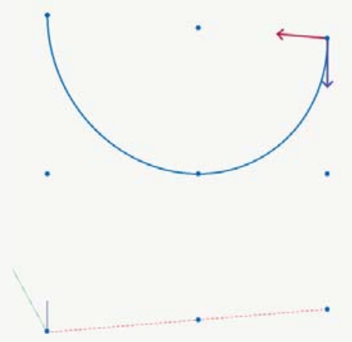
```
//Measurements - Path 7a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1;
r2 = H1/2;
plane = Plane.ByThreePoints(H, O, D);
geometry7a = EllipseArc.ByPlaneRadiiAngles(plane, r2, r1, 0, 180);
InfOutput = {geometry7a, H1, W1};
geometryOutput= {InfOutput, D};
```

Code 26: *Geometrical Atom - 7a*



Geometrical Atom: ***7b***

Coordinate System: ***(-x,-y)***
Number of object type: ***6***

```
//Measurements - Profile 7b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,-z)
Ax = W0-W1;
Az = H0-H1;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0-(H1/2);
Dz = H0;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

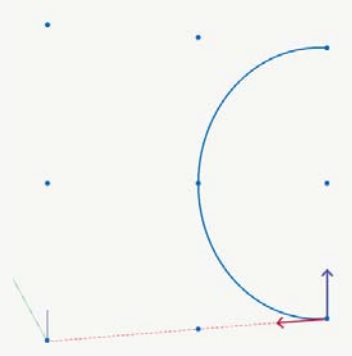
```
//Measurements - Path 7b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,-y)
Ax = W0-W1;
Ay = H0-H1;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1;
plane = Plane.ByThreePoints(G, D, O);
geometry7b = EllipseArc.ByPlaneRadiiAngles(plane, r2, r1, -90, 180);
InfOutput = {geometry7b, H1, W1};
geometryOutput= {InfOutput, D};
```

Code 27: *Geometrical Atom - 7b*



Geometrical Atom: ***7c***

Coordinate System: ***(-x,y)***
Number of object type: ***6***

```
//Measurements - Profile 7c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

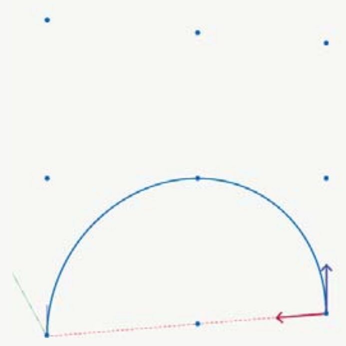
```
//Measurements - Path 7c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1;
r2 = H1/2;
plane = Plane.ByThreePoints(F, C, O);
geometry7c = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, -90, 180);
InfOutput = {geometry7c, H1, W1};
geometryOutput= {InfOutput, D};
```

Code 28: *Geometrical Atom - 7c*



Geometrical Atom: ***7d***

Coordinate System: ***(x,y)***
Number of object type: ***6***

```
//Measurements - Profile 7d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

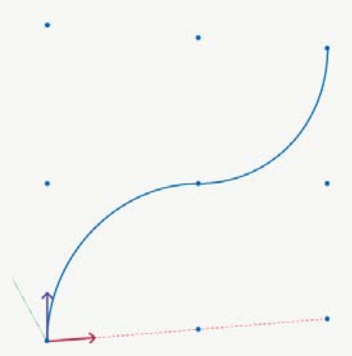
```
//Measurements - Path 7d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1;
plane = Plane.ByThreePoints(E, O, A);
geometry7d = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 0, 180);
InfOutput = {geometry7d, H1, W1};
geometryOutput= {InfOutput, D};
```

Code 29: *Geometrical Atom - 7d*



Geometrical Atom: ***8a***

Coordinate System: ***(x,y)***
Number of object type: ***26***

```
//Measurements - Profile 8a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

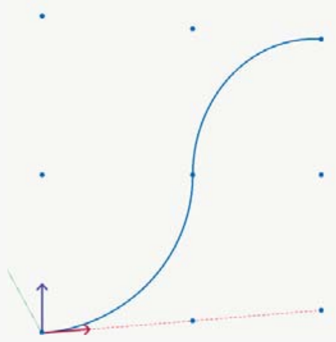
```
//Measurements - Path 8a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry8a = [Imperative]
{
if(H1>W1)
{
//Geometry by ellipse
r1 = W1/2;
r2 = H1/2;
planeE = Plane.ByThreePoints(E, O, A);
planeH = Plane.ByThreePoints(G, O, C);
Arc1 = EllipseArc.ByPlaneRadiiAngles(planeE, r1, r2, 0, 90);
Arc2 = EllipseArc.ByPlaneRadiiAngles(planeH, r1, r2, 0, 90);
geometry8a = {Arc1, Arc2};
InfOutput = {geometry8a, H1, W1};
return= {InfOutput, C};
}
else
{
//Geometry by arc
x1 = A.DistanceTo(C);
r=((x1/14)*6);
planeA = Plane.ByThreePoints(A, E, H);
planeO = Plane.ByThreePoints(O, F, G);
planeC = Plane.ByThreePoints(C, G, F);
circleA = Circle.ByPlaneRadius(planeA, r);
circleO = Circle.ByPlaneRadius(planeO, r);
circleC = Circle.ByPlaneRadius(planeC, r);
ipA = circleO.Intersect(circleA);
ipC = circleO.Intersect(circleC);
p1 = ipA[0];
p2 = ipA[1];
p3 = ipC[0];
p4 = ipC[1];
Arc1 = Arc.ByCenterPointStartPointEndPoint(p1, A, O);
Arc2 = Arc.ByCenterPointStartPointEndPoint(p4, C, O);
geometry8a = {Arc1, Arc2};
InfOutput = {geometry8a, H1, W1};
return= {InfOutput, C};
}
};
```

Code 30: *Geometrical Atom - 8a*



Geometrical Atom: ***8b***

Coordinate System: ***(x,y)***
Number of object type: ***26***

```
//Measurements - Profile 8b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
Ax = W0;
Az = H0;
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

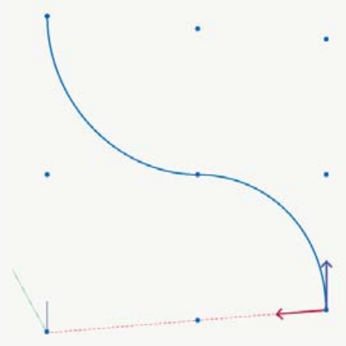
```
//Measurements - Path 8b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
Ax = W0;
Ay = H0-H1;
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0-(H1/2);
Cy = H0;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry8b = [Imperative]
{
if(H1>W1)
{
//Geometry by ellipse
r1 = W1/2;
r2 = H1/2;
planeE = Plane.ByThreePoints(E, O, A);
planeH = Plane.ByThreePoints(G, O, C);
Arc1 = EllipseArc.ByPlaneRadiiAngles(planeE, r1, r2, 0, 90);
Arc2 = EllipseArc.ByPlaneRadiiAngles(planeH, r1, r2, 0, 90);
geometry8b = {Arc1, Arc2};
InfOutput = {geometry8b, H1, W1};
return= {InfOutput, C};
}
else
{
//Geometry by arc
x1 = A.DistanceTo(C);
r=((x1/14)*6);
planeA = Plane.ByThreePoints(A, E, H);
planeO = Plane.ByThreePoints(O, F, G);
planeC = Plane.ByThreePoints(C, G, F);
circleA = Circle.ByPlaneRadius(planeA, r);
circleO = Circle.ByPlaneRadius(planeO, r);
circleC = Circle.ByPlaneRadius(planeC, r);
ipA = circleO.Intersect(circleA);
ipC = circleO.Intersect(circleC);
p1 = ipA[0];
p2 = ipA[1];
p3 = ipC[0];
p4 = ipC[1];
Arc1 = Arc.ByCenterPointStartPointEndPoint(p1, A, O);
Arc2 = Arc.ByCenterPointStartPointEndPoint(p4, C, O);
geometry8b = {Arc1, Arc2};
InfOutput = {geometry8b, H1, W1};
return= {InfOutput, C};
}
};
```

Code 31: *Geometrical Atom - 8b*



Geometrical Atom: ***8c***

Coordinate System: ***(-x,y)***
Number of object type: ***26***

```
//Measurements - Profile 8c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

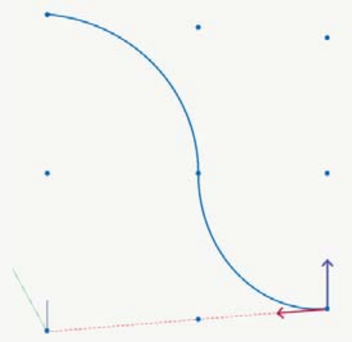
```
//Measurements - Path 8c
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry8c = [Imperative]
{
if(H1>W1)
{
//Geometry by ellipse
r1 = W1/2;
r2 = H1/2;
planeE = Plane.ByThreePoints(E, O, A);
planeH = Plane.ByThreePoints(G, O, C);
Arc1 = EllipseArc.ByPlaneRadiiAngles(planeE, r1, r2, 0, 90);
Arc2 = EllipseArc.ByPlaneRadiiAngles(planeH, r1, r2, 0, 90);
geometry8c = {Arc1, Arc2};
InfOutput = {geometry8c, H1, W1};
return= {InfOutput, C};
}
else
{
//Geometry by arc
x1 = A.DistanceTo(C);
r=((x1/14)*6);
planeA = Plane.ByThreePoints(A, E, H);
planeO = Plane.ByThreePoints(O, F, G);
planeC = Plane.ByThreePoints(C, G, F);
circleA = Circle.ByPlaneRadius(planeA, r);
circleO = Circle.ByPlaneRadius(planeO, r);
circleC = Circle.ByPlaneRadius(planeC, r);
ipA = circleO.Intersect(circleA);
ipC = circleO.Intersect(circleC);
p1 = ipA[0];
p2 = ipA[1];
p3 = ipC[0];
p4 = ipC[1];
Arc1 = Arc.ByCenterPointStartPointEndPoint(p1, A, O);
Arc2 = Arc.ByCenterPointStartPointEndPoint(p4, C, O);
geometry8c = {Arc1, Arc2};
InfOutput = {geometry8c, H1, W1};
return= {InfOutput, C};
}
};
```

Code 32: *Geometrical Atom - 8c*



Geometrical Atom: ***8d***

Coordinate System: ***(-x,y)***
Number of object type: ***26***

```
//Measurements - Profile 8d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
Ax = W0-W1;
Az = H0;
Ex = W0-(W1/2);
Bx = W0;
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

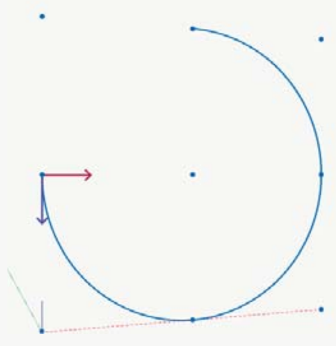
```
//Measurements - Path 8d
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
Ax = W0-W1;
Ay = H0;
Ox = W0-(W1/2);
Bx = W0;
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
geometry8b = [Imperative]
{
if(H1>W1)
{
//Geometry by ellipse
r1 = W1/2;
r2 = H1/2;
planeE = Plane.ByThreePoints(E, O, A);
planeH = Plane.ByThreePoints(G, O, C);
Arc1 = EllipseArc.ByPlaneRadiiAngles(planeE, r1, r2, 0, 90);
Arc2 = EllipseArc.ByPlaneRadiiAngles(planeH, r1, r2, 0, 90);
geometry8b = {Arc1, Arc2};
InfOutput = {geometry8b, H1, W1};
return= {InfOutput, C};
}
else
{
//Geometry by arc
x1 = A.DistanceTo(C);
r=((x1/14)*6);
planeA = Plane.ByThreePoints(A, E, H);
planeO = Plane.ByThreePoints(O, F, G);
planeC = Plane.ByThreePoints(C, G, F);
circleA = Circle.ByPlaneRadius(planeA, r);
circleO = Circle.ByPlaneRadius(planeO, r);
circleC = Circle.ByPlaneRadius(planeC, r);
ipA = circleO.Intersect(circleA);
ipC = circleO.Intersect(circleC);
p1 = ipA[0];
p2 = ipA[1];
p3 = ipC[0];
p4 = ipC[1];
Arc1 = Arc.ByCenterPointStartPointEndPoint(p1, A, O);
Arc2 = Arc.ByCenterPointStartPointEndPoint(p4, C, O);
geometry8b = {Arc1, Arc2};
InfOutput = {geometry8b, H1, W1};
return= {InfOutput, C};
}
};
```

Code 33: *Geometrical Atom - 8d*



Geometrical Atom: ***9a***

Coordinate System: ***(x,-y)***
Number of object type: ***4***

```
//Measurements - Profile 9a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,-z)
centered in H grid point
Ax = W0;
Az = H0-(H1/2);
Ex = W0+(W1/2);
Bx = W0+W1;
Hz = H0;
Dz = H0+(H1/2);

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

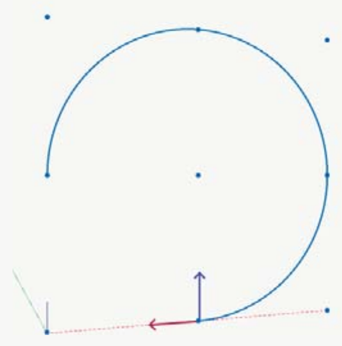
```
//Measurements - Path 9a
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,-y)
centered in H grid point
Ax = W0;
Ay = H0-(H1/2);
Ox = W0+(W1/2);
Bx = W0+W1;
Oy = H0;
Cy = H0+(H1/2);

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1/2;
plane = Plane.ByThreePoints(O, G, H);
geometry9a = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 90, 270);
InfOutput = {geometry9a, H1, W1};
GeometryOutput= {InfOutput, G};
```

Code 34: *Geometrical Atom - 9a*



Geometrical Atom: ***9b***

Coordinate System: ***(-x,y)***
Number of object type: ***4***

```
//Measurements - Profile 9b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
centered in E grid point
Ax = W0-(W1/2);
Az = H0;
Ex = W0;
Bx = W0+(W1/2);
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

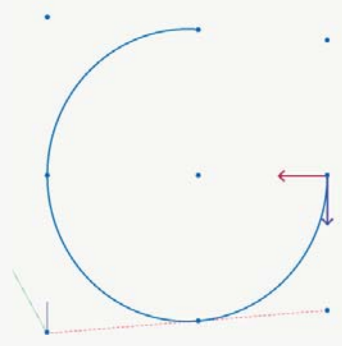
```
//Measurements - Path 9b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
centered in E grid point
Ax = W0-(W1/2);
Ay = H0;
Ox = W0;
Bx = W0+(W1/2);
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1/2;
plane = Plane.ByThreePoints(O, G, H);
geometry9b = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 0, 270);
InfOutput = {geometry9b, H1, W1};
GeometryOutput= {InfOutput, H};
```

Code 35: *Geometrical Atom - 9b*



Geometrical Atom: ***9c***

Coordinate System: ***(x,y)***
Number of object type: ***4***

```
//Measurements - Profile 9C
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
centered in F grid point
Ax = W0-W1;
Az = H0-(H1/2);
Ex = W0-(W1/2);
Bx = W0;
Hz = H0;
Dz = H0+(H1/2);

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

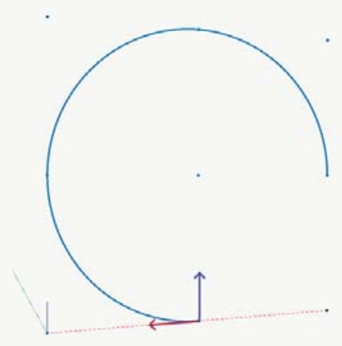
```
//Measurements - Path 9C
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
centered in F grid point
Ax = W0-W1;
Ay = H0-(H1/2);
Ox = W0-(W1/2);
Bx = W0;
Oy = H0;
Cy = H0+(H1/2);

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1/2;
plane = Plane.ByThreePoints(O, G, H);
geometry9b = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 0, 270);
InfOutput = {geometry9b, H1, W1};
GeometryOutput= {InfOutput, H};
```

Code 36: *Geometrical Atom - 9c*



Geometrical Atom: ***9d***

Coordinate System: ***(-x,y)***
Number of object type: ***4***

```
//Measurements - Profile 9b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (-x,z)
centered in E grid point
Ax = W0-(W1/2);
Az = H0;
Ex = W0;
Bx = W0+(W1/2);
Hz = H0+(H1/2);
Dz = H0+H1;

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

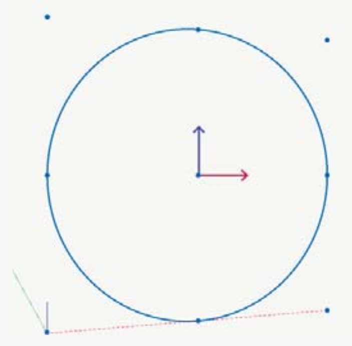
```
//Measurements - Path 9b
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (-x,y)
centered in E grid point
Ax = W0-(W1/2);
Ay = H0;
Ox = W0;
Bx = W0+(W1/2);
Oy = H0+(H1/2);
Cy = H0+H1;

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1/2;
plane = Plane.ByThreePoints(O, G, H);
geometry9d = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 270, 270);
InfOutput = {geometry9d, H1, W1};
GeometryOutput= {InfOutput, F};
```

Code 37: *Geometrical Atom - 9d*



Geometrical Atom: ***10a***

Coordinate System: ***(x,y)***
Number of object type: ***4***

```
//Measurements - Profile
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Z;

//Coordinate System (x,z)
centered in O grid point
Ax = W0-(W1/2);
Az = H0-(H1/2);
Ex = W0;
Bx = H0+(H1/2);
Hz = H0;
Dz = H0+(H1/2);

//9 Points grid - Profile
yPt= StartPt.Y;
A = Point.ByCoordinates(Ax,yPt,Az);
E = Point.ByCoordinates(Ex,yPt,Az);
B = Point.ByCoordinates(Bx,yPt,Az);
H = Point.ByCoordinates(Ax,yPt,Hz);
O = Point.ByCoordinates(Ex,yPt,Hz);
F = Point.ByCoordinates(Bx,yPt,Hz);
D = Point.ByCoordinates(Ax,yPt,Dz);
G = Point.ByCoordinates(Ex,yPt,Dz);
C = Point.ByCoordinates(Bx,yPt,Dz);
```

```
//Measurements - Path
H1=(i[n]);
W1=(i[n]);
W0= StartPt.X;
H0= StartPt.Y;

//Coordinate System (x,y)
centered in O grid point
Ax = W0-(W1/2);
Ay = H0-(H1/2);
Ox = W0;
Bx = H0+(H1/2);
Oy = H0;
Cy = H0+(H1/2);

//9 Points grid - Path
zPt= StartPt.Z;
A = Point.ByCoordinates(Ax,Ay,zPt);
E = Point.ByCoordinates(Ox,Ay,zPt);
B = Point.ByCoordinates(Bx,Ay,zPt);
H = Point.ByCoordinates(Ax,Oy,zPt);
O = Point.ByCoordinates(Ox,Oy,zPt);
F = Point.ByCoordinates(Bx,Oy,zPt);
D = Point.ByCoordinates(Ax,Cy,zPt);
G = Point.ByCoordinates(Ox,Cy,zPt);
C = Point.ByCoordinates(Bx,Cy,zPt);
```

```
//Geometry
r1 = W1/2;
r2 = H1/2;
plane = Plane.ByThreePoints(O, G, H);
geometry10a = EllipseArc.ByPlaneRadiiAngles(plane, r1, r2, 0, 360);
InfOutput = {geometry10a, H1, W1};
GeometryOutput= {InfOutput, O};
```

Code 38: *Geometrical Atom - 10a*