Athena Research Center

Research and Innovation Center in Information, Communication and Knowledge Technologies

MULTIMEDIA RESEARCH GROUP

3D Digitisation Case Studies

Creating 3D digital replicas of medium-to-large scale monuments for Web dissemination

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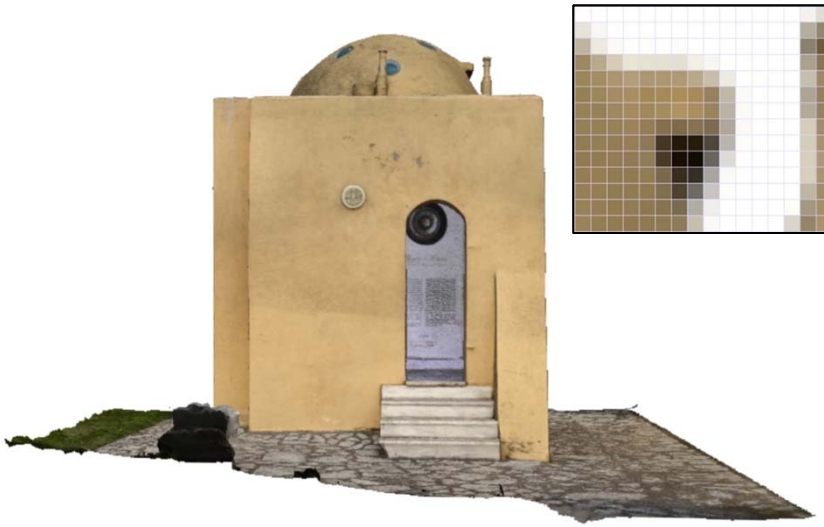
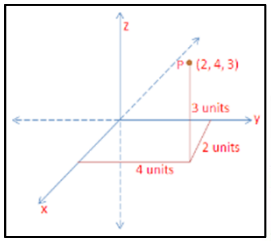
Digitisation in three dimensions…

Methods – Sampling procedures | Many approaches → Different needs
Target → Creation of digital subsets that carry geometrical and colour features from part of our real (*analog*) world

2D Digitisation → X,Y - R,G,B

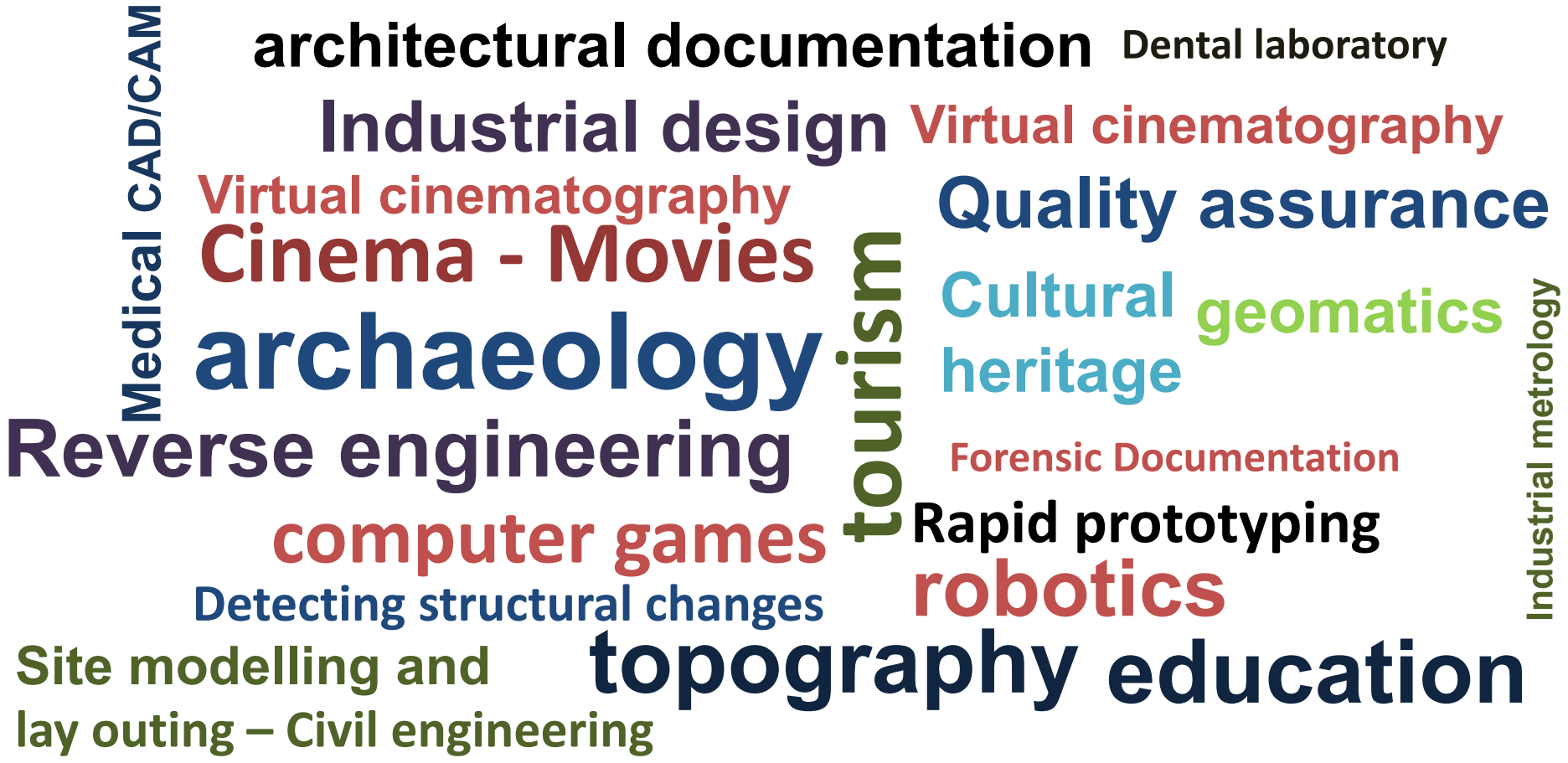


3D Digitisation X,Y,*Z* - R,G,B



An introduction

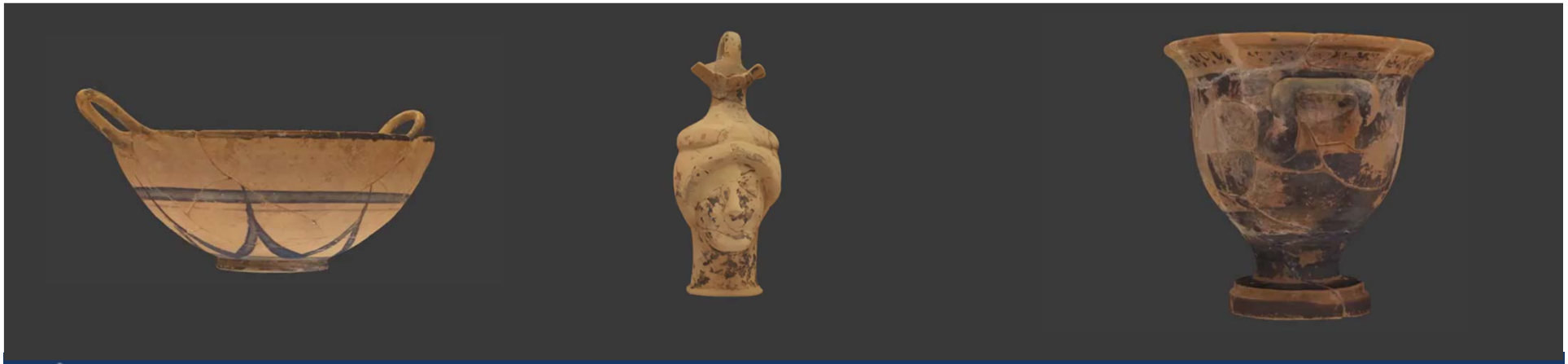
Applications of 3D Digitisation…



An introduction

3D Digitisation…A common practice in the CH domain

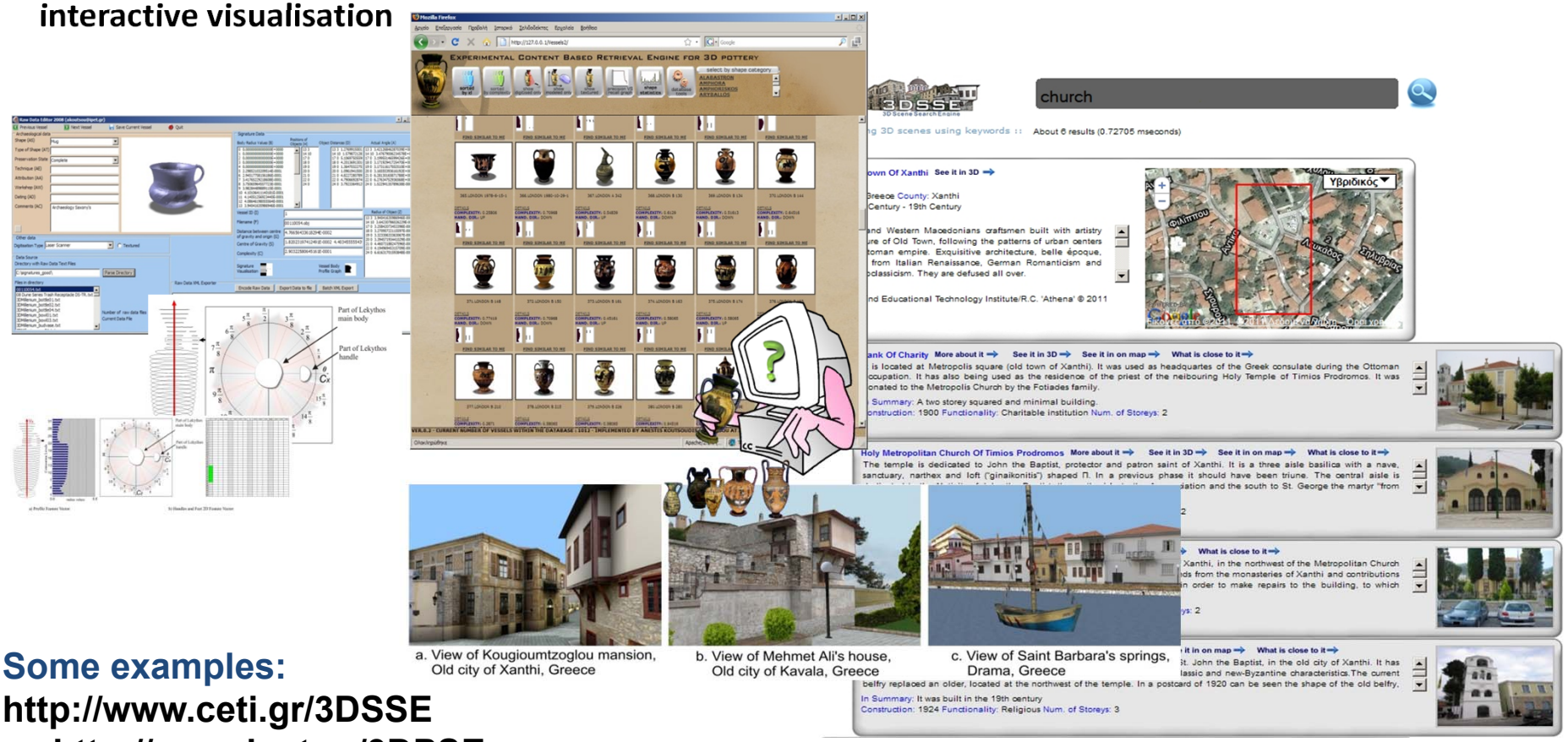
- **Preservation of cultural thesaurus through high quality 3D digital replicas enriched with physicochemical properties mapped on surface**



An introduction

3D Digitisation…A common practice in the CH domain

- **Creation digital repositories with functionalities such as automated categorisation, retrieval and interactive visualisation**



a. View of Kougioumtzoglou mansion, Old city of Xanthi, Greece

b. View of Mehmet Ali's house, Old city of Kavala, Greece

c. View of Saint Barbara's springs, Drama, Greece

Some examples:

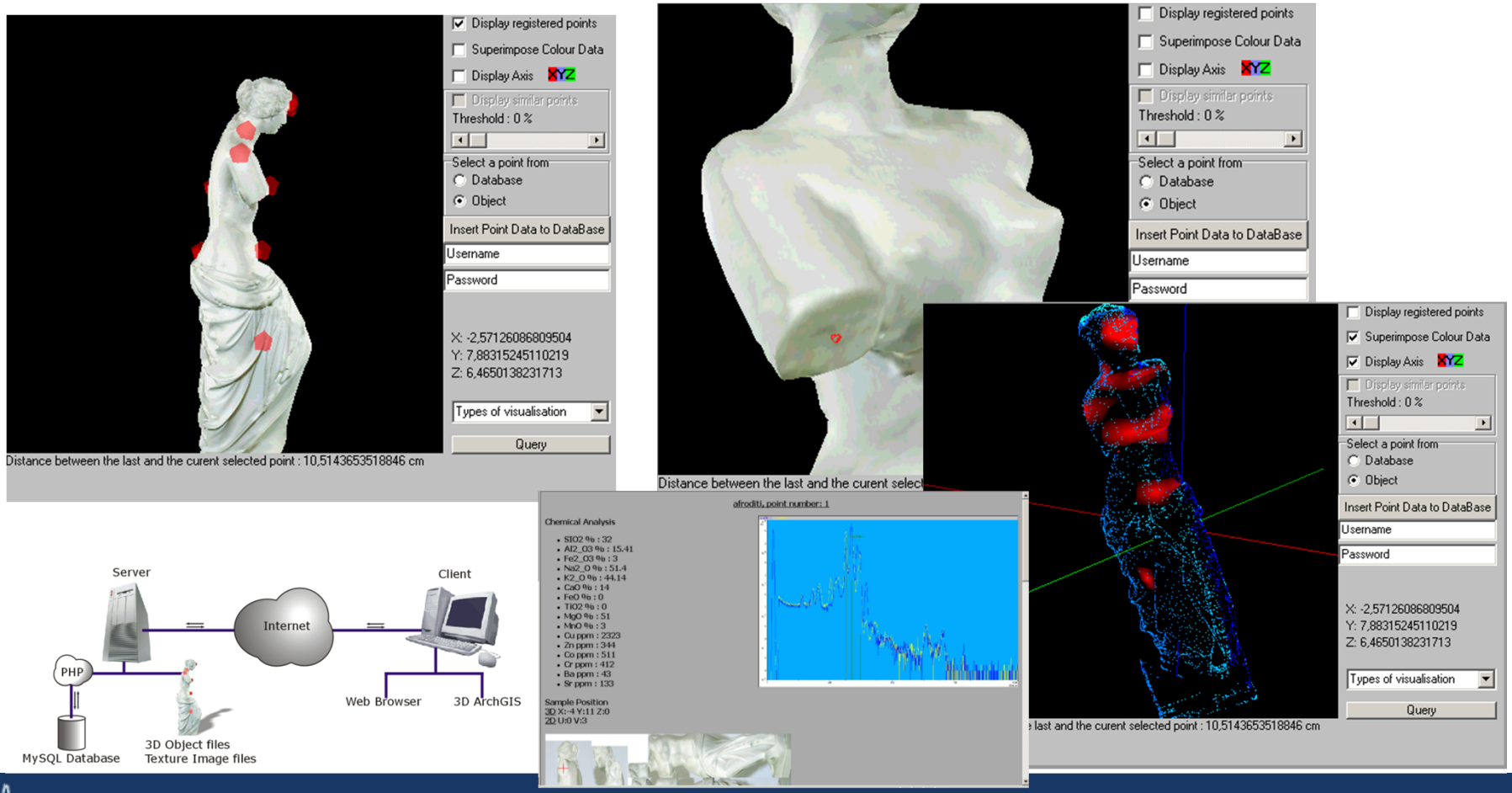
http://www.ceti.gr/3DSSE

http://www.ipet.gr/3DPSE

An introduction

3D Digitisation…A common practice in the CH domain

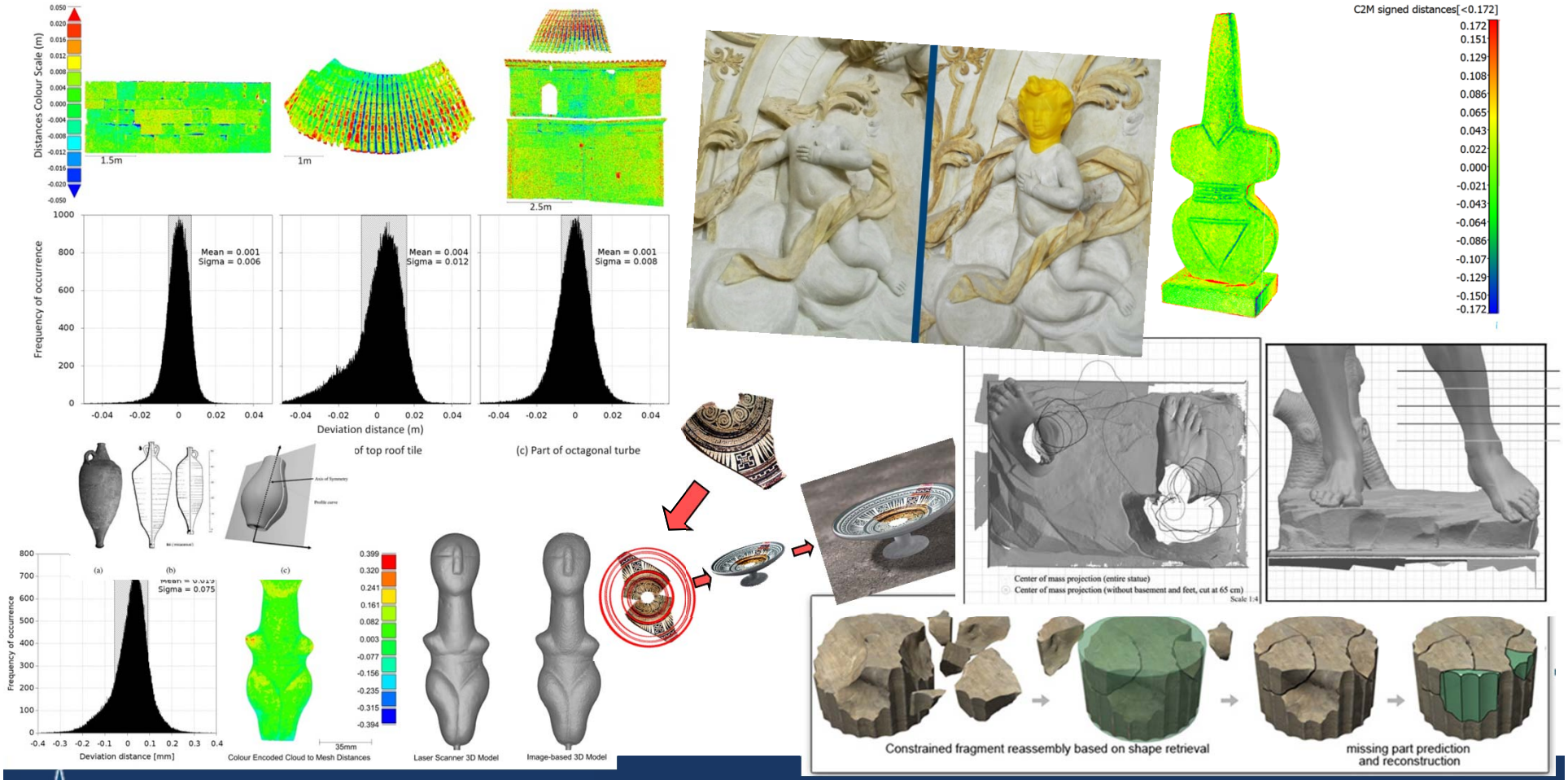
- **Documentation and study based on simultaneous access to digital replicas → min(artefact_danger**



An introduction

3D Digitisation…A common practice in the CH domain

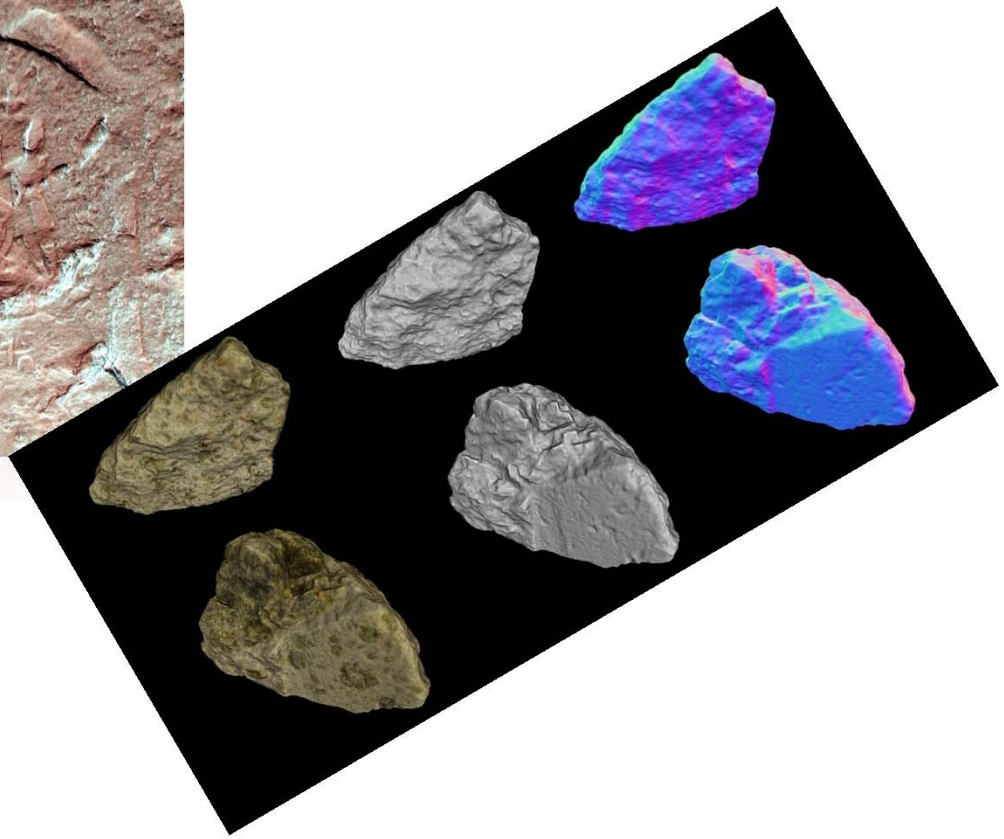
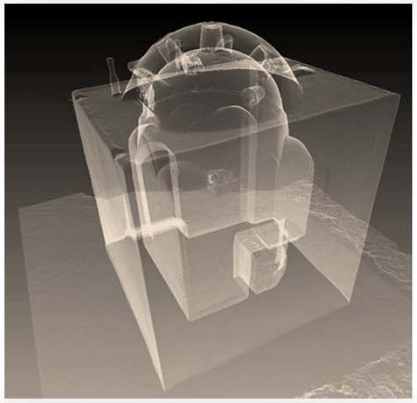
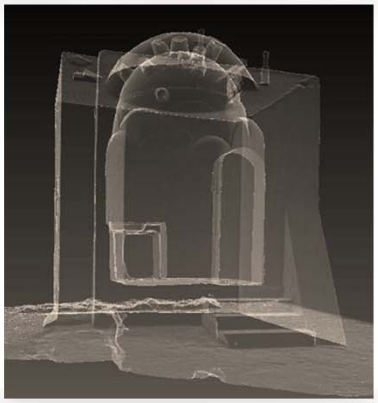
- **Data processing and shape analysis for virtual/actual restoration → 3D printing**



3D Digitisation…A common practice in the CH domain

- **Non-photorealistic shading, visualisation → Surface features exaggeration**



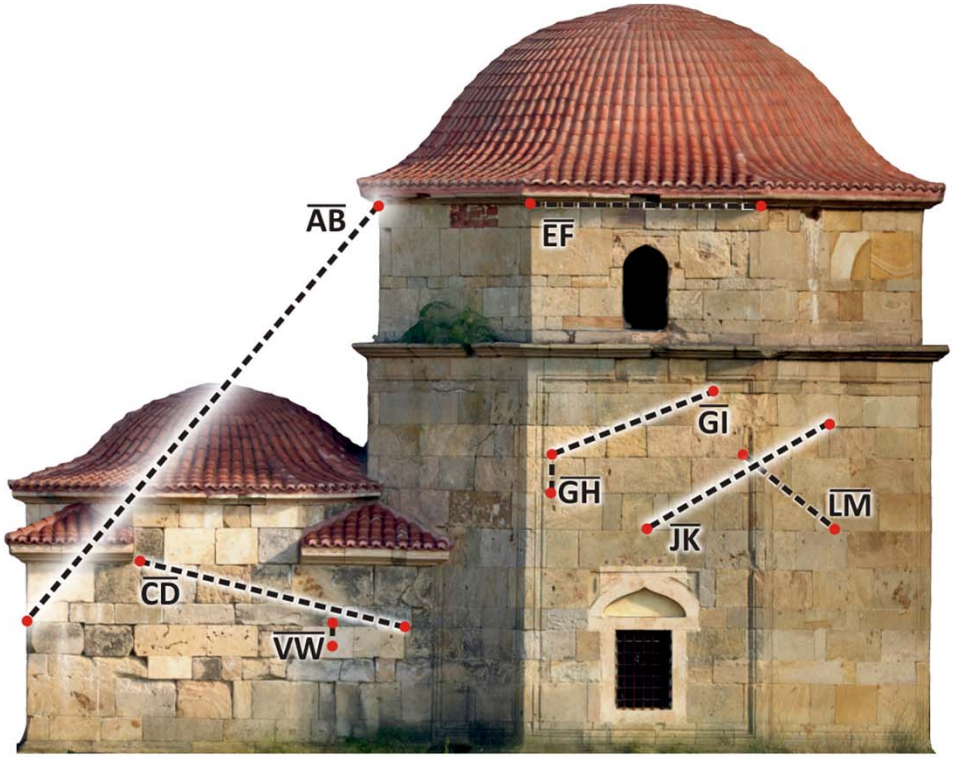
3D Digitisation…A common practice in the CH domain

- **Generation of impossible viewpoints**

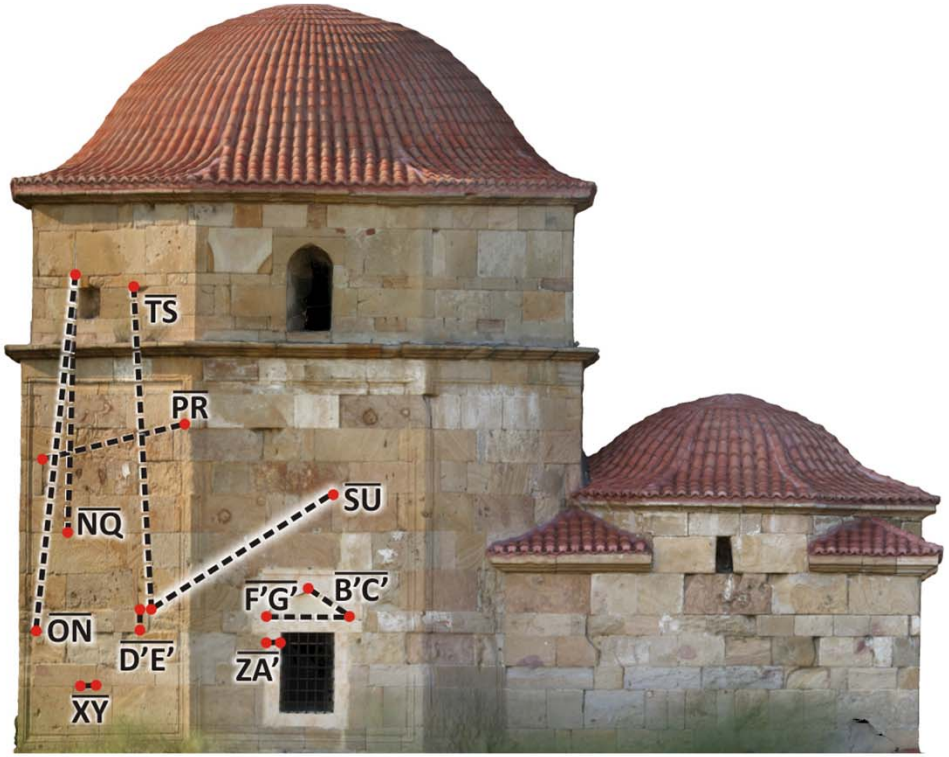
Episkopi, Byzantine Church, Stavri, 12th Centrury, Mani, Greece

3D Digitisation…A common practice in the CH domain

- **Orthographic projections → Performing measurements**



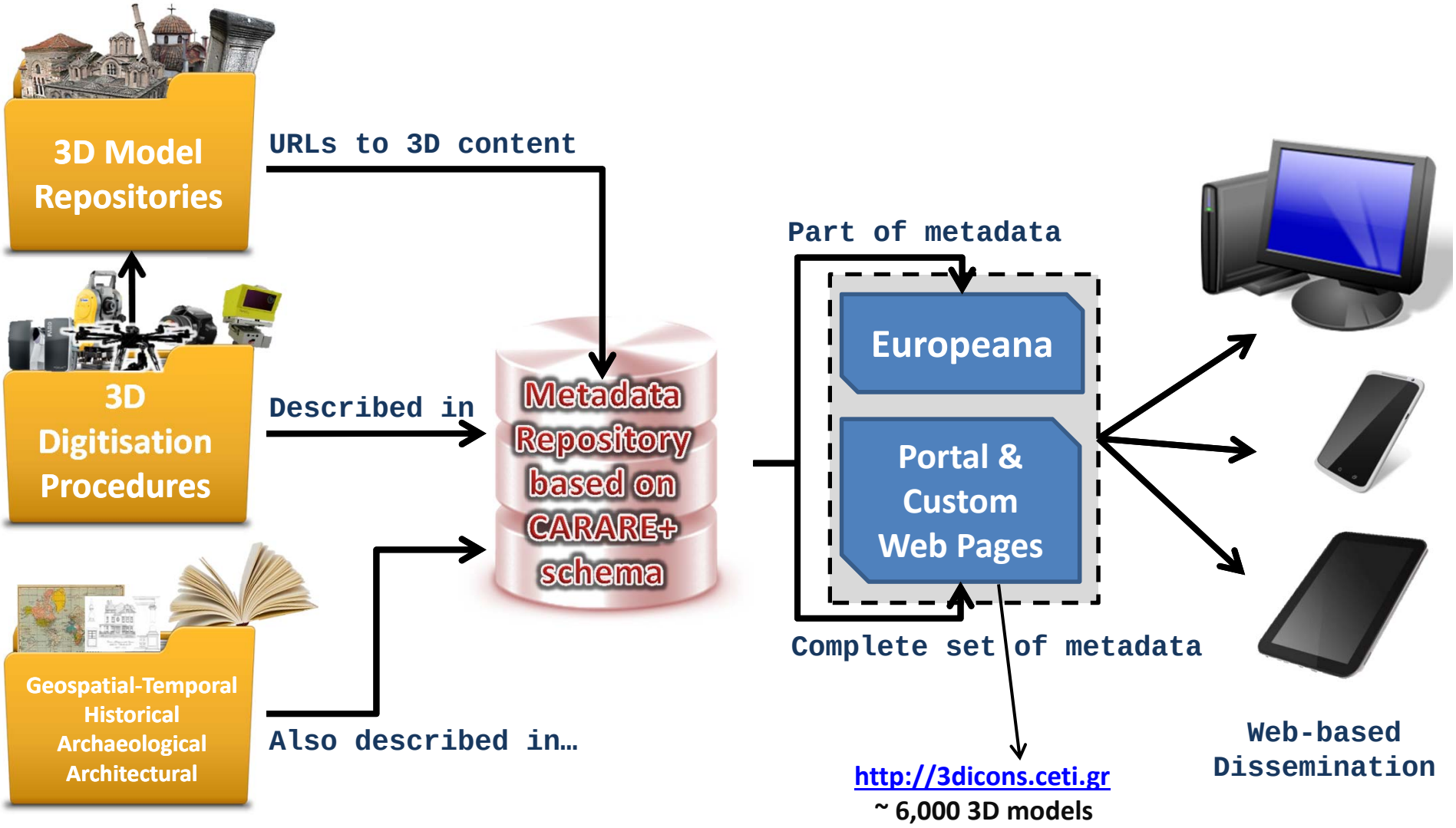
North view of the monument (Orthogonal Projection)



South view of the monument (Orthogonal Projection)

A good case study to start with…The 3D-ICONS project

Enrich Europeana with novel and high quality 3D replicas of monuments

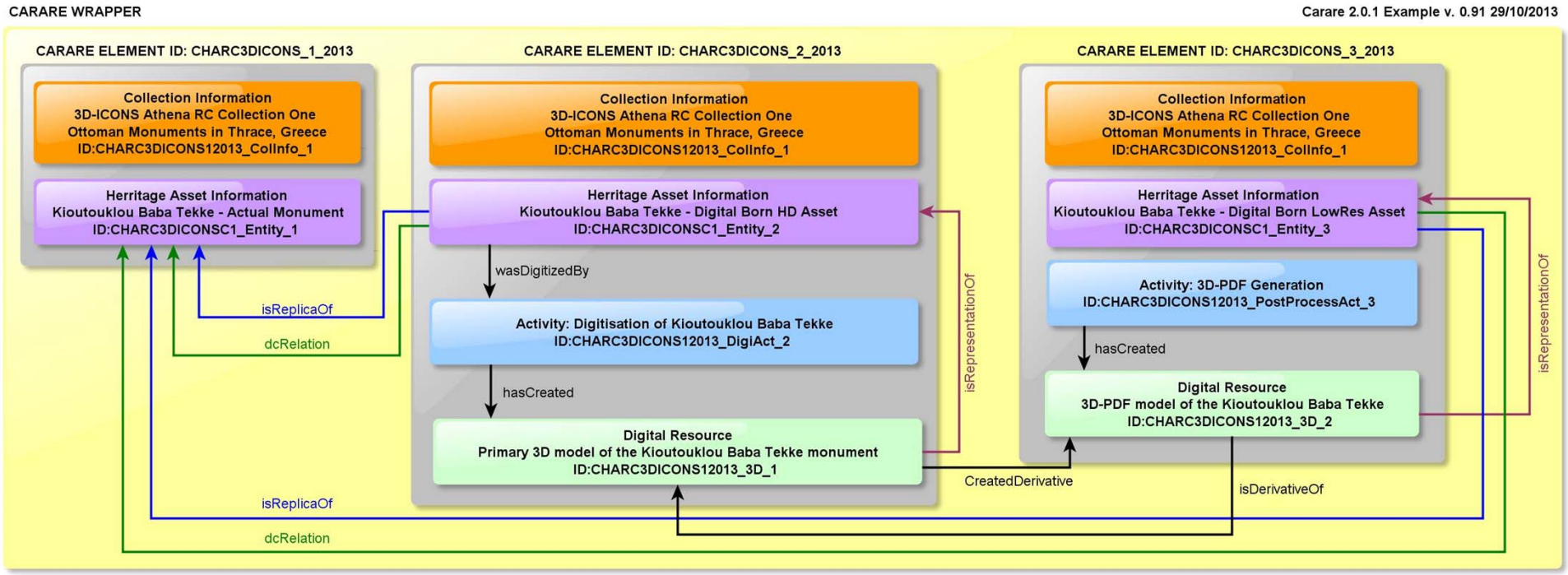


The 3D-ICONS project primary scope…simplified

The CARARE+ schema

A complex harvesting schema → Full range of descriptive information about monuments, buildings, landscape areas and their digital representations

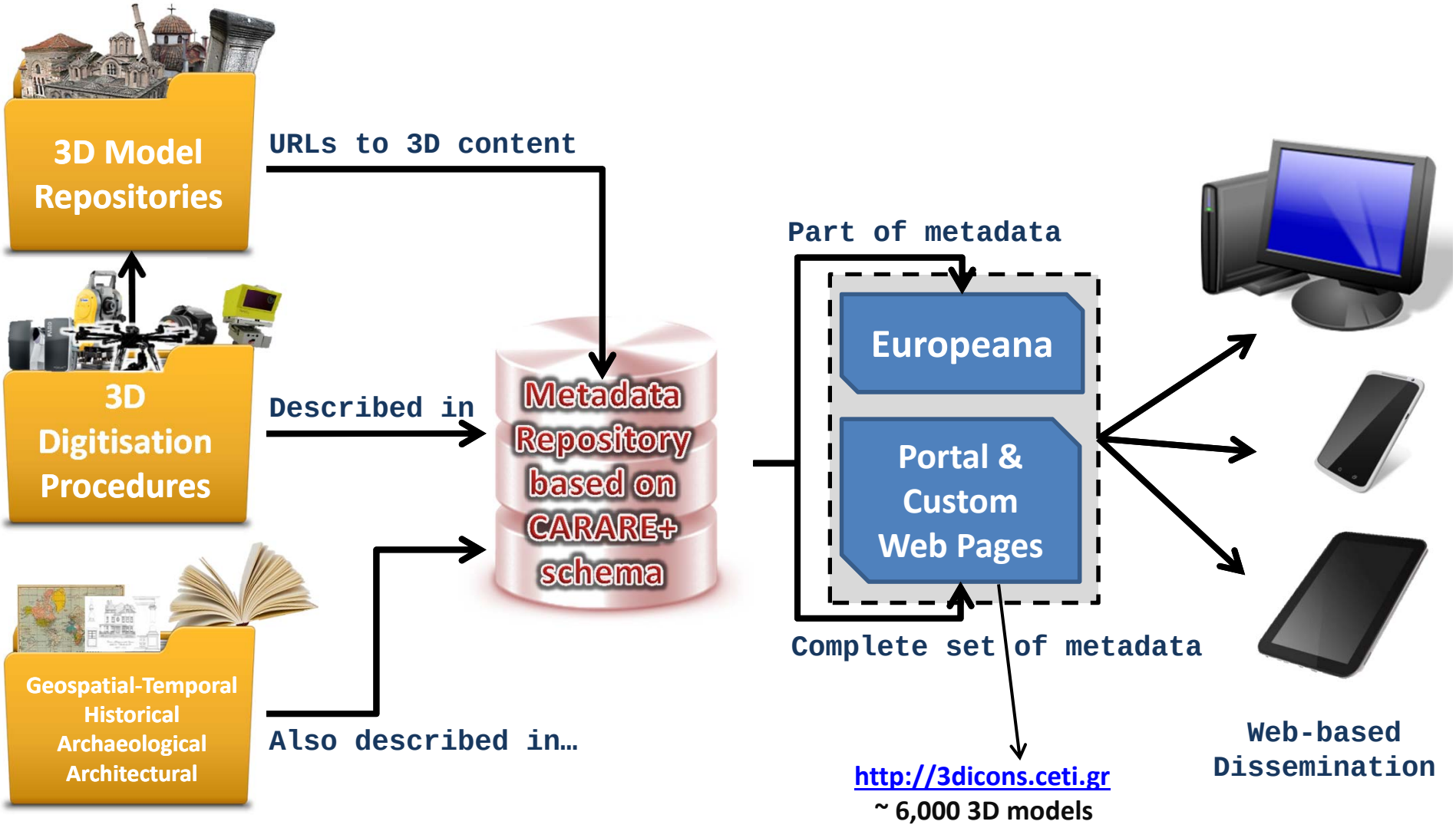
Supports the description of activities performed to produced digital resources
Allows the declaration of relationships between activities and digital resources



Note: The beginning of each line indicates the schema's elements where the relationship is being defined. The arrow points at the element's ID being mentioned

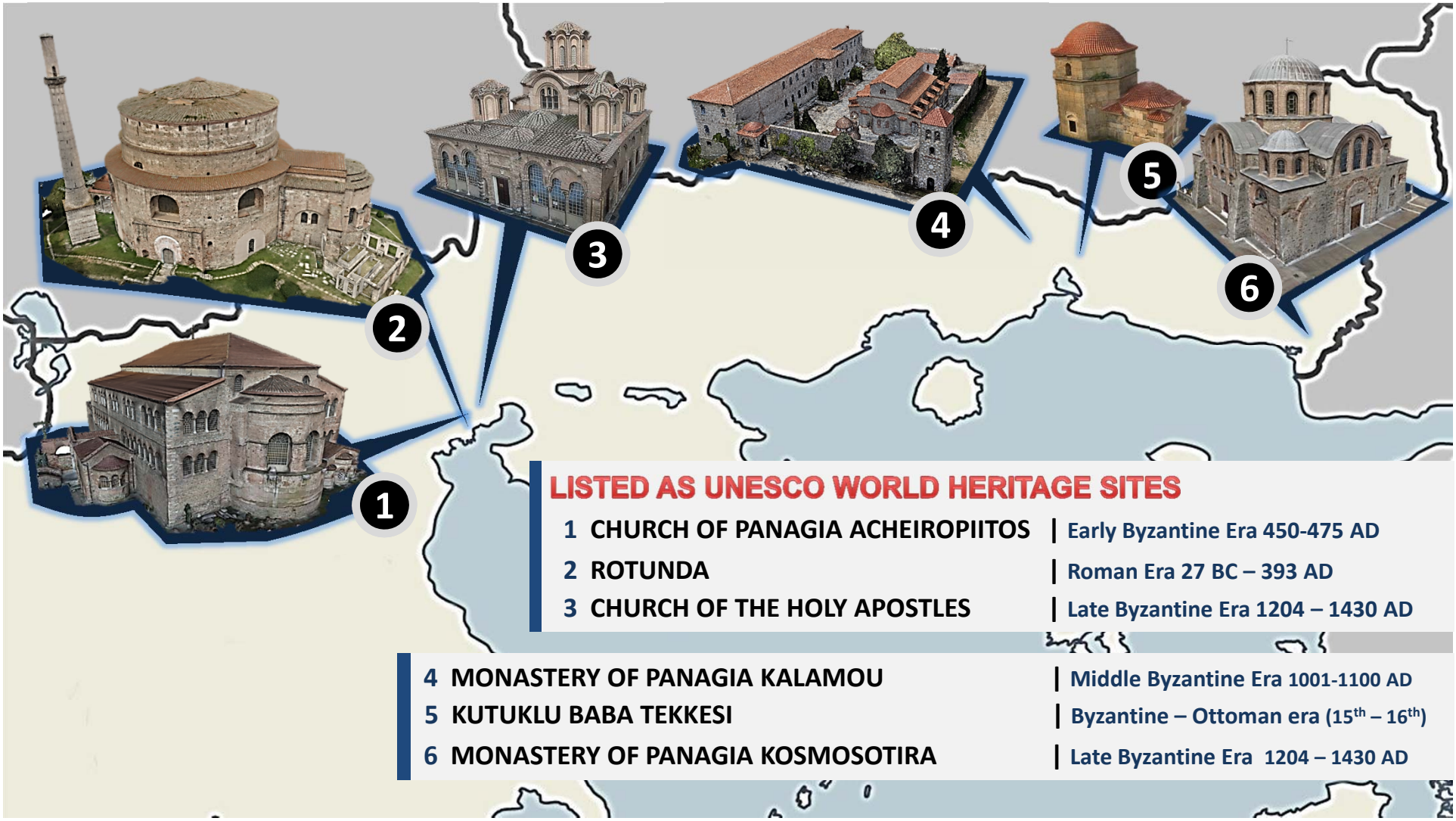
A good case study to start with…The 3D-ICONS project

Enrich Europeana with novel and high quality 3D replicas of monuments



Major 3D digitised monuments spatial distribution

East Macedonia and Thrace, Greece



LISTED AS UNESCO WORLD HERITAGE SITES

1	CHURCH OF PANAGIA ACHEIROPIITOS	Early Byzantine Era 450-475 AD
2	ROTUNDA	Roman Era 27 BC – 393 AD
3	CHURCH OF THE HOLY APOSTLES	Late Byzantine Era 1204 – 1430 AD
4	MONASTERY OF PANAGIA KALAMOU	Middle Byzantine Era 1001-1100 AD
5	KUTUKLU BABA TEKKESI	Byzantine – Ottoman era (15^{th} – 16^{th})
6	MONASTERY OF PANAGIA KOSMOSOTIRA	Late Byzantine Era 1204 – 1430 AD

On 3D content generation pipelines

Aspects of the pipeline applied

A two-stage approach…(20% - 80%)

i. Data Collection

Primary method → Structure-From-Motion / Multi-view Stereovision

- **Terrestrial & aerial photoshooting (UAV-based)**

Complementary methods → 3D model scaling & data quality quantification

- **TOF Laser Scanning →Partial capturing of monument's surfaces**
- **Total station and empirical measurements**
  Target positioning, distances between strong surface features

ii. Data Processing

Software Tools Arsenal - Open Source / Commercial

- **Generation of primary model (Triangulated mesh)**
- **Scale 3D model ← Based on comp. methods data**
- **Multiple mesh/texture resolutions generation**
- **Publish on-line → Use of appropriate file format**
- **Derivatives → Orthophotos | Fly-around video sequences |*3D Prints***

Data Collection

Equipment…

i. Terrestrial session

Set of Samsung NX1000 compact DSLRs 20MP 16mm fixed zoom & 22mm-55mm lenses
Set of tripods and custom variable height monopods, white balance boards
Optec Ilris 36D TOF laser scanner
Topcon GPT-3005N total station

ii. Aerial session

UAV specs – Custom design and implementation by Aeroview.gr

Hexacopter | X frame arrangement (Diameter: 80cm)
Naza-M controller board with GPS (Altitude hold, return home)
Payload capability 2Kg | Total Weight 4.7Kg
Flying time 15 mins | Five cell 18.5Volt Li-Po
Two axis (Yaw, Roll) antishock gimbal camera base
FPV – Telemetry functions (Viewpoint, altitude, voltage)

Data Collection

aka THE SHUTTER'S NIGHTMARE

Capture multiple closed loops image sequences at different height levels

Terrestrial (Height range *1.5m – 6m* using tripods, monopods)
Aerial (Height range *7m – 40m* e.g. Rotunda minaret)

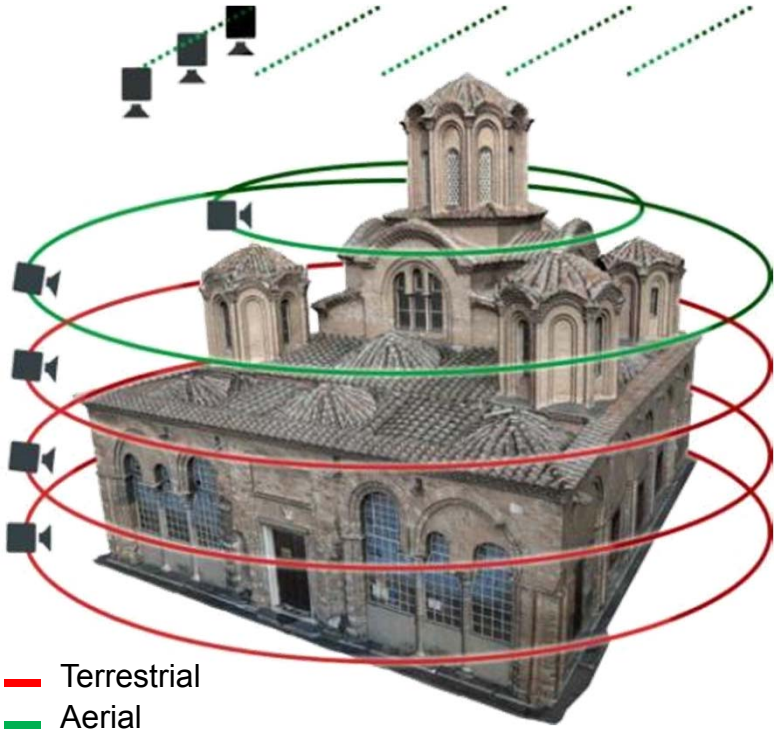
Top aerial image sequences capture approach

- **Low angle oblique**
- **Vertical titled**

Inevitable → Capture additional image sequences
Due to

- **High morphological complexity areas with occlusions**
- **Concavities**
- **Details**

No safe distance limit was introduced by the Ephorate!
Allowed us to fly close to the monuments (some cases < 3m)



Data Collection

Challenges…

Terrestrial Photoshooting Sessions

People

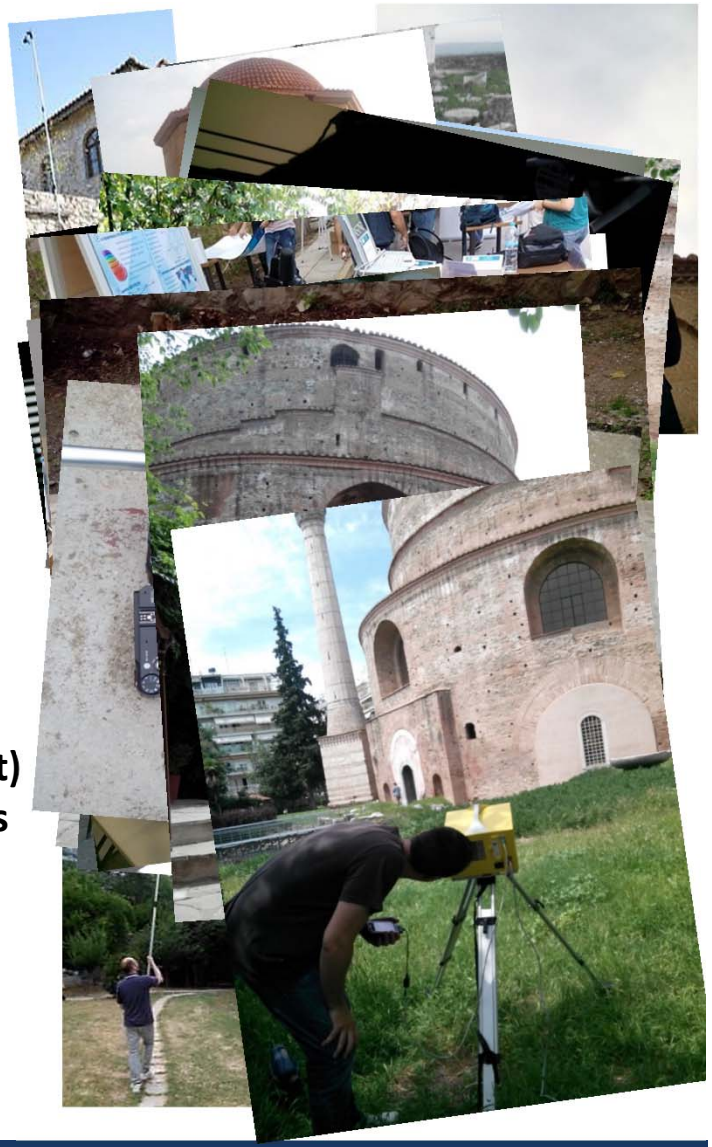
Inform personnel about our work and what we will be doing
Respect visitors → Had to stop data collection phase
Avoid long conversations with *experts & scholars*

Accessing the monument from all required viewpoints

Where not possible → Attempt airborne

Weather conditions

Tried to perform data collection always on cloudy days (overcast)
Absence of strong shadows → Overall similar lighting conditions
Useful when simulating different lighting conditions



Data Collection

More challenges…

Aerial Photoshooting Sessions

Wind gusts

Reduce total flying time
Hard to automatically keep a safe distance from target → GPS slow response
Dictates full-manual navigation

Environment – Monument's morphology

Difficult to keep the UAV in pilot's line-of-sight (LOS)
Pilot had to change ground positions to keep LOS
Flight plans complexity →Monument's morphology

The Birds…Alfred was right

Especially seagulls and crows
Flying too close to UAV → Attempt to scare it
Sometimes…Even try to attack the UAV!!!

Data Processing

The tools make the man…

Software arsenal

Primary 3D model generation software

Agisoft PhotoScan Professional edition

Mesh processing, analysis and video generation

Meshlab, X-normal, Blender, Arius 3D Pointstream Editor, Cloud Compare, InstantReality aopt tool and others

Hardware arsenal

6 x PC systems for data processing

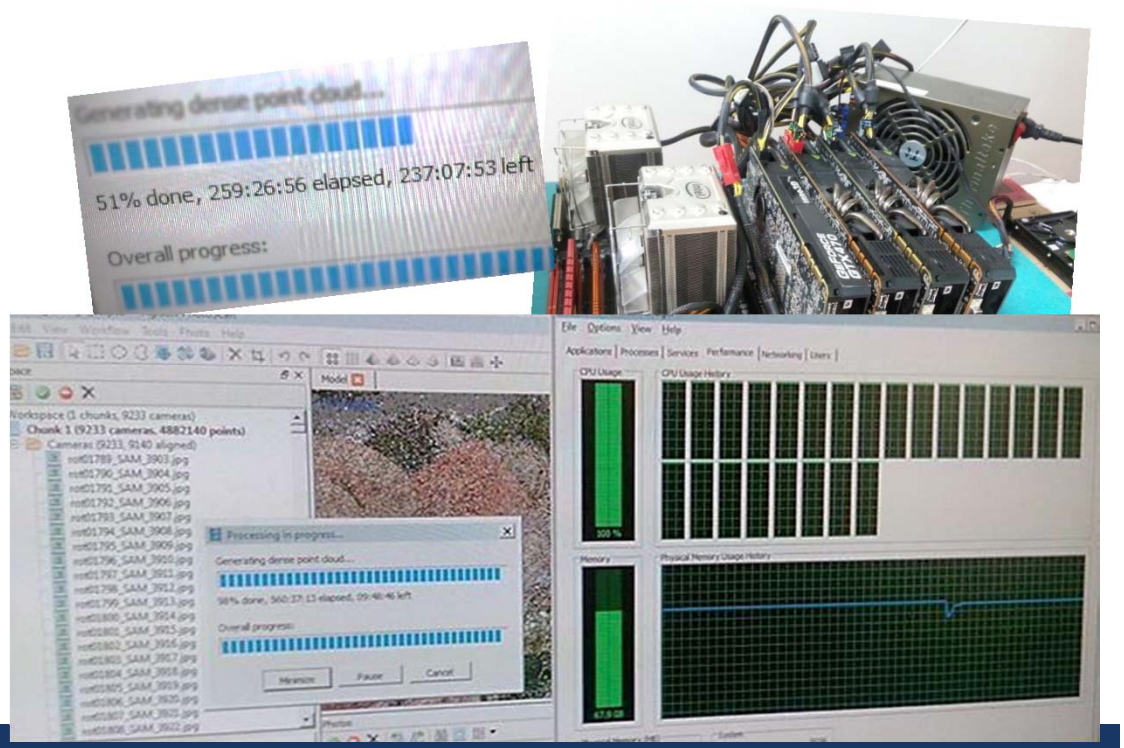
3 x 64GB , 2 x 32GB , 1 x 96GB RAM

4 x Intel i7 4-cores, 1 x 6-cores

ATI Radeon R9 280X

Geforce GTX 580

Microsoft Windows 7 Pro 64 bit



Data Processing

Some numbers…

Total number of images per project and some indication for processing times

Kioutouklou Baba Bekctashic Teke → **1.000 images**
Church of the Holy Apostles → **4.100**
Church of the Acheiropoietos → **5.000**
Church of St. George (Rotunda) → **9.200**
Monastery of Panagia Kalamou → **13.000**
Monastery of Panagia Kosmosotira → **4.000**

Image Alignment durations: 200 hours (9.200 images - 10.000 points per image) on an Intel i7 6-core *3.4Ghz*, ATI Radeon R9 200

Primary Models density: 20M-50M points | **Average distance consecutive points:** ~ 3 cm

Bounding Boxes in meters

10.6/8.4/13.4m | 20.5/20/23m | 23.4/45.1/56.9m | 68.3/58.7/52.2m | 60/51/52.2m | 17/21/23.5m

Data Processing

Some numbers…

Scaling models and data quality evaluation

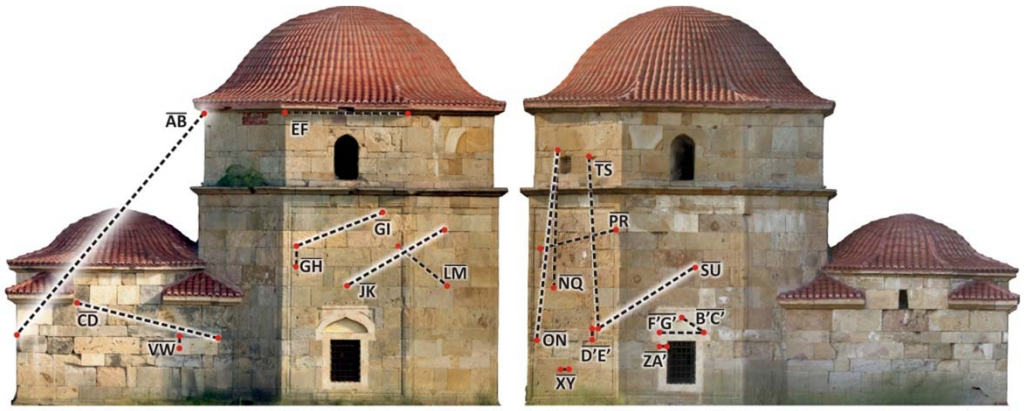
Scaling based on laser scanner data, total station, empirical measurements
Quantify Data quality → Surface deviations → CloudCompare → Laser (TOF) Data VS SFM/MVS Data
No deformations detected → Acceptable for project's requirements → Web dissemination
More can be found in…

A. Koutsoudis et al. ***Using Noise Function-Based Patterns to Enhance Photogrammetric 3D Reconstruction Performance of Featureless Surfaces***, Journal of Cultural Heritage, accepted for publication January 2015

A. Koutsoudis et al., ***Multi-Image 3D Reconstruction Data Evaluation****, J. of Cultural Heritage, Vol.15(1), 2014.*

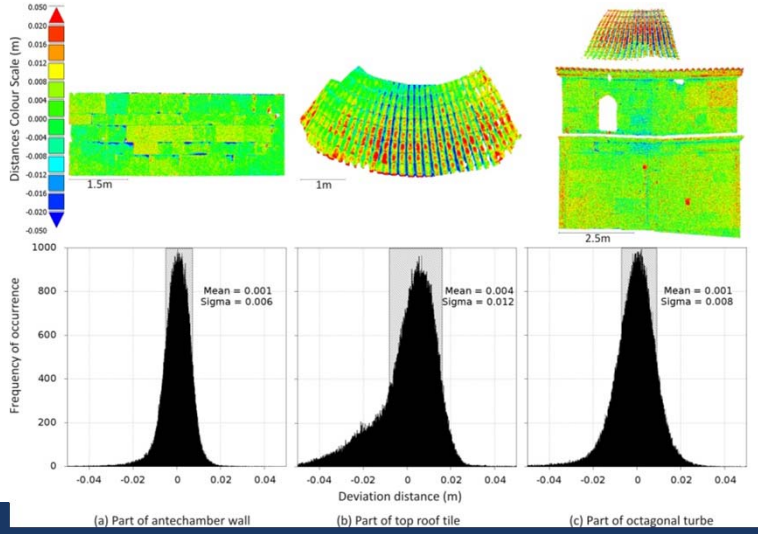
A. Koutsoudis et al ***Performance Evaluation of a Multi-Image 3D Reconstruction Software on a Low-Feature Artefact****, Journal of Archaeological Science, Vol. 40 (12),December 2013, pp.4450-4456.*

F. Remondino et al. ***Design and implement a reality-based 3D digitisation and modelling project****, Int. Con. Digital Heritage, 28 Oct - 01 Nov, Marseille, France, 2013.*



North view of the monument (Orthogonal Projection)

South view of the monument (Orthogonal Projection)



(a) Part of antechamber wall (b) Part of top roof tile (c) Part of octagonal turbe

Data Processing

Challenges…

Long processing times

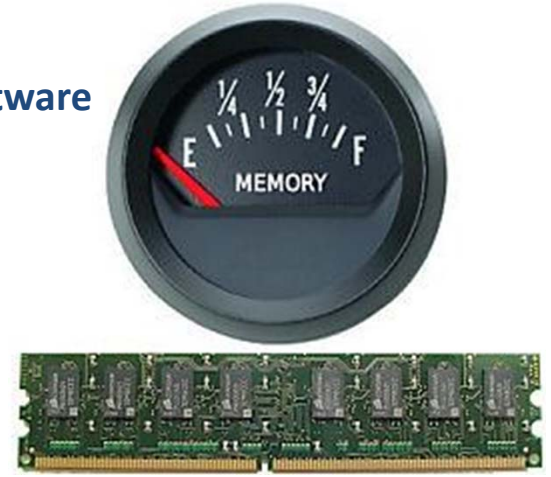
Image alignment and dense stereo reconstruction →Extremely demanding CPU/GPU/RAM
Viewing Reconstruction Results → Not as immediate as viewing data from a scanner

Exploit Agisoft Photoscan's Python scripting support

Perform dense stereo in multiple small regions
Able to get higher resolution results with less memory requirements during processing

Still unable to get the best out of the image sequences

Big data handling-visualisation inability using current hardware and software



Data Processing

Being more specific…

Using Agisoft Photoscan…How many GBs of RAM needed for my project?

As with any SFM/MVS software tool → Large Image Sets DEMAND Large amounts of RAM

IMAGE SET SPATIAL ALIGNMENT

Depends mainly on the number of images | Image resolution not important

Photos	100	200	500	1000	2000	5000	10000
Memory consumption	500 MB	1 GB	2.5 GB	5 GB	10 GB	25 GB	50 GB

DENSE POINT CLOUD GENERATION

Depends on number of images, resolution, overlapping, quality setting & morphology/shape of object (arbitrary m.)

RAM usage →Presents an almost linear dependency on the number of photos and resolution

For 12Mpix images you should expect something similar to the following

Photos	100	200	500	1000	2000	5000	10000
Lowest quality	25 MB	50 MB	125 MB	250 MB	500 MB	1.25 GB	2.5 GB
Low quality	100 MB	200 MB	500 MB	1 GB	2 GB	5 GB	10 GB
Medium quality	400 MB	800 MB	2 GB	4 GB	8 GB	20 GB	40 GB
High quality	1.6 GB	3.2 GB	8 GB	16 GB	32 GB	80 GB	160 GB
Ultra high quality	6.4 GB	12.8 GB	32 GB	64 GB	128 GB	320 GB	640 GB

Data Processing

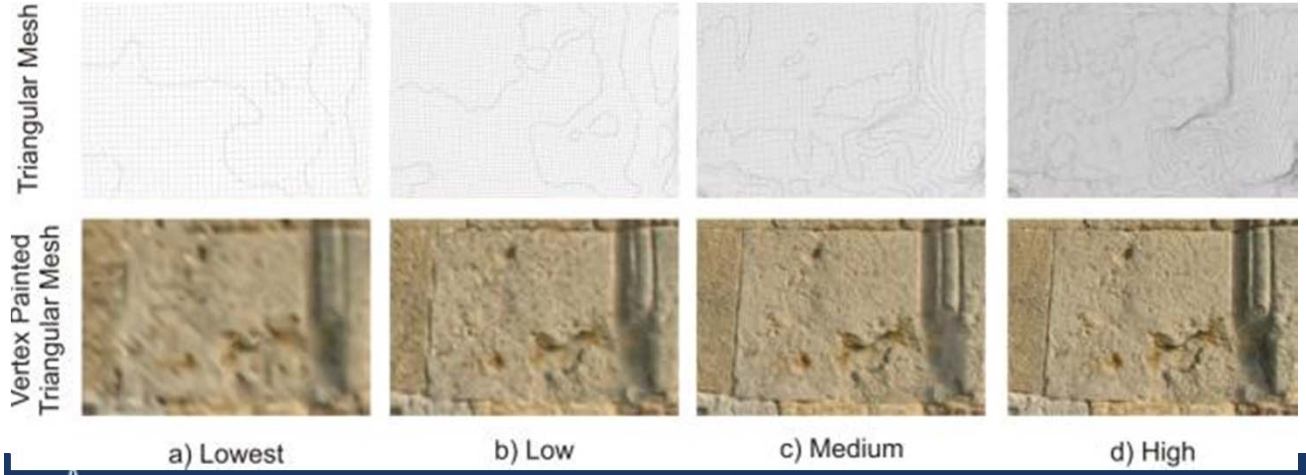
Continued…

Producing different resolution models

Export from PhotoScan
- Meshlab (> Mesh simplification)
  - Blender (> UV unwrap) → Better exploitation of the UV space
    - PhotoScan (Texture Mapping – Back Projection)

End up with four different mesh complexity levels

Lowest Res: <35K with 512^2 pixels texture map	| 3D Thumbnail
Low Res: <100K facets with 1024^2 pixels texture map	| Mobile devices & low bandwidth connections
Medium Res: <300K facets with 4096^2	| Average PCs
High Res: aprox. 1M facets with 8192^2	| High end PCs
Raw : >20M-50M facets with vertex colour	| Research purpose data



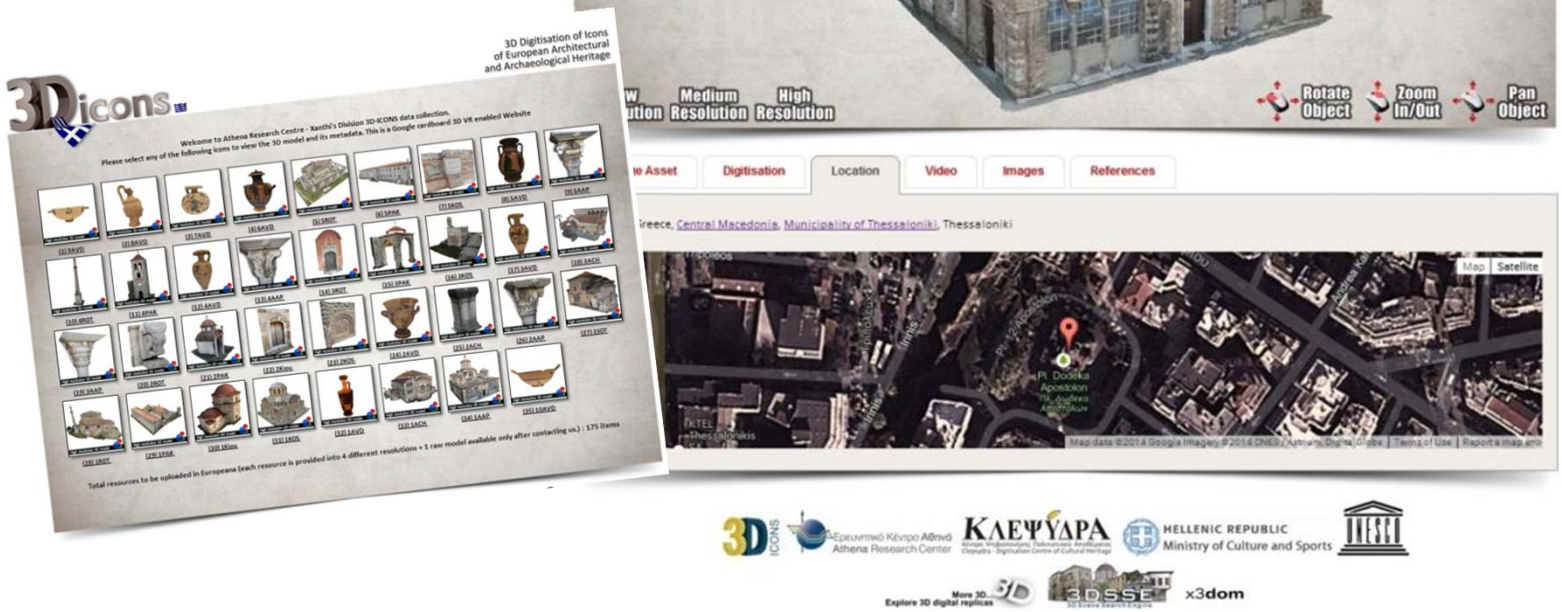
Data Processing

Aim towards Web Dissemination…

Landing page features

Use of the X3DOM Framework

- Deliver content on a wide range of platforms
  - Windows, Linuxoids, Mac OS, Android, IOS
- Patched version to display download progress
- Several navigation modes



Cheat mode URL: http://goo.gl/Q1GNyr

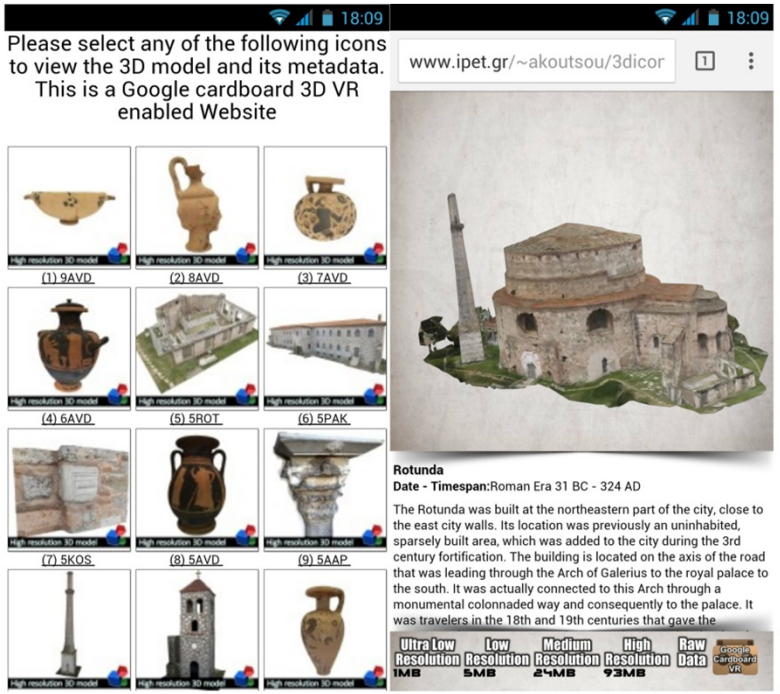
Data Processing

Aim towards Web Dissemination…

Landing page features

Device-aware content delivery

Desktop / Laptop / Tablet Rendition



Mobile Phone Rendition

Google Cardboard

Cheat mode URL: http://goo.gl/Q1GNyr

Data Processing

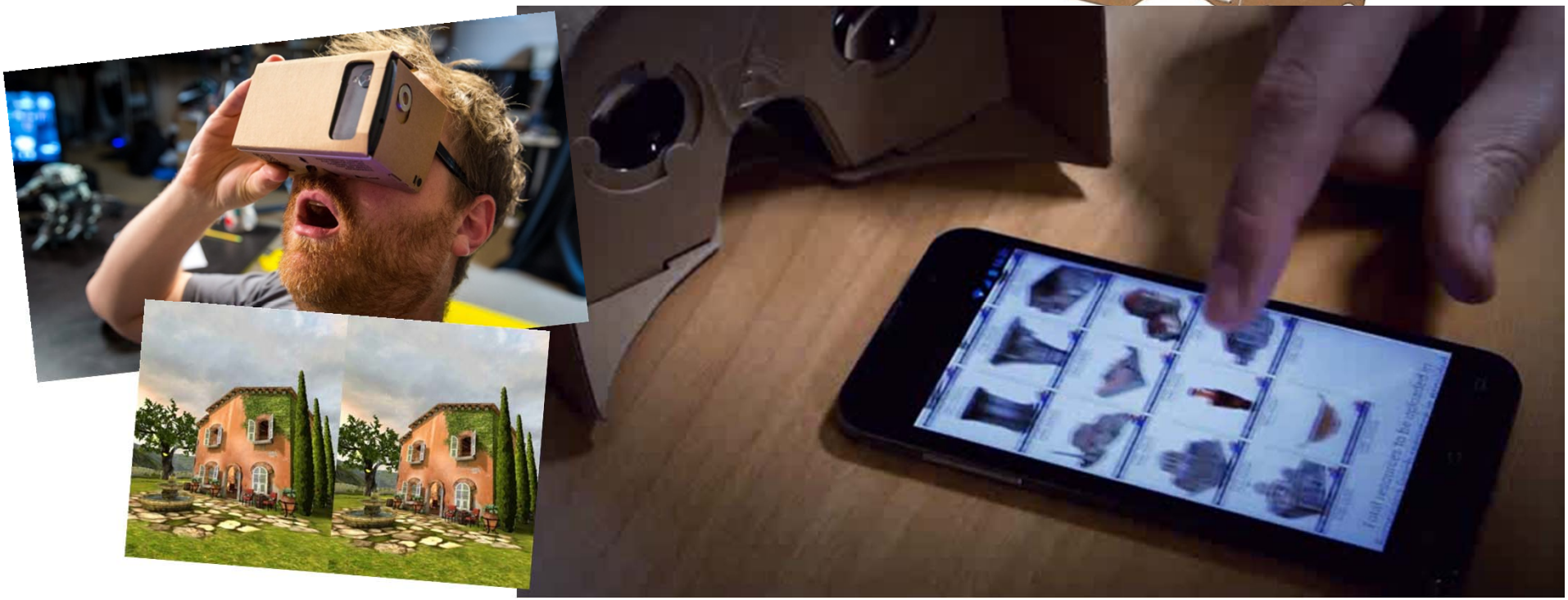
Aim towards Web Dissemination…

Landing page features

Provide content for Google Cardboard

Stereoscopic visualisation of 3D content

HTML5 → Read orientation/position sensors



Cheat mode URL: http://goo.gl/Q1GNyr

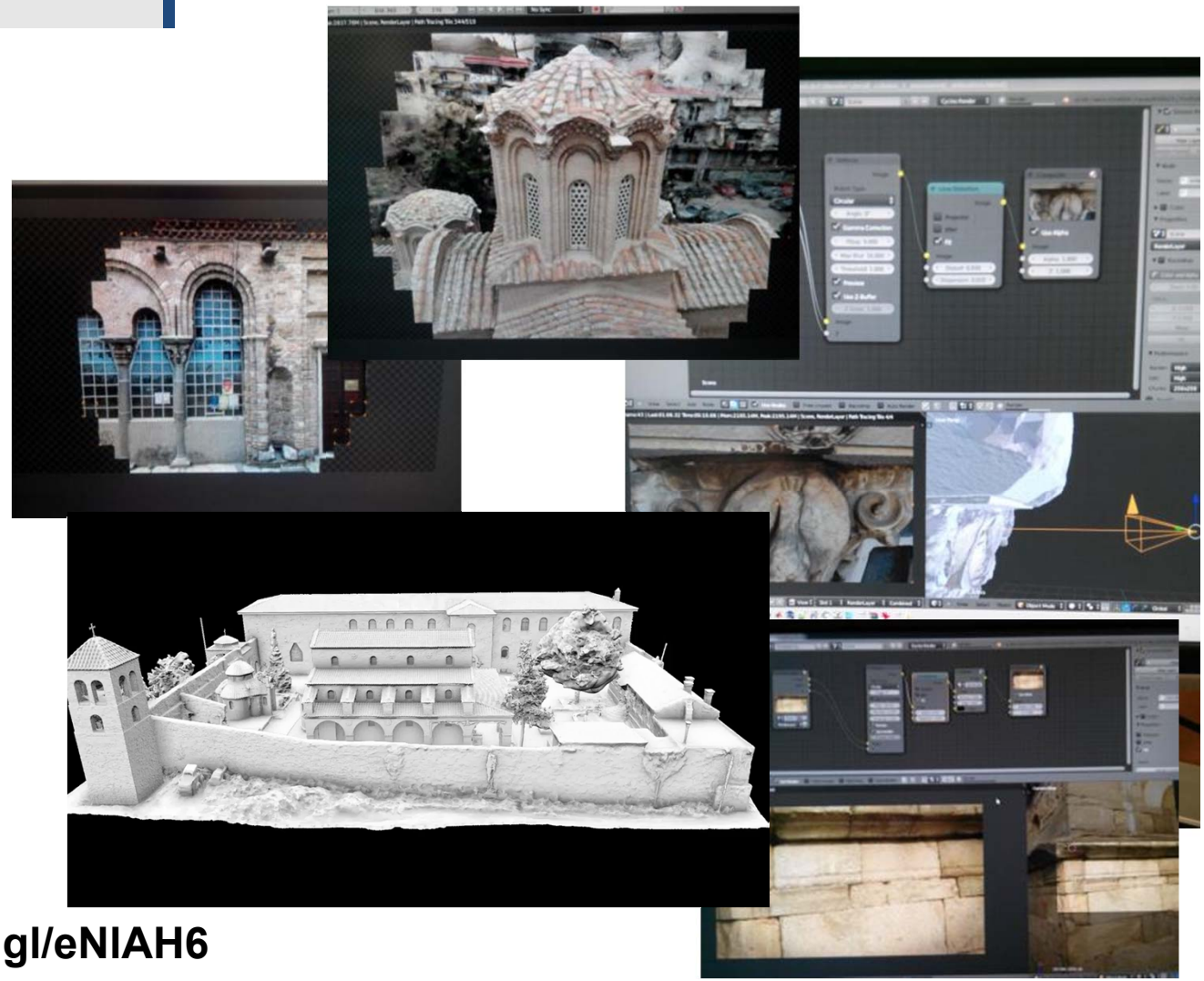
Data Processing

Derivatives…

On video sequences…

Rendered using Blender

- Cycles renderer
- Depth of field effects
- Barrel distortion
- Colour aberration
- Vignette
- 1080p
- Non-realistic



Another URL: http://goo.gl/eNIAH6

Fly-around video case studies

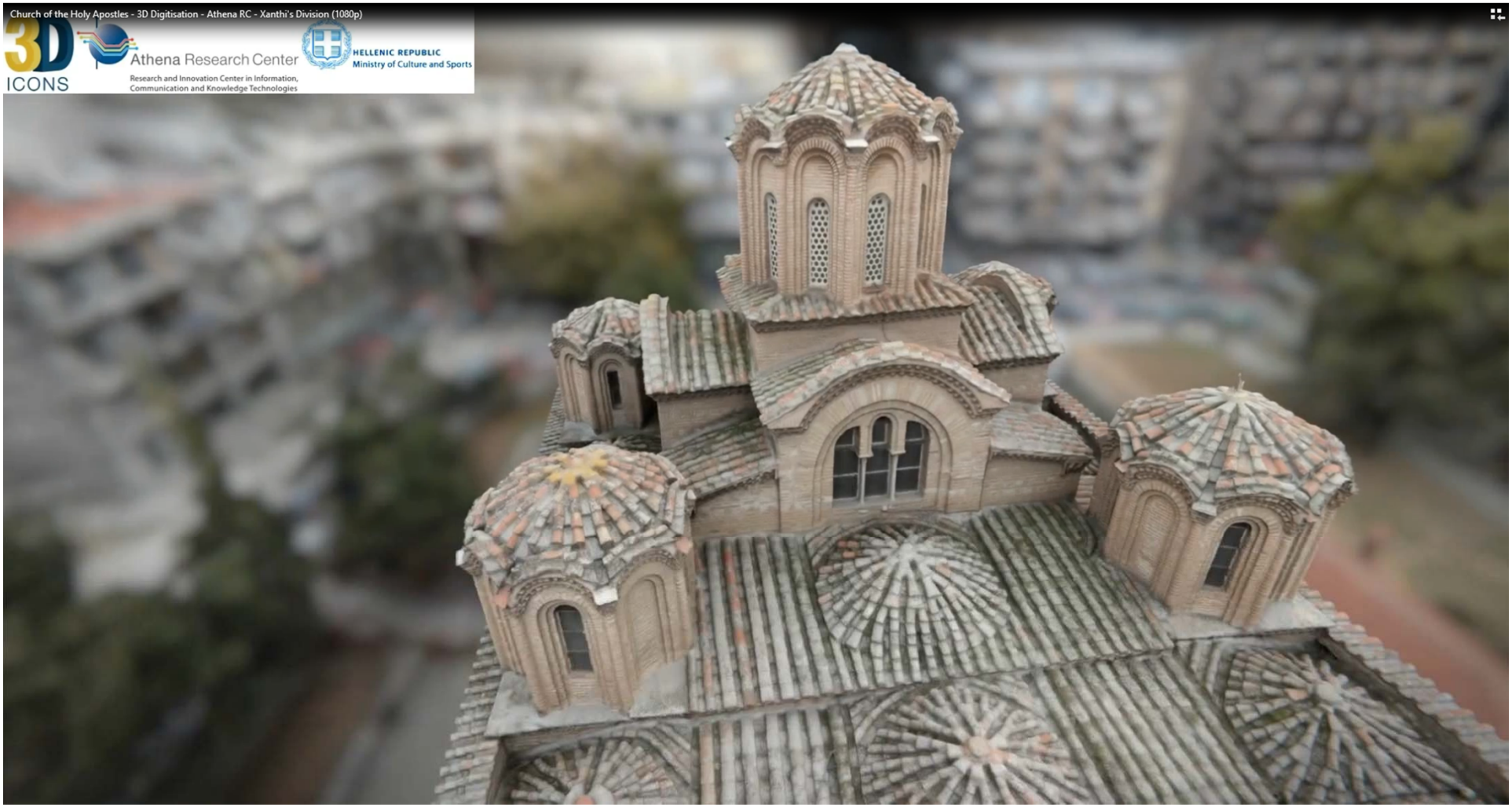
Church of St. George (Rotunda), Thessaloniki

Paleochristian and Byzantine Monuments in Northern Greece

Fly-around video case studies

Church of the Holy Apostles, Thessaloniki

Paleochristian and Byzantine Monuments in Northern Greece



Fly-around video case studies

Monastery of Panagia Kalamou in Xanthi

Monastic monuments of Northern Greece

Fly-around video case studies

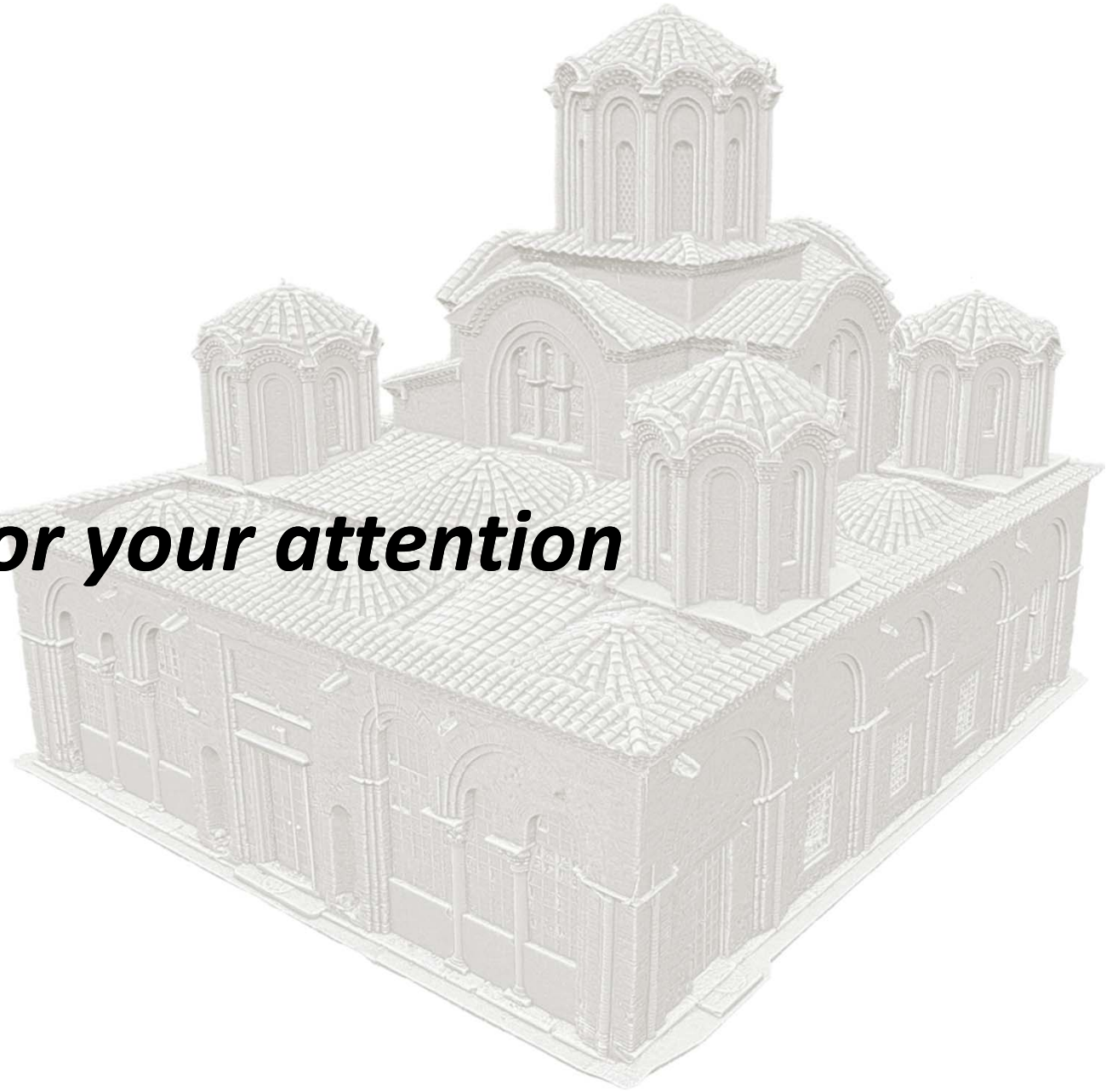
Monastery of Panagia Kosmosotira in Feres

Monastic monuments of Northern Greece

Fly-around video case studies

Church of the Acheiropoietos

Paleochristian and Byzantine Monuments in Northern Greece



Thank you for your attention