Reality based 3D models for the documentation of Cultural Heritage

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INTRODUCTION to the NEW 3D SURVEY TECHNOLOGIES

- Survey definitions and Cultural Heritage subject matter
- Non invasive 3D survey techniques: 1) long range scanner, 2) structured light scanner and 3) photogrammetry
- Survey results outcome: point cloud and/or mesh
- Use and processing of the data
- Web sharing of the data
- Conclusion/Bibliography

SURVEYING METHODS for CULTURAL HERITAGE

"Survey" is a knowledge process which makes it possible to represent the shape of objects.

The survey must follow several precise hierarchical steps:
- Inspection on the site/check object
- Selection of the representation scale
- Survey of the object with the available sensors
- Data elaboration
- Data restitution at a precise scale (generally in CH field from 1:1 to 1:100)

The two most used survey methods are:
- **Photogrammetry** (instruments: digital cameras)
- **Laser scanning** (instruments: laser TOF, Phase Shift, Triangulation-based systems)

By these methods and instruments it is possible to do a whole metric description of the object **(reality based model)**.

SURVEYING METHODS for CULTURAL HERITAGE

A 'good survey' requires **knowledge** of the instruments and techniques, **familiarity** with software for managing and processing data and the **clarity of purposes.**

An accurate 'survey' is the basis for a conservation project and further analisy.
It will contribute to growing the archives of the available documentation.

Cultural Heritage

- **DIMENSION** – small, medium, extended
- **COMPLEXITY** – decorations and undercuttes
- **MATERIAL AND SURFACE** – highly glossy or smoothed surfaces can create difficulties during the acquisition phase.
- **LIMITS** – impossibility to move, touch or reach the objects

SURVEYING METHODS for CULTURAL HERITAGE

Woman's head
private collection

Amphora
Umm El Dabadib, Egypt

Marble slab
Archaeological Museum of Naples

Column
archaeological area, Nemi Roma

Caryatid, Archaeological Museum, Villa Corsini Florence

Rural village
Ghesc, Domodossola

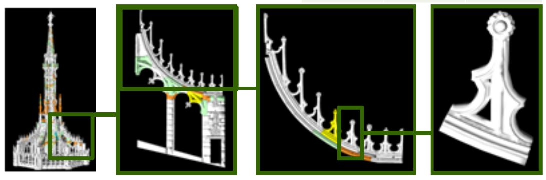
SURVEYING METHODS for CULTURAL HERITAGE

Typical representation scales for Cultural Heritage

Scale	ε (0.2mm * n)	T (ε * 2÷3)
1:1	0.2 mm	±0.4÷0.6 mm
1:2	0.4 mm	±0.8÷12 mm
1:5	1 mm	± 2÷3 mm
1:10	2 mm	±4÷6 mm
1:20	4 mm	±8÷12 mm
1:50	1cm	±2÷3 cm
1:100	2 cm	±4÷6 mm
1:200	4 cm	±8÷12 mm

…before starting the survey it is necessary to select the representation scale…

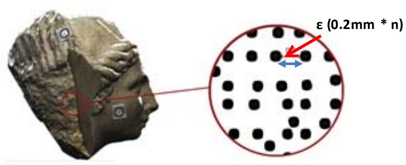
Level of detail



SURVEYING METHODS for CULTURAL HERITAGE

Distance beetwen points is equal to graphicism error*

**This value derive from the cartography field and is related to the precision of map, conventionally it is assumed to be equal to 0.2 mm * n (when n=representation scale).*

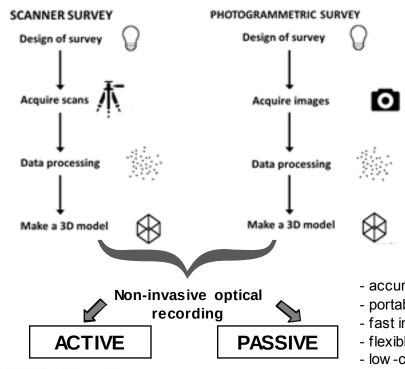


Different scale corresponding ➡ **differente Level of details.**

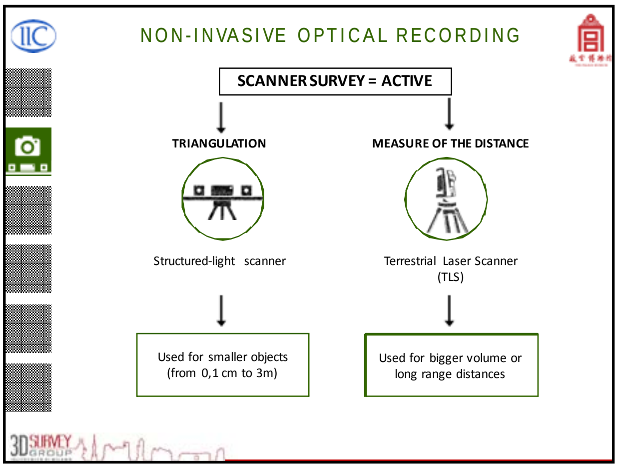
The results of the survey <u>must be detailed</u> and complete.

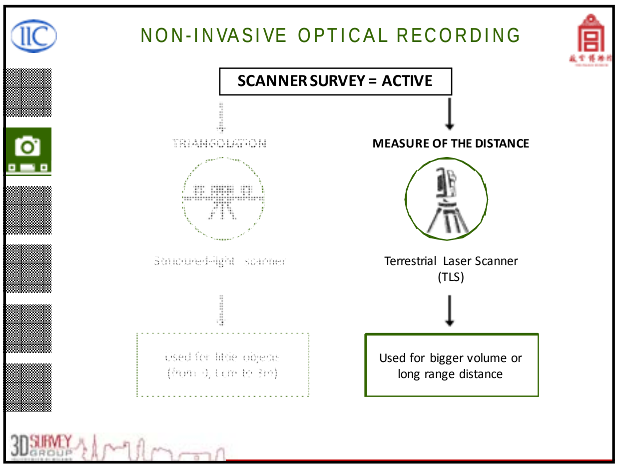
<u>Every object represents a special case</u>, while the survey methods are always the same, what changes is the operative execution procedures of the work and the instruments used.

NON-INVASIVE OPTICAL RECORDING



- accurate;
- portable;
- fast in acquisition;
- flexible,
- low-cost.


NON-INVASIVE OPTICAL RECORDING
SCANNER SURVEY = ACTIVE
TRIANGULATION
MEASURE OF THE DISTANCE
Structured-light scanner
Terrestrial Laser Scanner (TLS)
Used for smaller objects (from 0,1 cm to 3m)
Used for bigger volume or long range distances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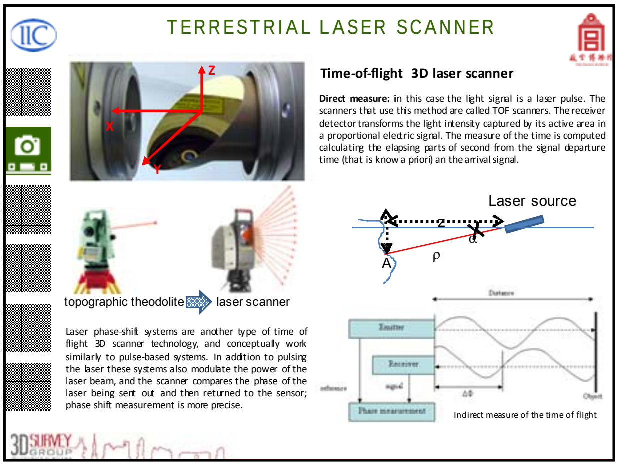
NON-INVASIVE OPTICAL RECORDING
Laser Scanner
Misuro tanti angoli e distanze
Archaeological site Umm al Dabadib - Egypt
Italy - MILAN Cathedral
Italy - San Marco Basilica in Venice
Italy Rural village
Italy – Naples Sub way & archaeological site

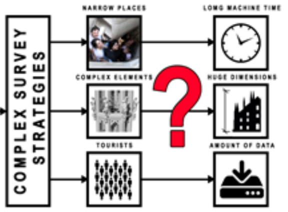

TERRESTRIAL LASER SCANNER
Time-of-flight 3D laser scanner
Direct measure: in this case the light signal is a laser pulse. The scanners that use this method are called TOF scanners. The receiver detector transforms the light intensity captured by its active area in a proportional electric signal. The measure of the time is computed calculating the elapsing parts of second from the signal departure time (that is know a priori) an the arrival signal.
Laser source
topographic theodolite
laser scanner
Laser phase-shift systems are another type of time of flight 3D scanner technology, and conceptually work similarly to pulse-based systems. In addition to pulsing the laser these systems also modulate the power of the laser beam, and the scanner compares the phase of the laser being sent out and then returned to the sensor; phase shift measurement is more precise.
Indirect measure of the time of flight

TERRESTRIAL LASER SCANNER

STEPS
- Plan the number of scans
- Acquisition
- Integration with other types of survey
- Data fusion in a raw model /alignment/georeferencing cloud
- Editing the model
- Processing of the data

...how to make a good survey?

Acquisition scans & problems



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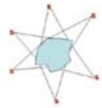
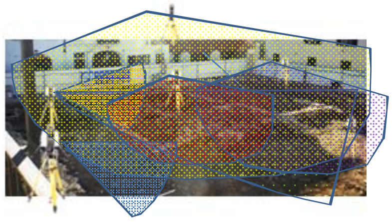
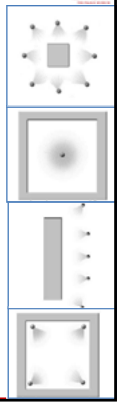


Dimension/environment





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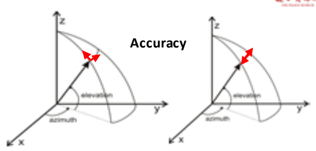
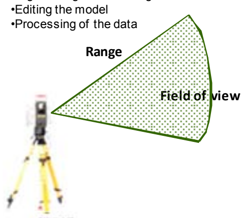
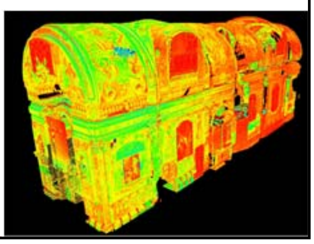




http://www.microgeo.it/



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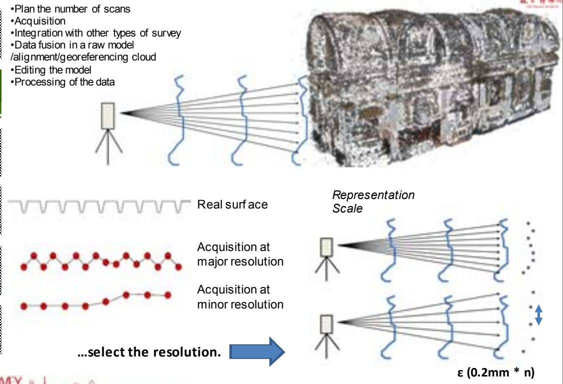

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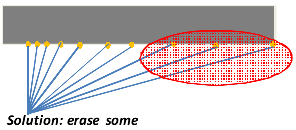
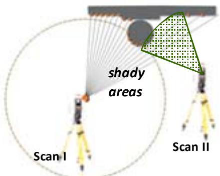
Acquisition scans & problems

Resolution & scale





TERRESTRIAL LASER SCANNER - acquisition

STEPS
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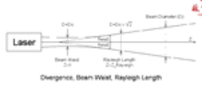
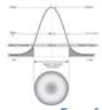
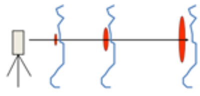
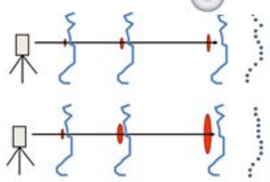




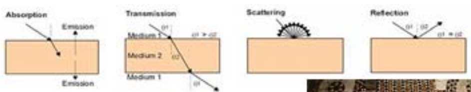
Acquisition scans & problems



On short distances the phenomenon is negligible, less at higher distances.



Acquisition scans & problems



• Superfici / materiali a comportamento quasi lambertiano:

Materiale	*Riflettività (ρ)*
Carta bianca	superiore al 100%
Legno asciutto	94%
Neve	80-90%
Calcare	argilla superiore al 75%
Alberi latifoglie	mediamente 60%
Alberi Aghifoglie	mediamente 30%
Sabbia in genere	mediamente 50%
Calcestruzzo liscio	24%
Asfalto con ciottoli	17%
Lava	8%
Neoprene di colore nero	5%
Gomma nera	2,00%

Superfici / materiali a comportamento quasi riflettente o superfici retroriflettenti:

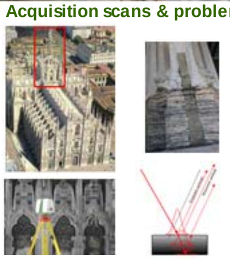
Materiale	*Riflettività (ρ)*
Foglio riflettente tipo 3M2000X	1250%
Plastica opaca bianca	110%
Plastica opaca nera	17%
Plastica	mediamente 50%

Behavior of the laser in contact with the materials

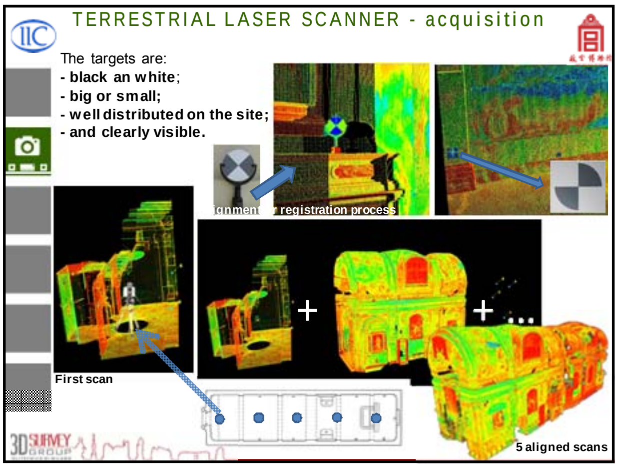
I valori di riflettività indicati sono validi per un laser con una lunghezza d'onda di ~ 0,9 μm.

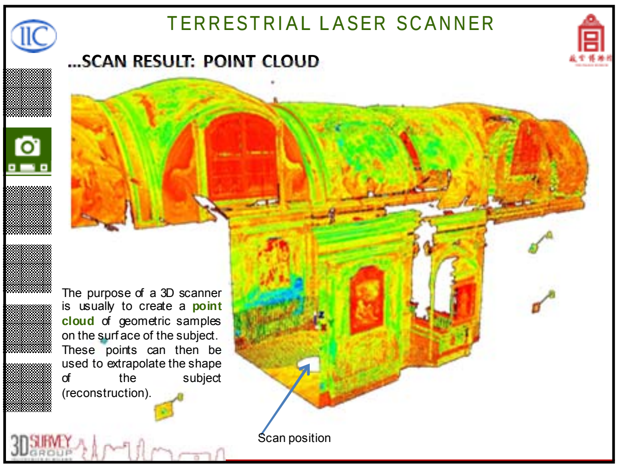
TERRESTRIAL LASER SCANNER - acquisition

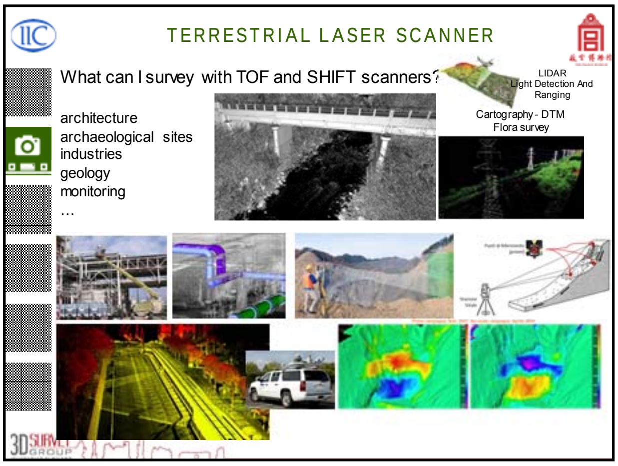
Acquisition scans & problems



Example of false laser scans. As the images show, the flat pillar surface and regular corner look irregular and deformed. This kind of scan can only be used for visualisation purposes, not in the modelling process. Examples of low quality point scan due to the marble surface inside the spire's helicoidal staircase.


TERRESTRIAL LASER SCANNER - acquisition
The targets are:
- black an white;
- big or small;
- well distributed on the site;
- and clearly visible.
registration process
First scan
5 aligned scans


TERRESTRIAL LASER SCANNER
...SCAN RESULT: POINT CLOUD
The purpose of a 3D scanner is usually to create a point cloud of geometric samples on the surface of the subject. These points can then be used to extrapolate the shape of the subject (reconstruction).
Scan position


TERRESTRIAL LASER SCANNER
What can I survey with TOF and SHIFT scanners?
LIDAR
Light Detection And Ranging
Cartography - DTM
Flora survey
architecture
archaeological sites
industries
geology
monitoring
…


TERRESTRIAL LASER SCANNER
What can I survey with TOF and SHIFT scanners?
ARCHAEOLOGICAL AREAS/ HISTORIC BUILDINGS
APPLICATION FIELDS
Professional work
Research – University
Training

NON-INVASIVE OPTICAL RECORDING

SCANNER SURVEY = ACTIVE

TRIANGULATION

Structured-light scanner

Used for little objects (from 0,1 cm to 3m)

MEASURE OF THE DISTANCE

Terrestrial Laser Scanner (TLS)

Used for bigger volume or long range distance

3D SURVEY GROUP

STRUCTURED-LIGHT SCANNER

Triangulation Scanner

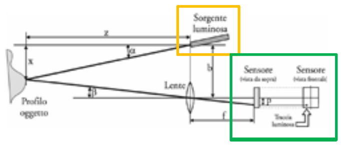
The system is very simple and the functioning is analogous to the topographic concept of triangulation. The triangle is the base of many measurement techniques.

The system is composed by a **light source** (generally a laser beam) and by a plane sensor that are bounded strictly each other.

The light source projects a light beam on the surface and the **sensor**, normally a digital video camera takes the image of the light point on the surface: the light source, the light spot on the surface and the camera form a triangle. To measure the coordinate X, Y, Z of the point on the surface some parts of the triangle geometry must be known a priori:

- The **distance b** between source and camera (Baseline)
- The **focal distance** between sensor plane and lenses.
- The **inclination** α of the light source

RANGE 7 3D Laser Scanner
Konica Minolta Range 7

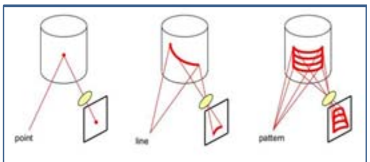


3D SURVEY GROUP

STRUCTURED-LIGHT SCANNER

Laser triangulation scanners use either a laser line or single laser point to scan across an object. A sensor picks up the laser light that is reflected off the object, and using trigonometric triangulation, the system calculates the distance from the object to the scanner. The distance between the laser source and the sensor is known very precisely, as well as the angle between the laser and the sensor.

As the laser light reflects off the scanned object, the system can discern what angle it is returning to the sensor at, and therefore the distance from the laser source to the object's surface.



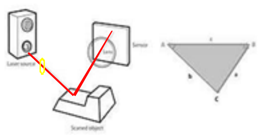
Single spot scanner — Slit Scanner — Pattern Scanner

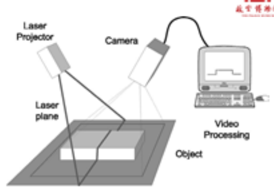
- **very high accuracy (sub-millimeter)**
- **limited range (usually 1 m)**
- **quite high acquisition times**

3D SURVEY GROUP

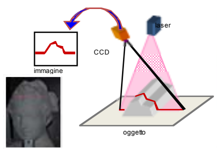
STRUCTURED-LIGHT SCANNER

Single spot scanner





The slit scanner are the natural development of the single spot scanner. They don't project a point on the surface but a laser line and let to collect the entire object profiles.

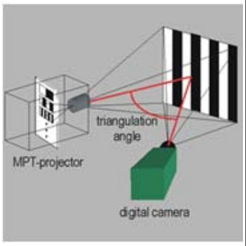


3D SURVEY GROUP

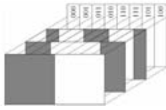
STRUCTURED-LIGHT SCANNER

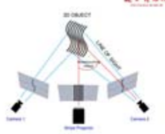
Structured light is a method of 3D scanning where we project a known pattern onto an unknown surface and by analyzing the deformation (warping) of the known pattern we can mathematically reconstruct the surface virtually. Normally this pattern is a sequence of vertical black and white strips.

Structured Light Devices



STRUCTURED-LIGHT SCANNER

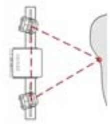




The sequence of codec pattern during the scan.

Another methodology is to use the Moiré effect. It is the result of the fusion of two pattern that are similar but not identical and that create interference figures when superimposed. The deviation from planarity of a pattern projected on a surface produces a series of deformations (pulls and compressions) that are the local variation of the pattern phase. The entity of this variation is correlated with the deviation amplitude and with the trend of the analyzed surface. Calibrating the system with this methodology it is possible to measure the geometry of a surface with great accuracy.

STRUCTURED-LIGHT SCANNER



STRUCTURED-LIGHT SCANNER

SLIT scanner

Time of the survey the face of Michelangelo's David at the Galleria degli Uffizi in Florence with the laser scanner triangulation: Cyberware 3030 MS.

STRUCTURED-LIGHT SCANNER

RANGE 7 3D Laser Scanner
Konica Minolta Range 7

- Each scan maximum of 1,310,000 points
- Foot print of about 20x30 cm2 object at a distance of between 45 and 80 cm.
- uncertainty about the point about 0.1 mm.

Milan' Cathedral – hight detailed survey of statue

178 scans – raw model 200 milion points

Final model, 6 hours elaboartion

STRUCTURED-LIGHT SCANNER

Cronos3D

Sensors: 2 * 3,1 Mpix b/n cameras
Footprint: 500 * 400 mm
Certified precision: 0,004 mm

SENSORE	Cronos 3D
OBIETTIVO	2 telecamere di tipo industriale, 3,1 mpx
ATTREZZATURA	Cavalletto, scatto remoto
DIASTANZA DI ACQUISIZIONE	80 cm ÷ 1 m (footprint 500 mm)
GEOMTERIA DI ACQUISIZIONE	Ottimizzata di scansione in scansione per raggiungere tutte le porzioni del manufatto
NUMERO DI SCANSIONI	270
TARGET	Circolari non codificati
PRECISIONE	Compresa tra 20 e 40 micron sulla singola scansione
RISOLUZIONE	0,2 mm
DEVIAZIONE MASSIMA TEORICA	± 0,06 mm

STRUCTURED-LIGHT SCANNER

TARGET:

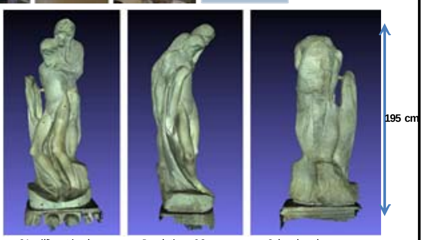
1:1 MODEL

Pietà Rondanini Statue

- Marble statue
- Height 195 cm ca
- High detailed

Survey specifications

- 270 scans
- 80 cm distance
- Optimized geometry
- Use of circular targets



- 21 millions triangles
- Resolution = 0,2 mm
- Colored mesh

STRUCTURED-LIGHT SCANNER

November 2016

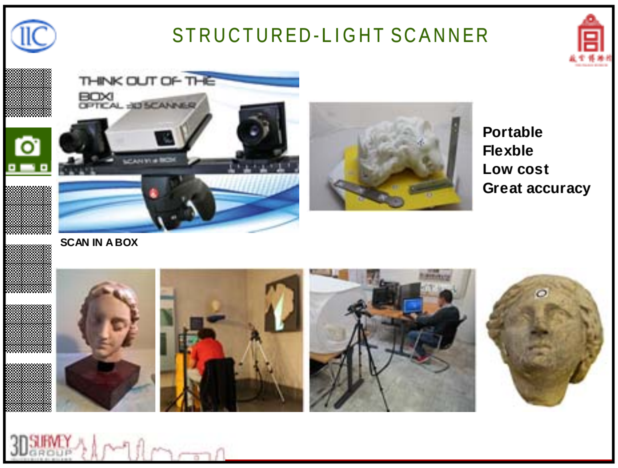
https://www.artec3d.com/artec-eva

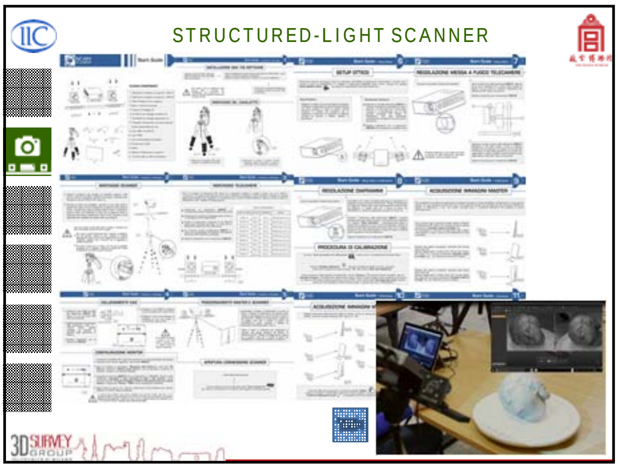
Handheld 3D Data Capture on a Tablet

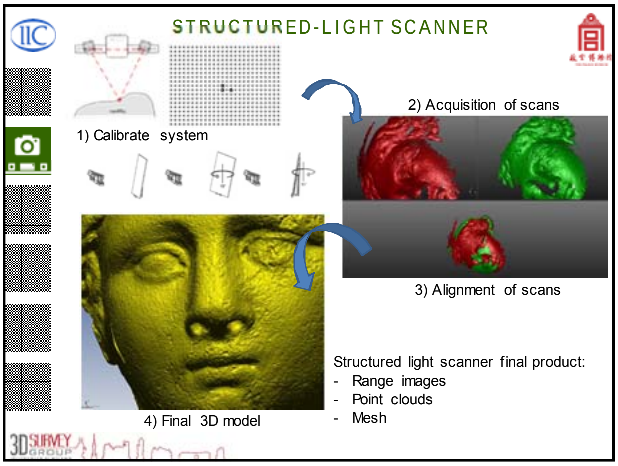
Structured Light scanner DAVID SLS-2

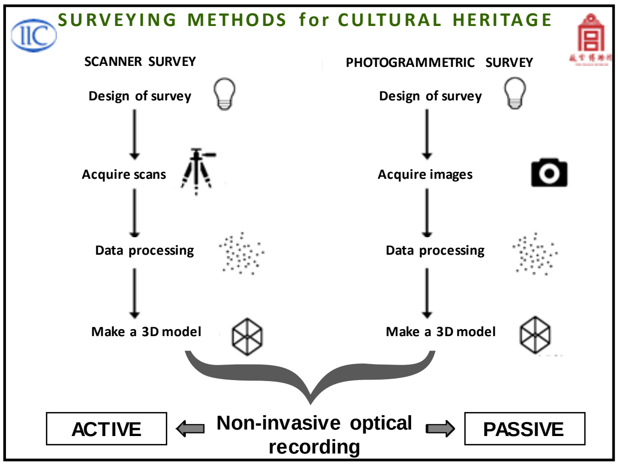
GO!SCAN 3D

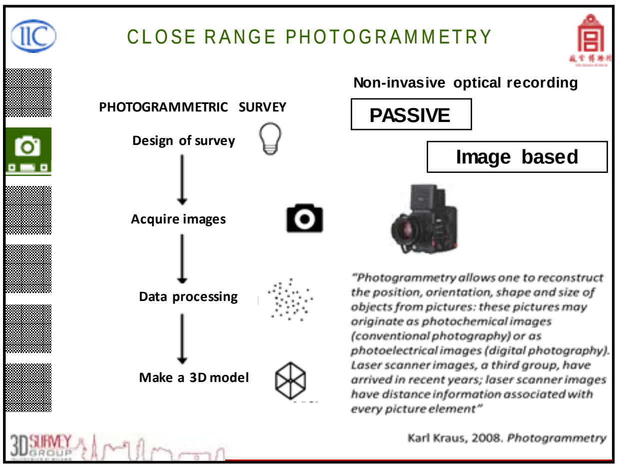
http://www.creaform3d.com/en/metrology-solutions/portable-3d-scanners

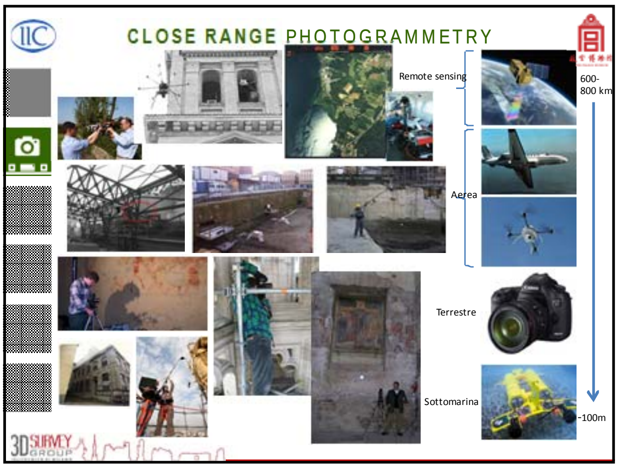

STRUCTURED-LIGHT SCANNER
THINK OUT OF THE BOX!
OPTICAL 3D SCANNER
SCAN IN A BOX
Portable
Flexble
Low cost
Great accuracy

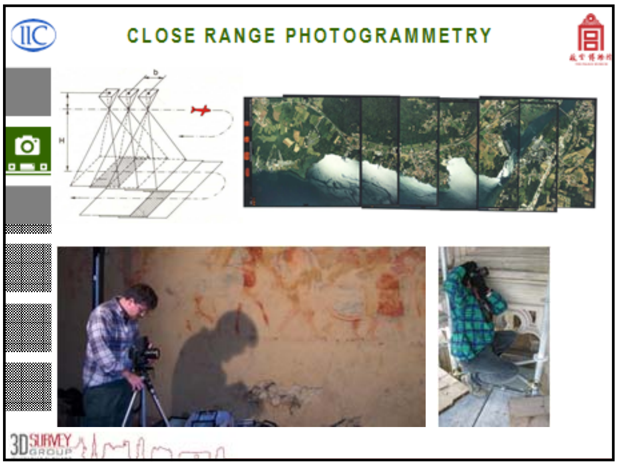

STRUCTURED-LIGHT SCANNER

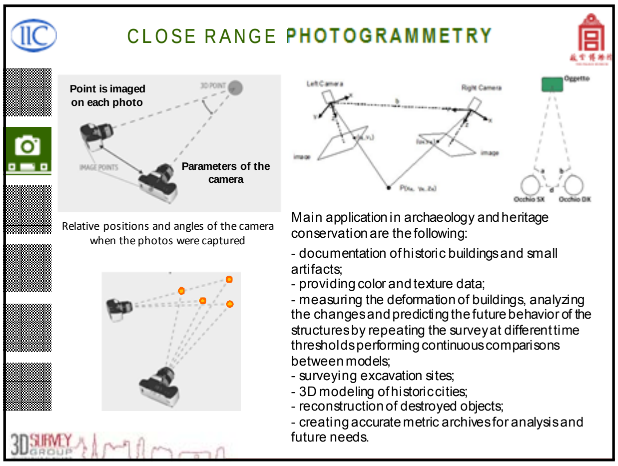

STRUCTURED-LIGHT SCANNER
1) Calibrate system
2) Acquisition of scans
3) Alignment of scans
4) Final 3D model
Structured light scanner final product:
- Range images
- Point clouds
- Mesh

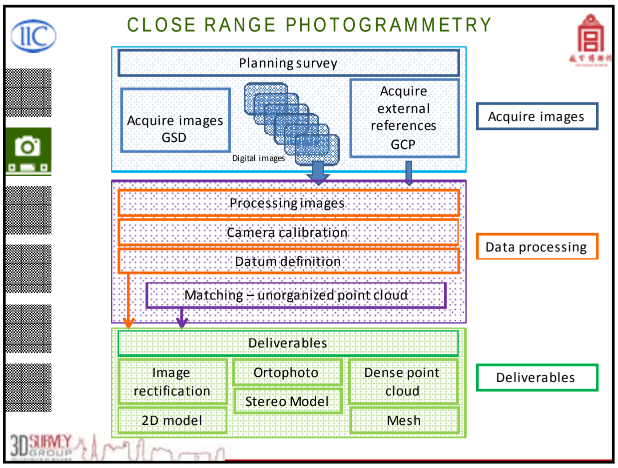

SURVEYING METHODS for CULTURAL HERITAGE
SCANNER SURVEY
Design of survey
Acquire scans
Data processing
Make a 3D model
PHOTOGRAMMETRIC SURVEY
Design of survey
Acquire images
Data processing
Make a 3D model
ACTIVE
Non-invasive optical recording
PASSIVE

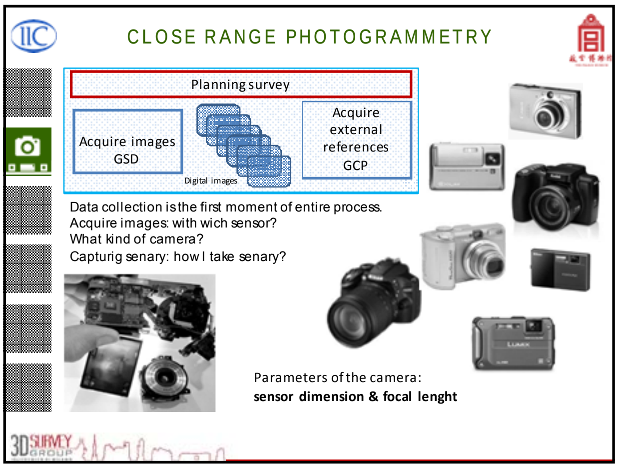

CLOSE RANGE PHOTOGRAMMETRY
PHOTOGRAMMETRIC SURVEY
Design of survey
Acquire images
Data processing
Make a 3D model
Non-invasive optical recording
PASSIVE
Image based
"Photogrammetry allows one to reconstruct the position, orientation, shape and size of objects from pictures: these pictures may originate as photochemical images (conventional photography) or as photoelectrical images (digital photography). Laser scanner images, a third group, have arrived in recent years; laser scanner images have distance information associated with every picture element"
Karl Kraus, 2008. Photogrammetry

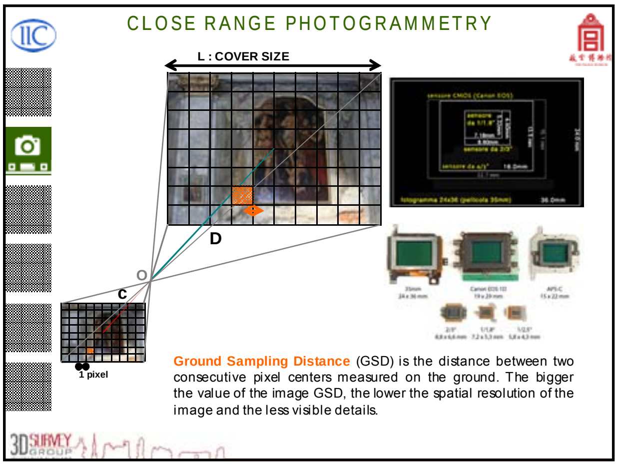

CLOSE RANGE PHOTOGRAMMETRY
Remote sensing
600-800 km
Aerea
Terrestre
Sottomarina
-100m

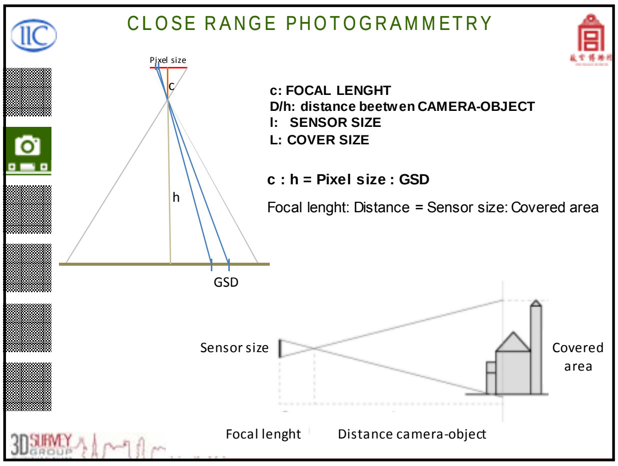

CLOSE RANGE PHOTOGRAMMETRY


CLOSE RANGE PHOTOGRAMMETRY
Point is imaged on each photo
Parameters of the camera
Relative positions and angles of the camera when the photos were captured
Main application in archaeology and heritage conservation are the following:
- documentation of historic buildings and small artifacts;
- providing color and texture data;
- measuring the deformation of buildings, analyzing the changes and predicting the future behavior of the structures by repeating the survey at different time thresholds performing continuous comparisons between models;
- surveying excavation sites;
- 3D modeling of historic cities;
- reconstruction of destroyed objects;
- creating accurate metric archives for analysis and future needs.

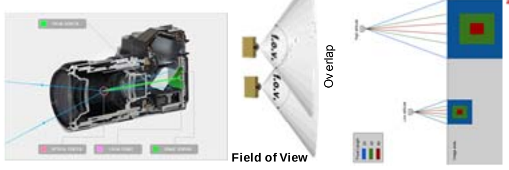

CLOSE RANGE PHOTOGRAMMETRY
Planning survey
Acquire images GSD
Digital images
Acquire external references GCP
Acquire images
Processing images
Camera calibration
Datum definition
Matching – unorganized point cloud
Data processing
Deliverables
Image rectification
Ortophoto
Dense point cloud
Stereo Model
2D model
Mesh
Deliverables


CLOSE RANGE PHOTOGRAMMETRY
Planning survey
Acquire images GSD
Digital images
Acquire external references GCP
Data collection is the first moment of entire process.
Acquire images: with wich sensor?
What kind of camera?
Capturig senary: how I take senary?
Parameters of the camera:
sensor dimension & focal lenght


CLOSE RANGE PHOTOGRAMMETRY
L : COVER SIZE
D
O
c
1 pixel
Ground Sampling Distance (GSD) is the distance between two consecutive pixel centers measured on the ground. The bigger the value of the image GSD, the lower the spatial resolution of the image and the less visible details.

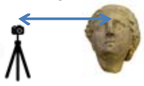

CLOSE RANGE PHOTOGRAMMETRY
Pixel size
c
h
GSD
c: FOCAL LENGHT
D/h: distance beetwen CAMERA-OBJECT
l: SENSOR SIZE
L: COVER SIZE
c : h = Pixel size : GSD
Focal lenght: Distance = Sensor size: Covered area
Sensor size
Covered area
Focal lenght
Distance camera-object

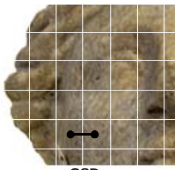
CLOSE RANGE PHOTOGRAMMETRY



How to select Camera Focal Length and distance considering the desired Ground Sampling Distance and object dimension? Two possibility.

Defined distance, increasing the focal length

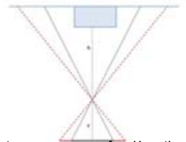




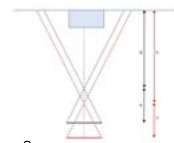
Defined focal length, decreasing the distance

CLOSE RANGE PHOTOGRAMMETRY

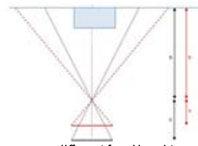
c : h = Pixel size : GSD



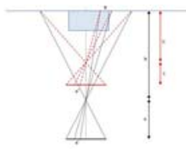
Different cameras - same focal length - different sensors. The scale factor it is the same for the two cameras but it is different the covered area.



Same cameras, same sensors, same focal lenght. Different distances. GSD > for black camera



Same sensor, different focal lenght. GSD > for black camera

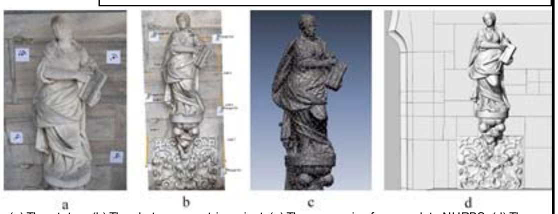


Different focal lenght, different distances. Same GSD

CLOSE RANGE PHOTOGRAMMETRY

How to select Camera Focal Length and distance considering the desired Ground Sampling Distance and object dimension? Two possibility.

Pixel size (mm)	Sensor size (mm)	GSD at 1:1 map scale (mm)	Focal length (mm)	Distance of acquisition (mm)	Area covered (m^2)
			20	160 ÷ 320	
0.00625	24 * 36	0.05 ÷ 0.1	35	280 ÷ 560	0.24
			85	680 ÷ 1360	

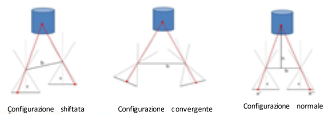


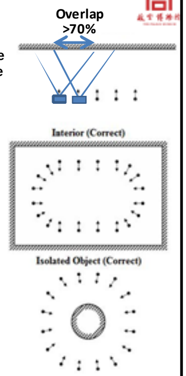
(a) The statue; (b) The photogrammetric project; (c) The conversion from mesh to NURBS; (d) The NURBS model into Rhinoceros

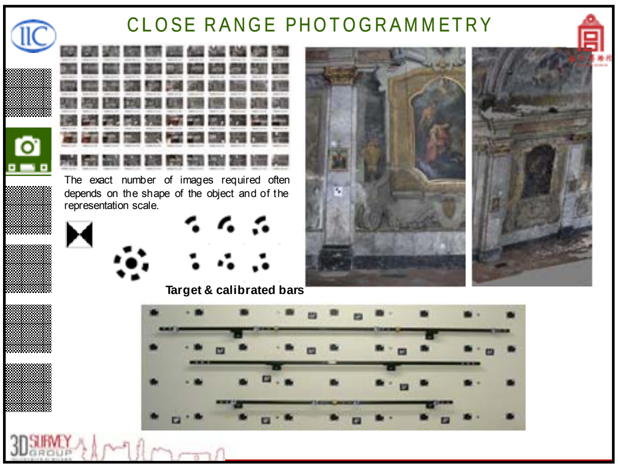
CLOSE RANGE PHOTOGRAMMETRY

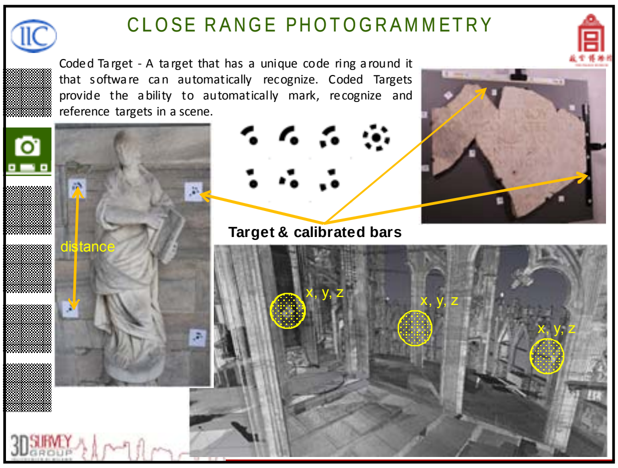
Capturing scenarios

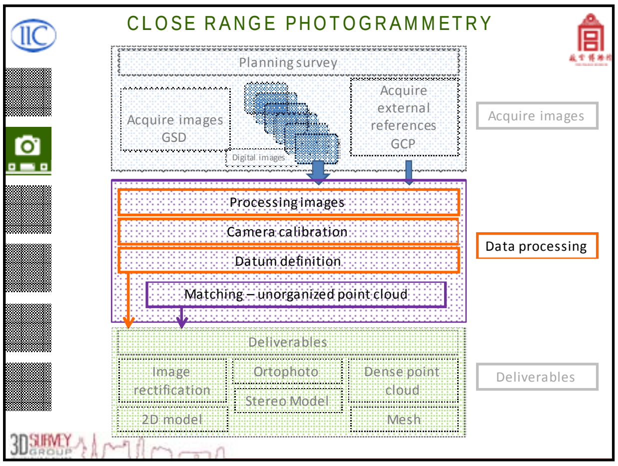
- Image acquisition plan type
- Ground Sampling Distance
- Overlap






CLOSE RANGE PHOTOGRAMMETRY
The exact number of images required often depends on the shape of the object and of the representation scale.
Target & calibrated bars


CLOSE RANGE PHOTOGRAMMETRY
Coded Target - A target that has a unique code ring around it that software can automatically recognize. Coded Targets provide the ability to automatically mark, recognize and reference targets in a scene.
Target & calibrated bars
distance
x, y, z
x, y, z
x, y, z


CLOSE RANGE PHOTOGRAMMETRY
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Datum definition
Matching – unorganized point cloud
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2D model
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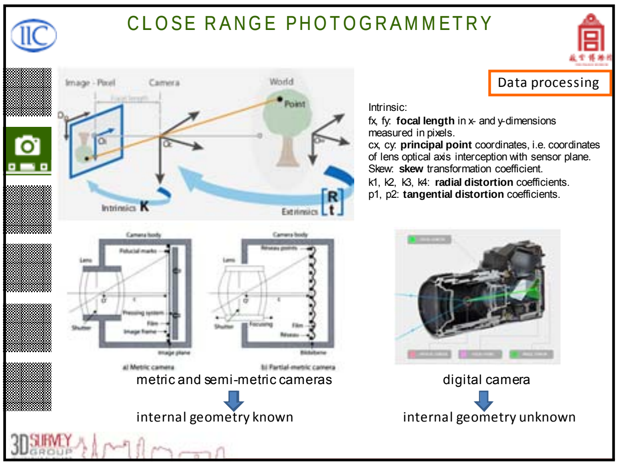
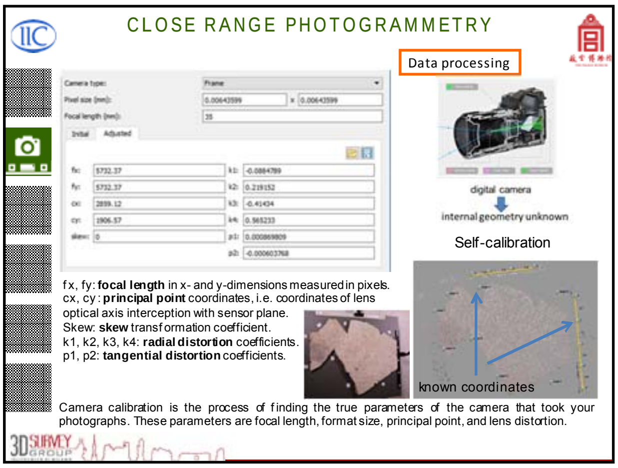
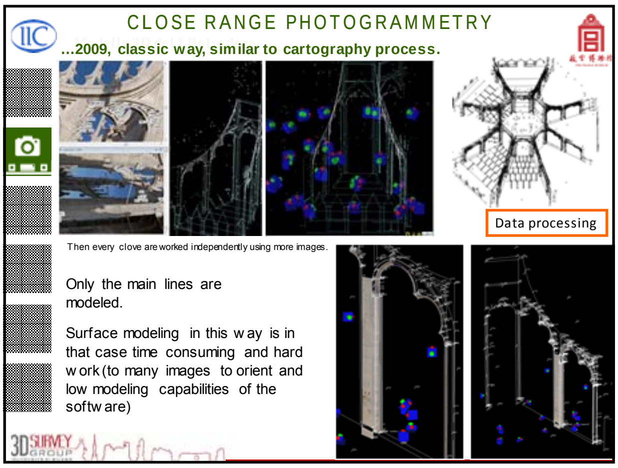
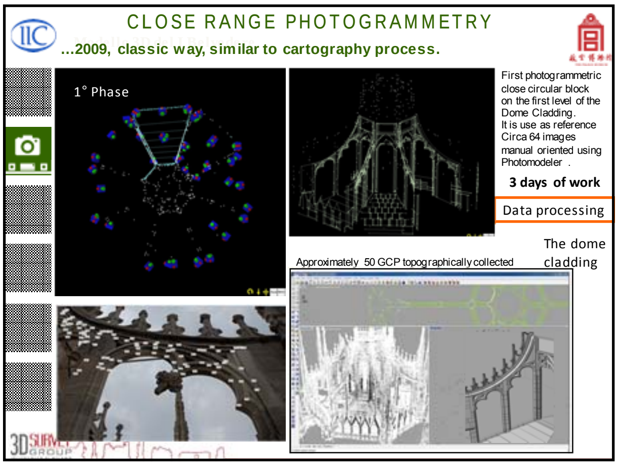
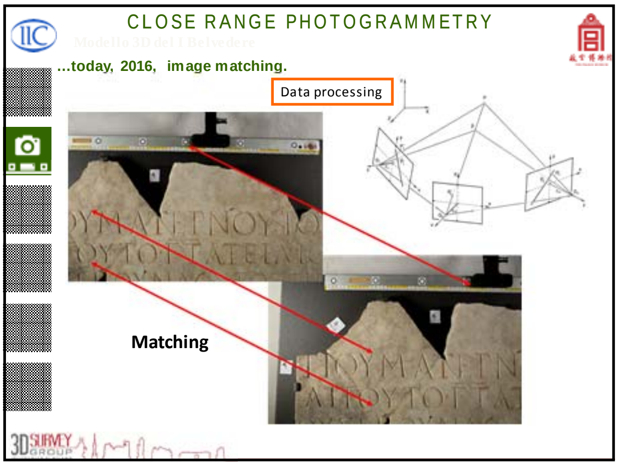
Deliverables

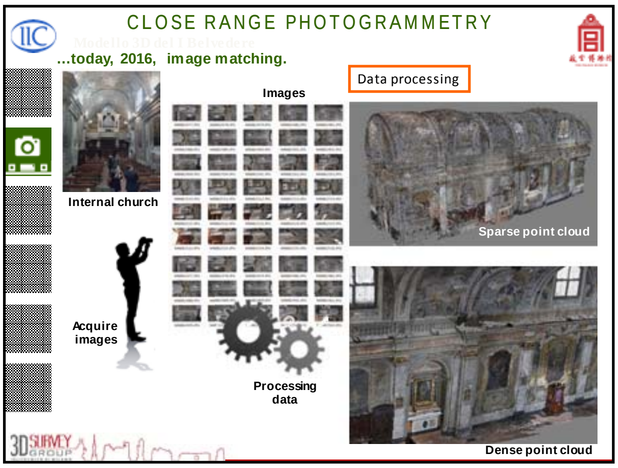

CLOSE RANGE PHOTOGRAMMETRY
Data processing
Intrinsic:
fx, fy: focal length in x- and y-dimensions measured in pixels.
cx, cy: principal point coordinates, i.e. coordinates of lens optical axis interception with sensor plane.
Skew: skew transformation coefficient.
k1, k2, k3, k4: radial distortion coefficients.
p1, p2: tangential distortion coefficients.
metric and semi-metric cameras
internal geometry known
digital camera
internal geometry unknown

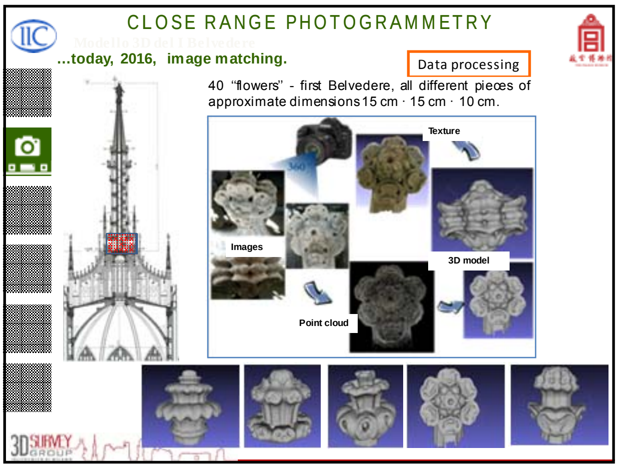

CLOSE RANGE PHOTOGRAMMETRY
Data processing
digital camera
internal geometry unknown
Self-calibration
fx, fy: focal length in x- and y-dimensions measured in pixels.
cx, cy: principal point coordinates, i.e. coordinates of lens optical axis interception with sensor plane.
Skew: skew transformation coefficient.
k1, k2, k3, k4: radial distortion coefficients.
p1, p2: tangential distortion coefficients.
known coordinates
Camera calibration is the process of finding the true parameters of the camera that took your photographs. These parameters are focal length, format size, principal point, and lens distortion.

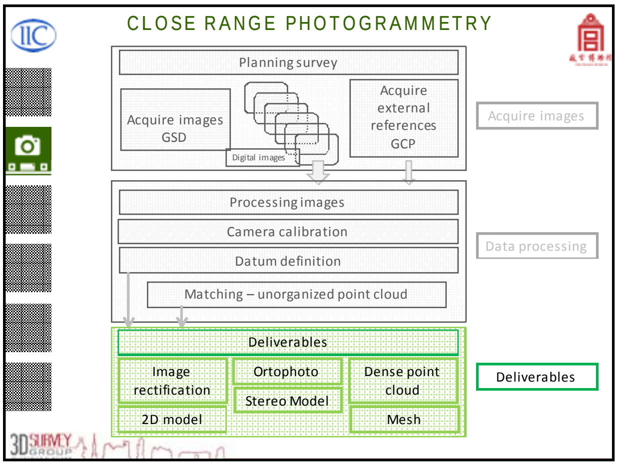

CLOSE RANGE PHOTOGRAMMETRY
...2009, classic way, similar to cartography process.
Data processing
Then every clove are worked independently using more images.
Only the main lines are modeled.
Surface modeling in this way is in that case time consuming and hard work (to many images to orient and low modeling capabilities of the software)


CLOSE RANGE PHOTOGRAMMETRY
...2009, classic way, similar to cartography process.
1° Phase
First photogrammetric close circular block on the first level of the Dome Cladding.
It is use as reference
Circa 64 images
manual oriented using Photomodeler .
3 days of work
Data processing
The dome cladding
Approximately 50 GCP topographically collected


CLOSE RANGE PHOTOGRAMMETRY
...today, 2016, image matching.
Data processing
Matching


CLOSE RANGE PHOTOGRAMMETRY
...today, 2016, image matching.
Data processing
Images
Internal church
Sparse point cloud
Acquire images
Processing data
Dense point cloud


CLOSE RANGE PHOTOGRAMMETRY
...today, 2016, image matching.
Data processing
40 “flowers” - first Belvedere, all different pieces of approximate dimensions 15 cm · 15 cm · 10 cm.
Texture
Images
3D model
Point cloud


CLOSE RANGE PHOTOGRAMMETRY
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2D model
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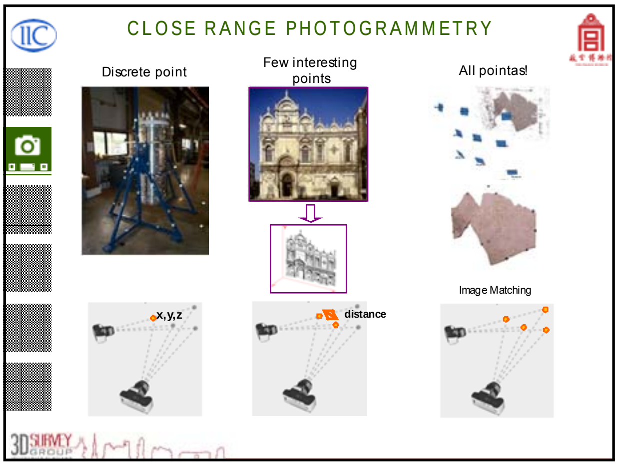
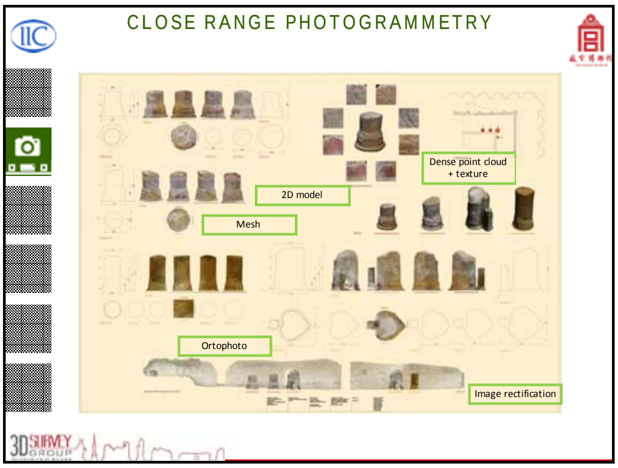
Deliverables


CLOSE RANGE PHOTOGRAMMETRY
Discrete point
Few interesting points
All pointas!
Image Matching
x,y,z
distance



CLOSE RANGE PHOTOGRAMMETRY

Basic rules - summary

- Spending some time planning your shot session might be very useful.
- Use a digital camera with reasonably high resolution.
- Wide angle lenses suit better for reconstructing spatial relations between objects than telephoto ones.
- Place correct number of target/bars.
- Avoid not textured and flat objects or scenes (matching fails).
- Avoid shiny and transparent objects.
- Shoot pictures of the scene with a lot of overlap.
- Capture most important scene content from multiple viewpoints (3 or more).
- Do not crop or geometrically transform the images.
- More photos is better than not enough.

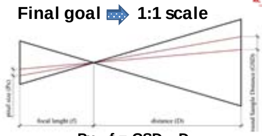
…from the point cloud to the solid model and extraction of 2D information…

CLOSE RANGE PHOTOGRAMMETRY

EXERCISE

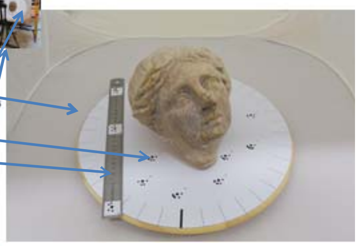
INSTRUMENTS:
Camera: CANON 5D MARK III
Sensor size: 24 mm x 36 mm
Pixel size: 0.00625 mm
Focal lenght: 35 mm

Final goal ➡ 1:1 scale



Px : f = GSD : D

TOOLS:
- 1 rotating plate
- 10 degrees reference lines on the plate
- 15 coded markers
- 1 calibrated bar
- 1 flexible meter
- 1 still life cube
- 1 photographic tripod



CLOSE RANGE PHOTOGRAMMETRY

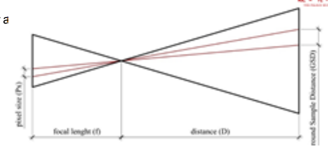
DESIGNED GSD: 0,1 mm (sufficient for a rendering scale equal to 1:1)

Px : f = GSD : D

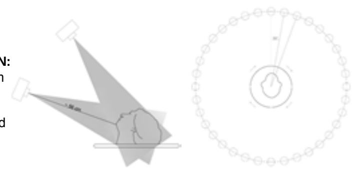
Px = Pixel size of the camera sensor
f = focal lenght
GSD = ground sampling distance (expected resolution of the model)
D = distance of acquisition

0,00625 mm : 35 mm = 0,1 mm : D

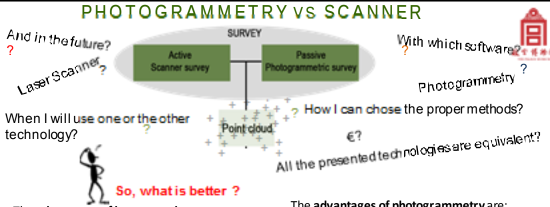
D = 56 cm



GEOMETRY OF ACQUISITION:
- Distance of acquisition: 56 cm
- 1 shot every 10 degrees
- 2 different heights of camera
- 2 different position of the head



PHOTOGRAMMETRY VS SCANNER



The **advantages of long range laser scanner** are:
- large amount of information;
- high accuracy;
- indipendent of light and texture
- point cloud describe simple and complex features.

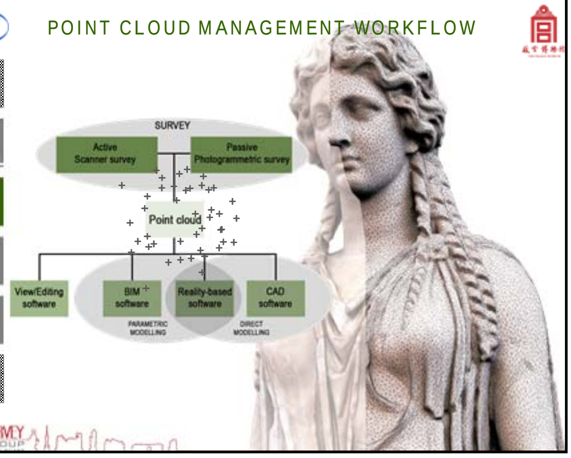
Disadvantages:
- Complex and time consuming elaboration;
- heavy data;
- more expensive
- not easily portable

The **advantages of photogrammetry** are:
- ease in creating photographic and 3D archives at the same time;
- large amount of information;
- high accuracy;
- metric, vector & raster data provided together;
- low-cost and portable equipment.

Disadvantages:
- not easy to use by non-expert users;
- dependent on the resolution of the camera;
- applicable only on textured, non-shining objects.

…"as for every survey project, a testing of measurements and of final restitution must always be carried out!"

POINT CLOUD MANAGEMENT WORKFLOW



POINT CLOUD MANAGEMENT WORKFLOW

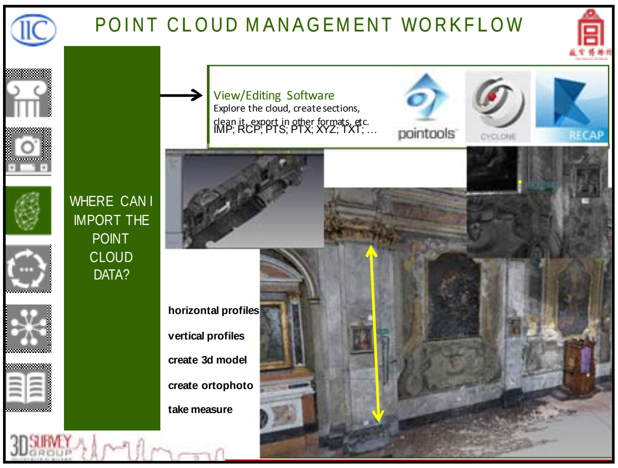
WHERE CAN I IMPORT THE POINT CLOUD DATA?

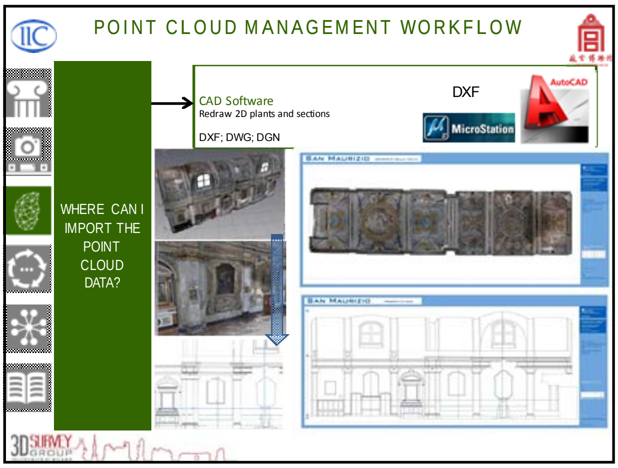
View/Editing Software
Explore the cloud,
create sections,
clean it,
export in other formats, etc.

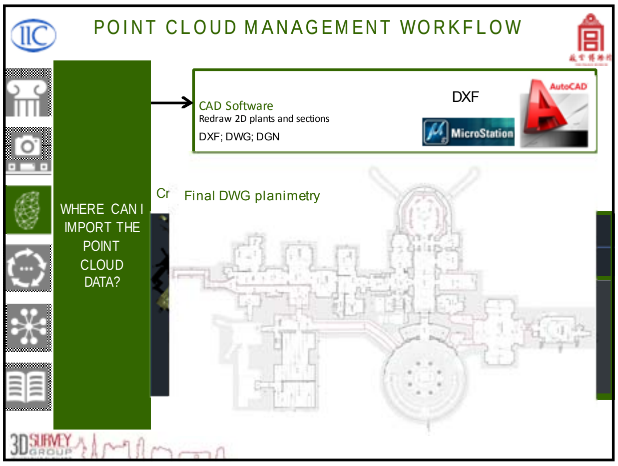
CAD Software
Redraw 2D plants and sections

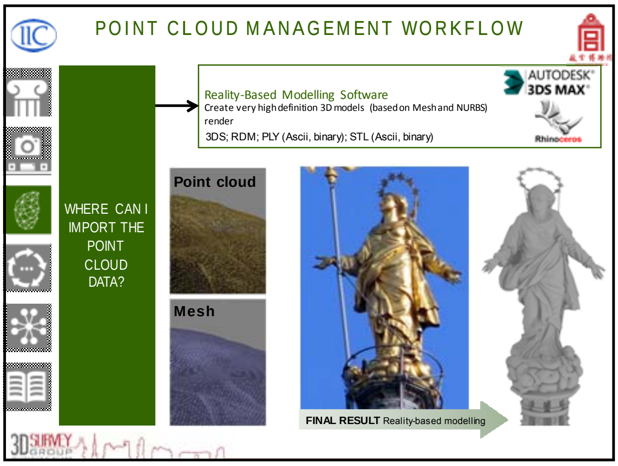
Reality-Based Modelling Software
Create very high definition 3D models (based on Mesh and NURBS) render

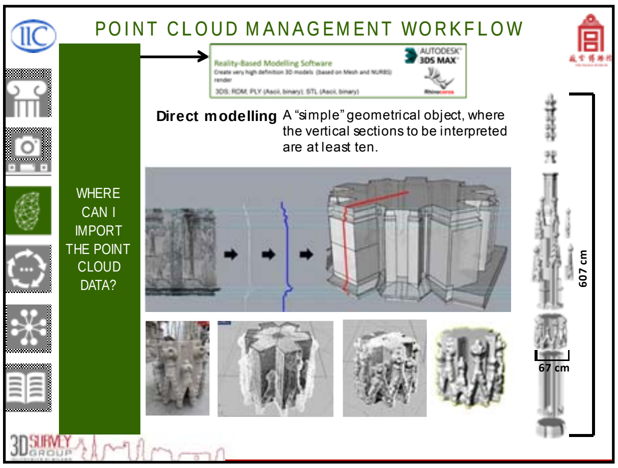
BIM Software
Create parametric models (based on libraries of objects)
insert data and information

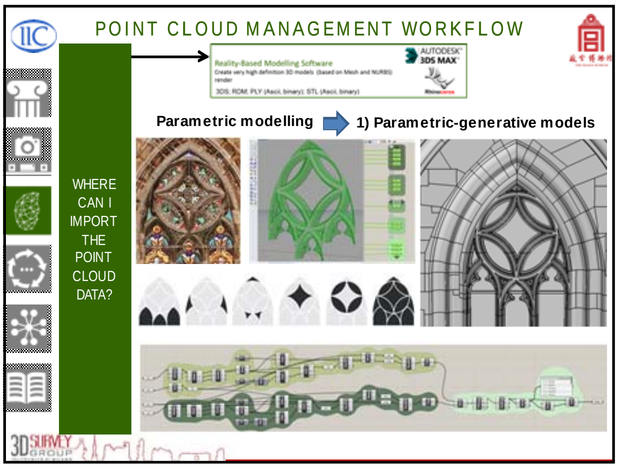

POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
View/Editing Software
Explore the cloud, create sections, clean it, export in other formats, etc.
IMP; RCP; PTS; PTX; XYZ; TXT; ...
pointools
CYCLONE
RECAP
horizontal profiles
vertical profiles
create 3d model
create ortophoto
take measure
3D SURVEY GROUP

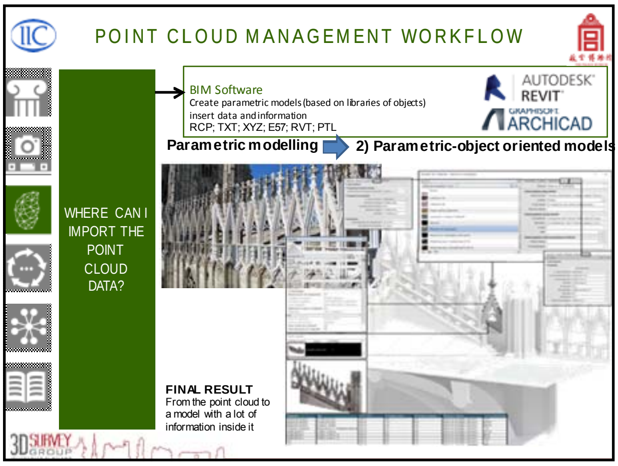

POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
CAD Software
Redraw 2D plants and sections
DXF; DWG; DGN
DXF
AutoCAD
MicroStation
3D SURVEY GROUP

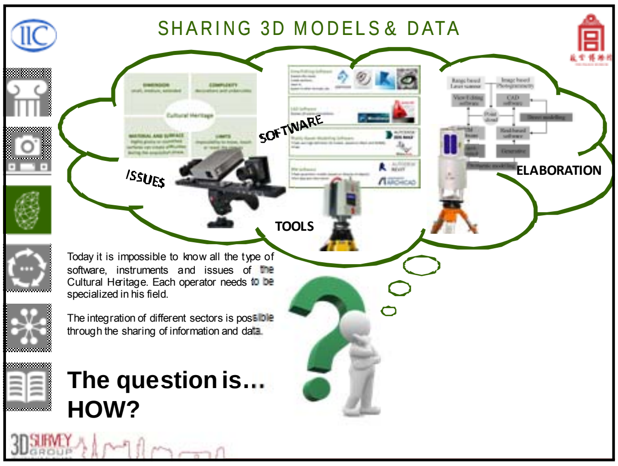

POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
CAD Software
Redraw 2D plants and sections
DXF; DWG; DGN
DXF
AutoCAD
MicroStation
Final DWG planimetry
3D SURVEY GROUP


POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
Reality-Based Modelling Software
Create very high definition 3D models (based on Mesh and NURBS)
render
3DS; RDM; PLY (Ascii, binary); STL (Ascii, binary)
AUTODESK® 3DS MAX®
Rhinoceros
Point cloud
Mesh
FINAL RESULT Reality-based modelling
3D SURVEY GROUP


POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
Reality-Based Modelling Software
AUTODESK 3DS MAX
Direct modelling
A "simple" geometrical object, where the vertical sections to be interpreted are at least ten.
607 cm
67 cm


POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
Reality-Based Modelling Software
AUTODESK 3DS MAX
Parametric modelling
1) Parametric-generative models


POINT CLOUD MANAGEMENT WORKFLOW
WHERE CAN I IMPORT THE POINT CLOUD DATA?
BIM Software
Create parametric models (based on libraries of objects)
insert data and information
RCP; TXT; XYZ; E57; RVT; PTL
AUTODESK REVIT
GRAPHISOFT ARCHICAD
Parametric modelling
2) Parametric-object oriented models
FINAL RESULT
From the point cloud to a model with a lot of information inside it


SHARING 3D MODELS & DATA
SOFTWARE
ISSUES
TOOLS
ELABORATION
Today it is impossible to know all the type of software, instruments and issues of the Cultural Heritage. Each operator needs to be specialized in his field.
The integration of different sectors is possible through the sharing of information and data.
The question is…
HOW?

WEB SHARING 3D MODEL&DATA

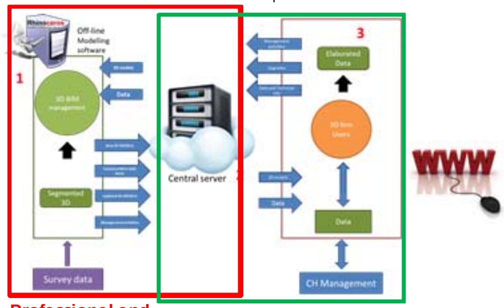
3DHOP **NUBES**

Our aims is…

- to **define** and create an innovative **multi-digitalization approaches** that permit to **view on-line digital models** related to pieces of arts and **query them** obtaining **information** and insights;
- to study and **create** a **platform** that gave the users the possibility to **easily access to Cultural Heritage**;
- to **support** the work of the scientists with the implementation of an **advanced diagnostic system** aimed to the protection and safeguard of CH.

WEB SHARING 3D MODEL&DATA

The web information system named **BIM3DSG** is completely **designed by us, in Politecnico di Milano**. BIM3DSG is divided in two parts:



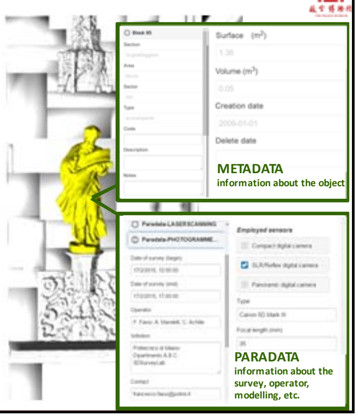
Professional and 3D specialists

All users

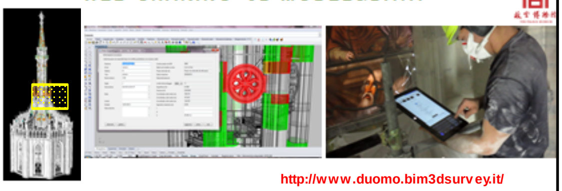
WEB SHARING 3D MODEL&DATA

The system **has** to:

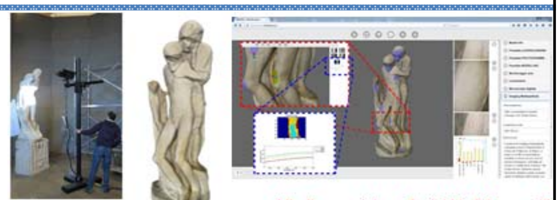
- **visualize** very **high resolution 3D models** and textures;
- **provide** a **robust database of information**, able to store big quantity of data;
- **grant** standard **metadata** and **paradata** schemas; the term metadata refers to the **information of the physical object** (such as surface, volume, dimensions, material, etc.), paradata instead are the **features that describe its model** (instruments used to extract the metadata, date of survey, operator, modelling info, etc.);
- **involve** users in active fruition of **artefacts through a clear interface.**



WEB SHARING 3D MODEL&DATA



http://www.duomo.bim3dsurvey.it/



http://www.pietarondanini.bim3dsurvey.it/


Milan Cathedral: sharing large and complex architectonical model
http://www.duomomilano.it/
http://www.duomomilano.it/
http://www.nationalgeographic.it/
http://www.duomomilano.it/
3D SURVEY GROUP


Milan Cathedral: sharing large and complex architectonical model
http://www.duomomilano.it/
http://www.nationalgeographic.it/
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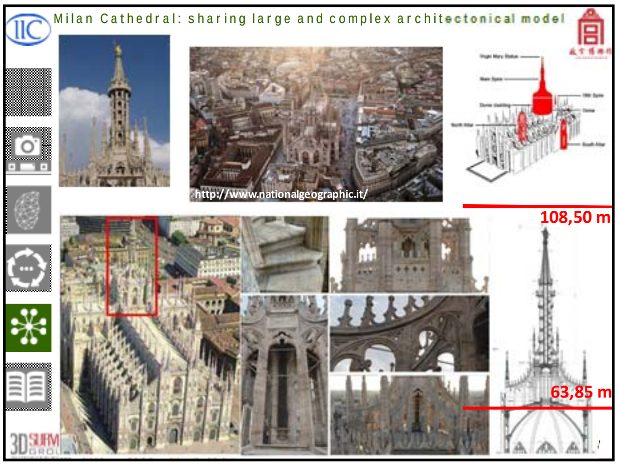
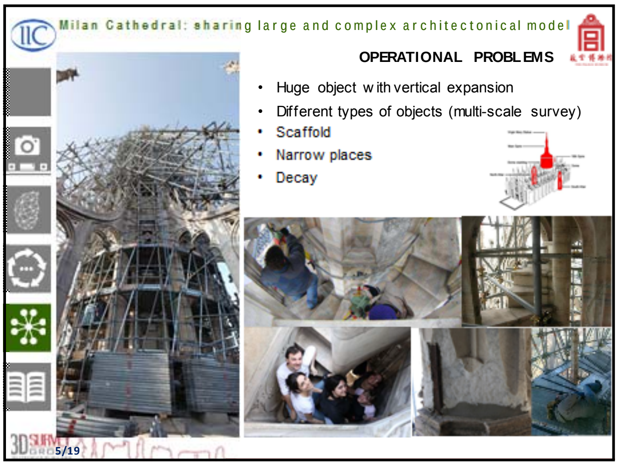
3D SURVEY GROUP


Milan Cathedral: sharing large and complex architectonical model
http://www.nationalgeographic.it/
108,50 m
63,85 m


Milan Cathedral: sharing large and complex architectonical model
OPERATIONAL PROBLEMS
• Huge object with vertical expansion
• Different types of objects (multi-scale survey)
• Scaffold
• Narrow places
• Decay
5/19

Milan Cathedral: sharing large and complex architectonical model

3D MODEL OF THE MILAN CATHEDRAL

Reality based model

- Represent the real situation
- Accurate survey
- 3D constructive catalogue
- Base for restoration
- Base for spire disassembly
- Simulations (static e dynamic)
- Automatic extraction of plants, prospects and sections

3D SURVEY GROUP

Milan Cathedral: sharing large and complex architectonical model

3D MODEL OF THE MILAN CATHEDRAL

Reality based model | Accurate

- Suitable for extraction of metrical information at 1:20 – 1:50 scale
- Some part modeled at 1:1 in order to 3d printing
- Measurements of areas and volumes

3D SURVEY GROUP

Milan Cathedral: sharing large and complex architectonical model

3D MODEL OF THE MILAN CATHEDRAL

Reality based model | Accurate | Complete

- All parts must be modelled from decorations to structural parts

3D SURVEY GROUP 5/19

Milan Cathedral: sharing large and complex architectonical model

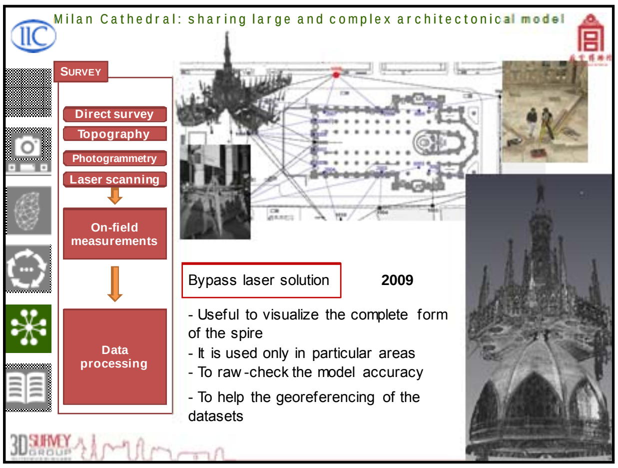
3D MODEL OF THE MILAN CATHEDRAL

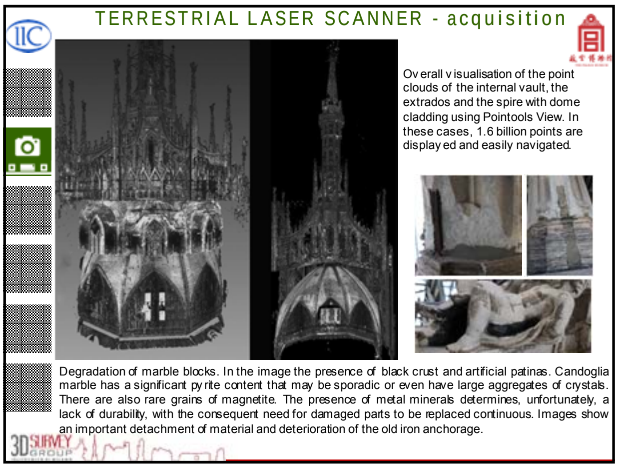
Reality based model | Accurate | Complete | Easy-to-use

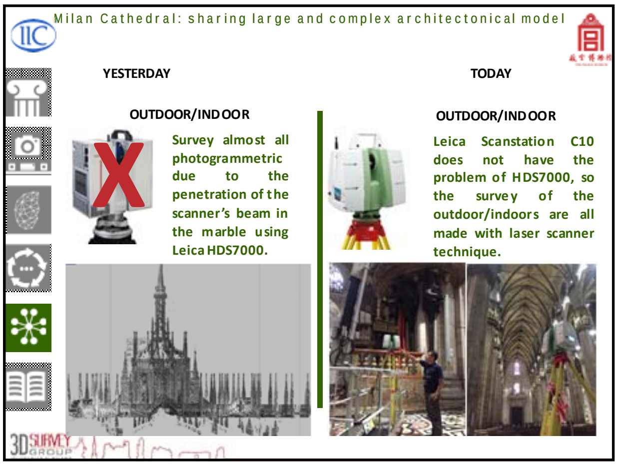
- It should be used daily for restoration and scheduled maintenance
- It should be used by different operators
- It should be upgradable

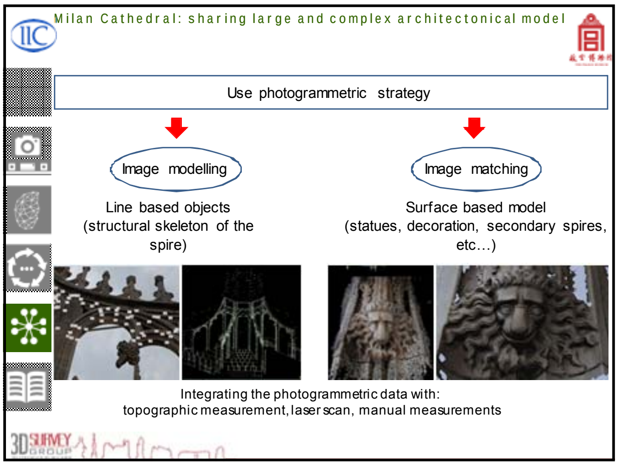
****Damages and decay will not be modelled, these information will be added separately.***

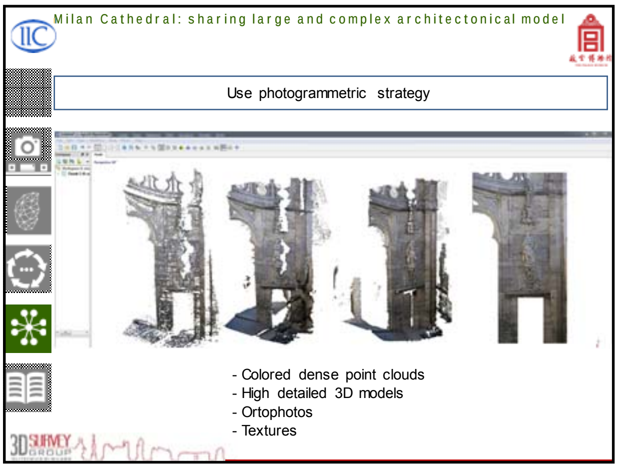
3D SURVEY GROUP

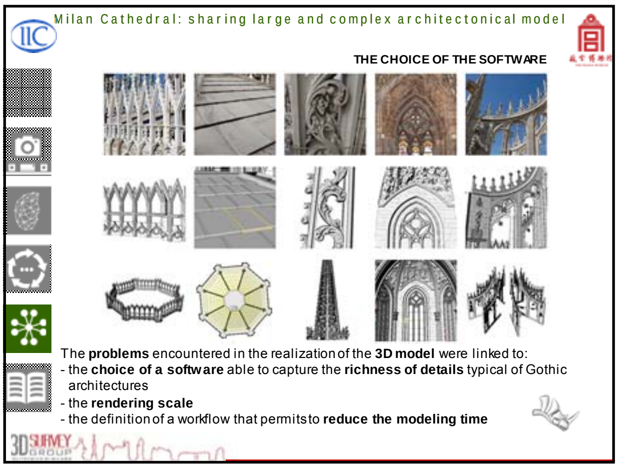

Milan Cathedral: sharing large and complex architectonical model
SURVEY
Direct survey
Topography
Photogrammetry
Laser scanning
On-field measurements
Data processing
Bypass laser solution
2009
- Useful to visualize the complete form of the spire
- It is used only in particular areas
- To raw-check the model accuracy
- To help the georeferencing of the datasets
3D SURVEY GROUP

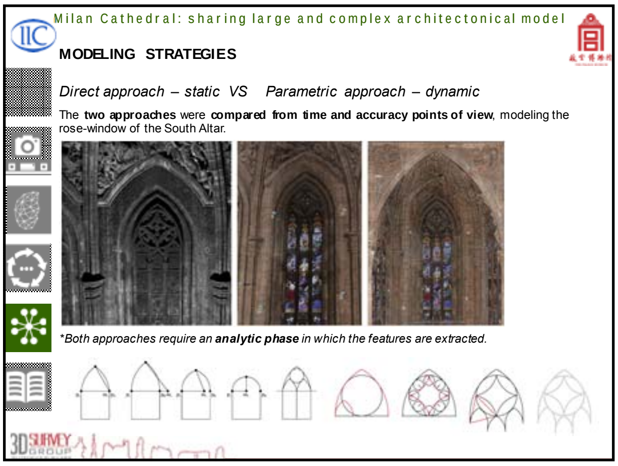

TERRESTRIAL LASER SCANNER - acquisition
Overall visualisation of the point clouds of the internal vault, the extrados and the spire with dome cladding using Pointools View. In these cases, 1.6 billion points are displayed and easily navigated.
Degradation of marble blocks. In the image the presence of black crust and artificial patinas. Candoglia marble has a significant pyrite content that may be sporadic or even have large aggregates of crystals. There are also rare grains of magnetite. The presence of metal minerals determines, unfortunately, a lack of durability, with the consequent need for damaged parts to be replaced continuous. Images show an important detachment of material and deterioration of the old iron anchorage.
3D SURVEY GROUP

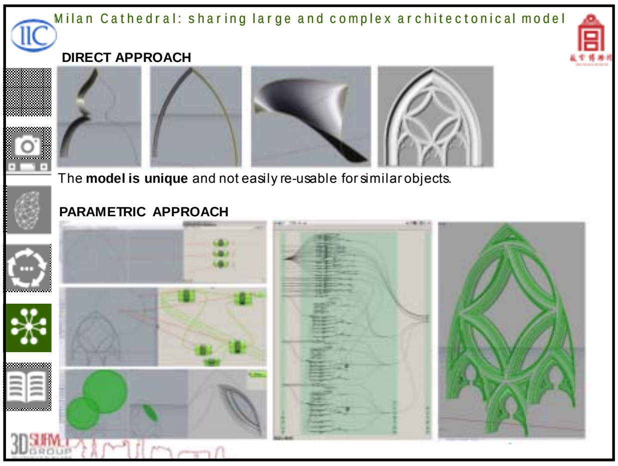

Milan Cathedral: sharing large and complex architectonical model
YESTERDAY
OUTDOOR/INDOOR
Survey almost all photogrammetric due to the penetration of the scanner's beam in the marble using Leica HDS7000.
TODAY
OUTDOOR/INDOOR
Leica Scanstation C10 does not have the problem of HDS7000, so the survey of the outdoor/indoors are all made with laser scanner technique.
3D SURVEY GROUP

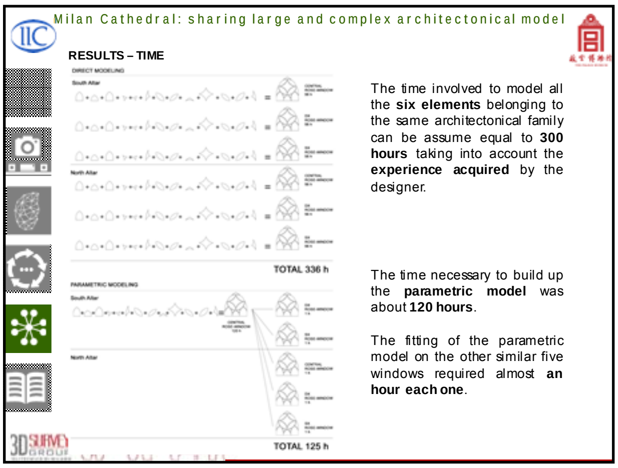

Milan Cathedral: sharing large and complex architectonical model
Use photogrammetric strategy
Image modelling
Image matching
Line based objects (structural skeleton of the spire)
Surface based model (statues, decoration, secondary spires, etc…)
Integrating the photogrammetric data with:
topographic measurement, laser scan, manual measurements
3D SURVEY GROUP

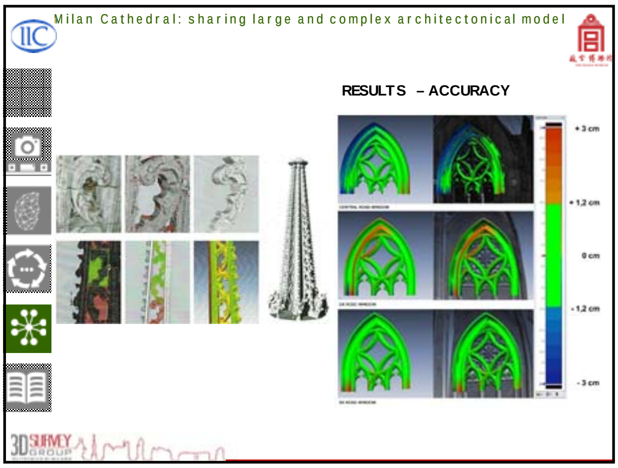

Milan Cathedral: sharing large and complex architectonical model
Use photogrammetric strategy
- Colored dense point clouds
- High detailed 3D models
- Ortophotos
- Textures
3D SURVEY GROUP

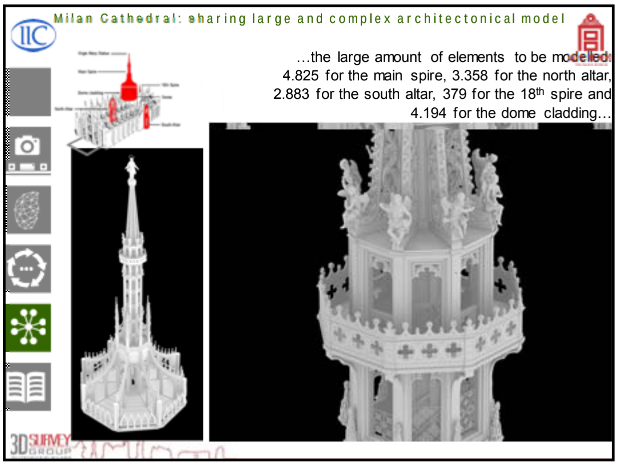

Milan Cathedral: sharing large and complex architectonical model
THE CHOICE OF THE SOFTWARE
The problems encountered in the realization of the 3D model were linked to:
- the choice of a software able to capture the richness of details typical of Gothic architectures
- the rendering scale
- the definition of a workflow that permits to reduce the modeling time
3D SURVEY GROUP

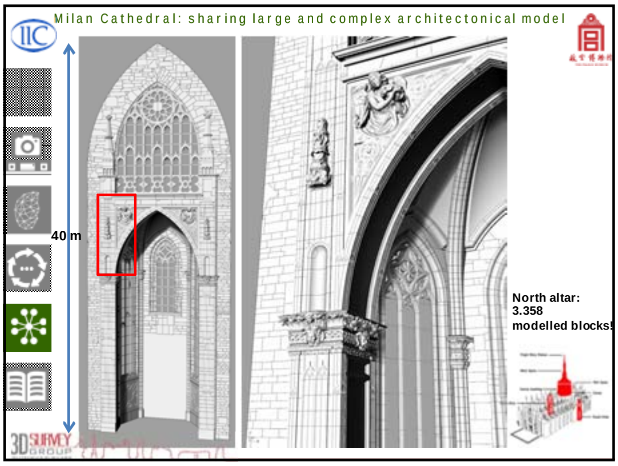

Milan Cathedral: sharing large and complex architectonical model
MODELING STRATEGIES
Direct approach – static VS Parametric approach – dynamic
The two approaches were compared from time and accuracy points of view, modeling the rose-window of the South Altar.
*Both approaches require an analytic phase in which the features are extracted.
3D SURVEY GROUP

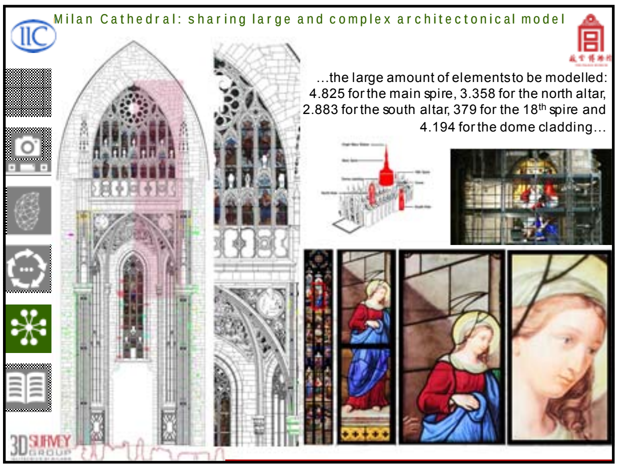

Milan Cathedral: sharing large and complex architectonical model
DIRECT APPROACH
The model is unique and not easily re-usable for similar objects.
PARAMETRIC APPROACH
3D SURVEY GROUP

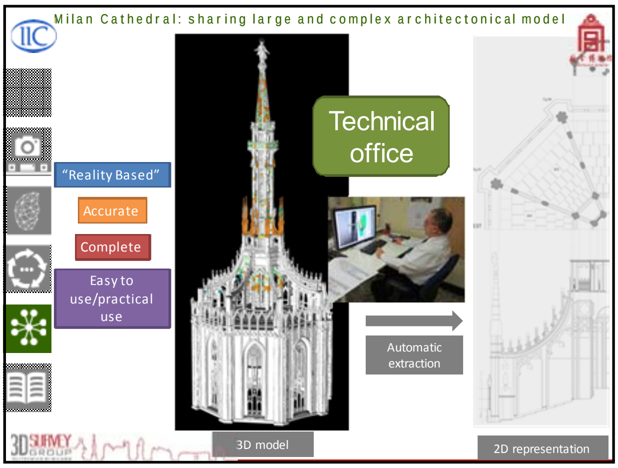

Milan Cathedral: sharing large and complex architectonical model
RESULTS – TIME
TOTAL 336 h
TOTAL 125 h
The time involved to model all the six elements belonging to the same architectonical family can be assume equal to 300 hours taking into account the experience acquired by the designer.
The time necessary to build up the parametric model was about 120 hours.
The fitting of the parametric model on the other similar five windows required almost an hour each one.

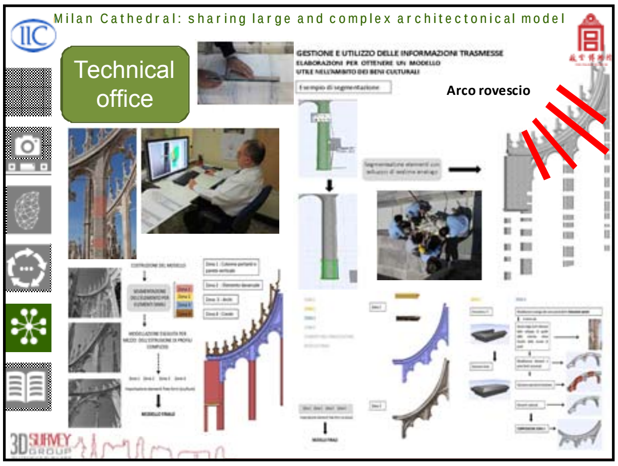

Milan Cathedral: sharing large and complex architectonical model
RESULTS – ACCURACY
+3 cm
+1,2 cm
0 cm
-1,2 cm
-3 cm

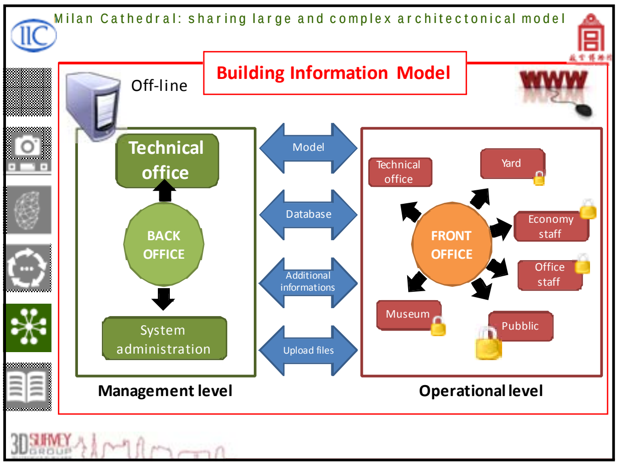

Milan Cathedral: sharing large and complex architectonical model
…the large amount of elements to be modelled: 4.825 for the main spire, 3.358 for the north altar, 2.883 for the south altar, 379 for the 18th spire and 4.194 for the dome cladding…

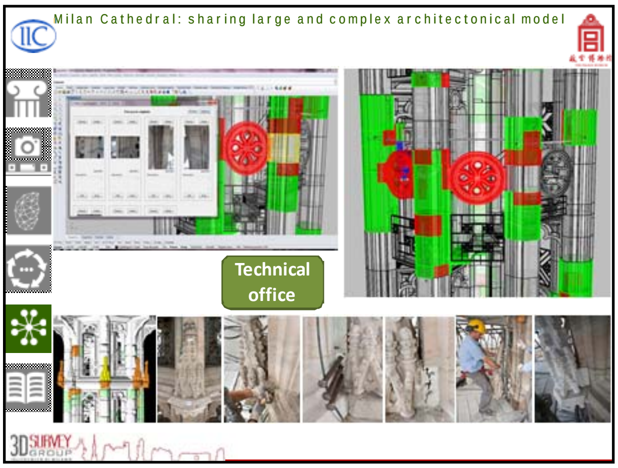

Milan Cathedral: sharing large and complex architectonical model
40 m
North altar: 3.358 modelled blocks!


Milan Cathedral: sharing large and complex architectonical model
...the large amount of elements to be modelled: 4.825 for the main spire, 3.358 for the north altar, 2.883 for the south altar, 379 for the 18th spire and 4.194 for the dome cladding...
3D SURVEY GROUP

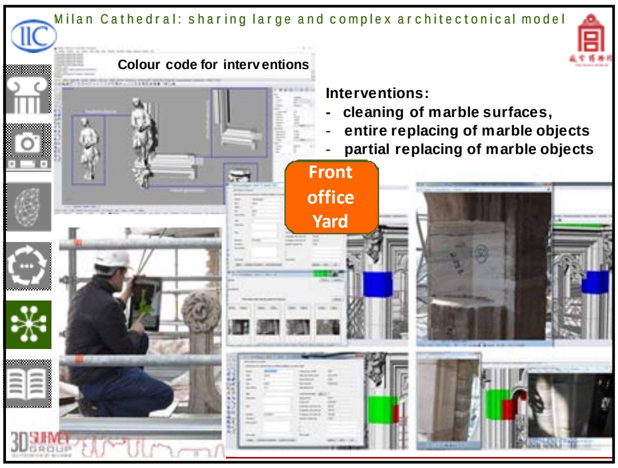

Milan Cathedral: sharing large and complex architectonical model
Technical office
"Reality Based"
Accurate
Complete
Easy to use/practical use
Automatic extraction
3D model
2D representation
3D SURVEY GROUP


Milan Cathedral: sharing large and complex architectonical model
Technical office
GESTIONE E UTILIZZO DELLE INFORMAZIONI TRASMESSE
ELABORAZIONI PER OTTENERE UN MODELLO
UTILE NELL'AMBITO DEI BENI CULTURALI
Arco rovescio
3D SURVEY GROUP

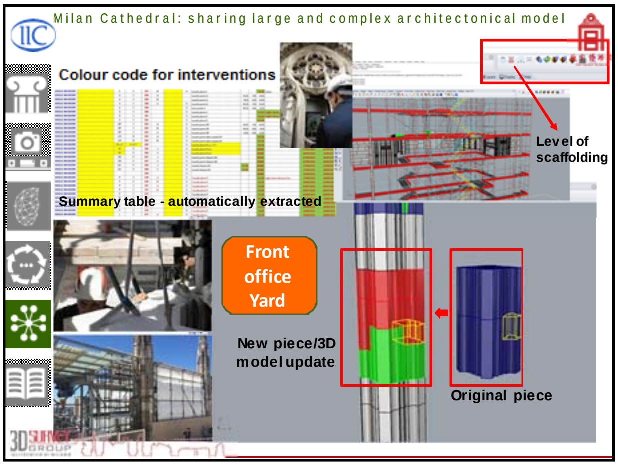

Milan Cathedral: sharing large and complex architectonical model
Off-line
Building Information Model
WWW
Technical office
BACK OFFICE
System administration
Model
Database
Additional informations
Upload files
Technical office
Yard
FRONT OFFICE
Economy staff
Office staff
Museum
Pubblic
Management level
Operational level
3D SURVEY GROUP



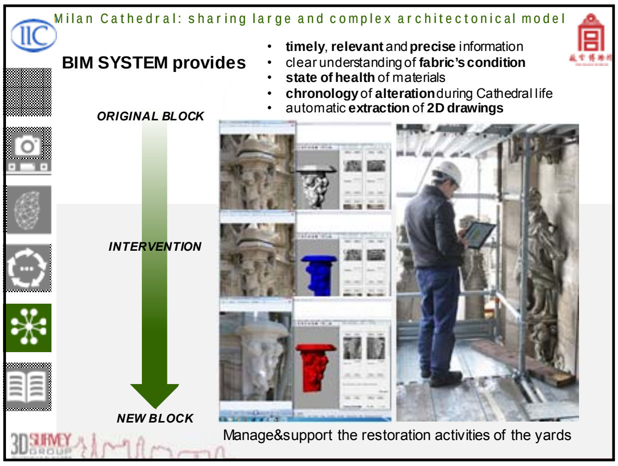
Milan Cathedral: sharing large and complex architectonical model
Technical office



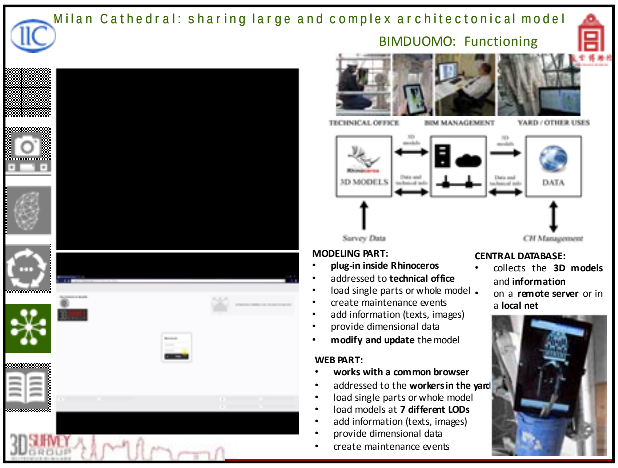
Milan Cathedral: sharing large and complex architectonical model
Colour code for interventions
Interventions:
- cleaning of marble surfaces,
- entire replacing of marble objects
- partial replacing of marble objects
Front office Yard

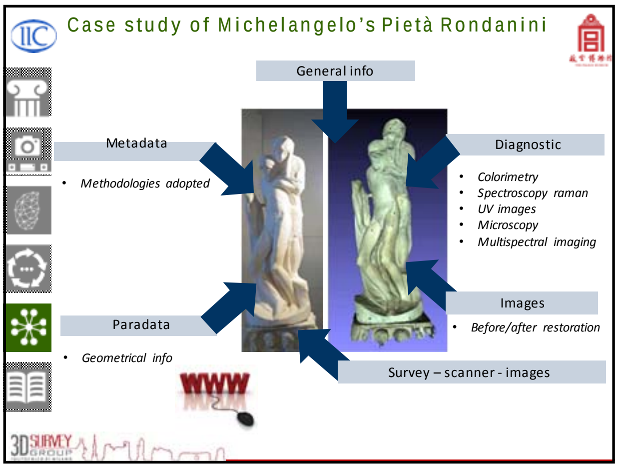


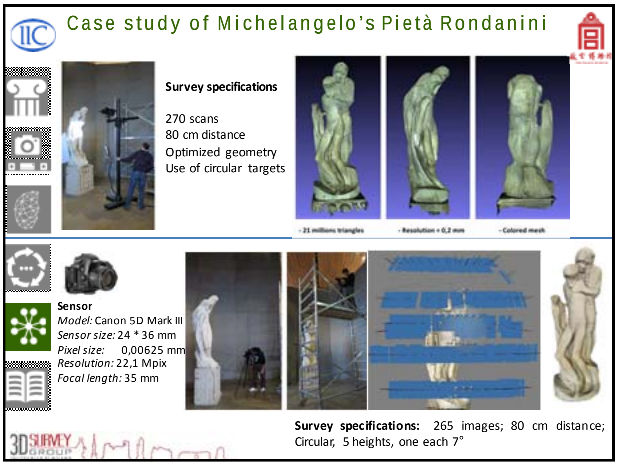
Milan Cathedral: sharing large and complex architectonical model
Colour code for interventions
Level of scaffolding
Summary table - automatically extracted
Front office Yard
New piece/3D model update
Original piece

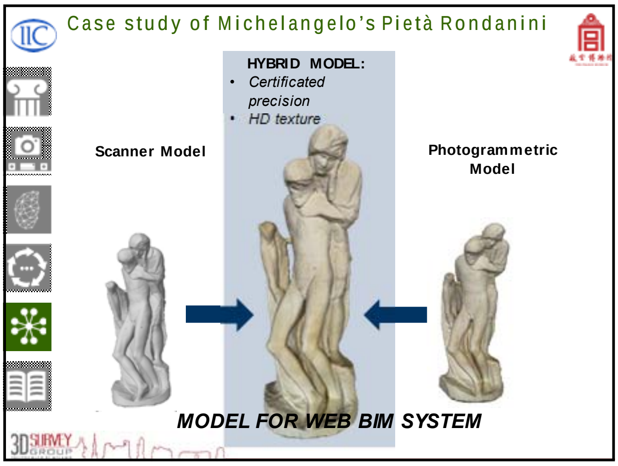


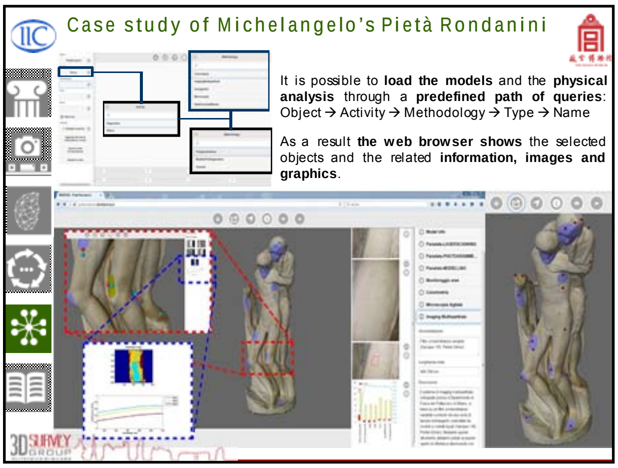
Milan Cathedral: sharing large and complex architectonical model
BIM SYSTEM provides
• timely, relevant and precise information
• clear understanding of fabric's condition
• state of health of materials
• chronology of alteration during Cathedral life
• automatic extraction of 2D drawings
ORIGINAL BLOCK
INTERVENTION
NEW BLOCK
Manage&support the restoration activities of the yards

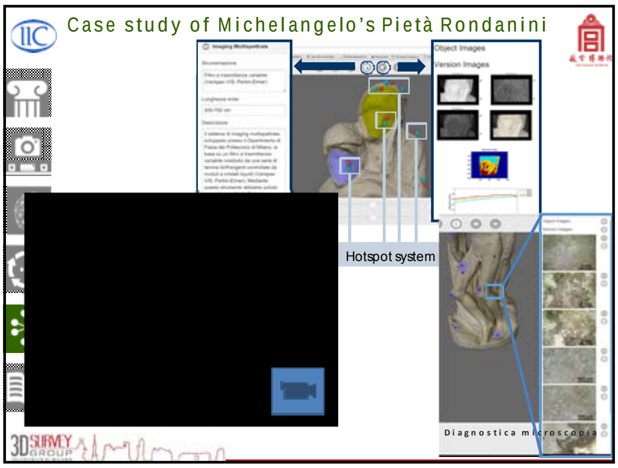

Milan Cathedral: sharing large and complex architectonical model
BIMDUOMO: Functioning
TECHNICAL OFFICE
BIM MANAGEMENT
YARD / OTHER USES
3D MODELS
DATA
Survey Data
CH Management
MODELING PART:
• plug-in inside Rhinoceros
• addressed to technical office
• load single parts or whole model
• create maintenance events
• add information (texts, images)
• provide dimensional data
• modify and update the model
CENTRAL DATABASE:
• collects the 3D models and information
• on a remote server or in a local net
WEB PART:
• works with a common browser
• addressed to the workers in the yard
• load single parts or whole model
• load models at 7 different LODs
• add information (texts, images)
• provide dimensional data
• create maintenance events
3D SURVEY GROUP

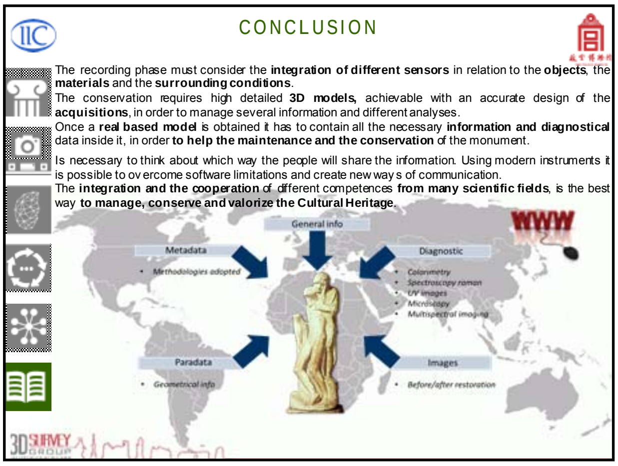

Case study of Michelangelo's Pietà Rondanini
General info
Metadata
• Methodologies adopted
Diagnostic
• Colorimetry
• Spectroscopy raman
• UV images
• Microscopy
• Multispectral imaging
Images
• Before/after restoration
Paradata
• Geometrical info
Survey – scanner - images
WWW
3D SURVEY GROUP


Case study of Michelangelo's Pietà Rondanini
Survey specifications
270 scans
80 cm distance
Optimized geometry
Use of circular targets
- 21 millions triangles
- Resolution = 0,2 mm
- Colored mesh
Sensor
Model: Canon 5D Mark III
Sensor size: 24 * 36 mm
Pixel size: 0,00625 mm
Resolution: 22,1 Mpix
Focal length: 35 mm
Survey specifications: 265 images; 80 cm distance; Circular, 5 heights, one each 7°
3D SURVEY GROUP


Case study of Michelangelo's Pietà Rondanini
HYBRID MODEL:
• Certificated precision
• HD texture
Scanner Model
Photogrammetric Model
MODEL FOR WEB BIM SYSTEM
3D SURVEY GROUP


Case study of Michelangelo's Pietà Rondanini
It is possible to load the models and the physical analysis through a predefined path of queries: Object → Activity → Methodology → Type → Name
As a result the web browser shows the selected objects and the related information, images and graphics.


Case study of Michelangelo's Pietà Rondanini
Object Images
Version Images
Hotspot system
Diagnostica microscopia


CONCLUSION
The recording phase must consider the integration of different sensors in relation to the objects, the materials and the surrounding conditions.
The conservation requires high detailed 3D models, achievable with an accurate design of the acquisitions, in order to manage several information and different analyses.
Once a real based model is obtained it has to contain all the necessary information and diagnostical data inside it, in order to help the maintenance and the conservation of the monument.
Is necessary to think about which way the people will share the information. Using modern instruments it is possible to overcome software limitations and create new ways of communication.
The integration and the cooperation of different competences from many scientific fields, is the best way to manage, conserve and valorize the Cultural Heritage.
General info
Metadata
Methodologies adopted
Diagnostic
Colorimetry
Spectroscopy raman
UV images
Microscopy
Multispectral imaging
Paradata
Geometrical info
Images
Before/after restoration
WWW