

“VIRTUAL RECONSTRUCTION
OF LOST ARCHITECTURE:
A MODEL STUDY OF BIBI
JAWINDI’S TOMB AT UCH
SHARIF”

RESEARCH SUPERVISOR:
DR. MUNAZZAH AKHTAR

M.ARCH THESIS BY:
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DEPARTMENT OF ARCHITECTURE
UNIVERSITY OF ENGINEERING & TECHNOLOGY,
LAHORE



Research Objectives

Short Video

Methodology

Results

Future Work

Acknowledgments

Questions

ABOUT ME



Ar. Abdullah Saeed
B. Arch UET Lahore, Member PCATP, IAP
TA at Department of Architecture UET Lahore

In general, my career as a practicing and teaching architect, I am skilled in digital design applications. I am a passionate lifelong learner with strong belief to bridge the gap between Academia & Practice.

Background



Deterioration of Architectural Heritage

- Heritage of ancient civilizations
- Natural disasters, armed conflicts, and the passage of time
- Loss of significant historical structures



Potential Solution: Augmented Reality (AR)

- AR allows users to visualize and interact with reconstructed aspects
- More immersive and realistic manner by overlaying digital models onto the real-world environment.

PROBLEM STATEMENT

Urgent Preservation and Renovation

- Facing considerable degradation



Need for economical and Interactive Reconstruction

- Need for a method that is both creative and precise.



Challenges with Traditional Methods

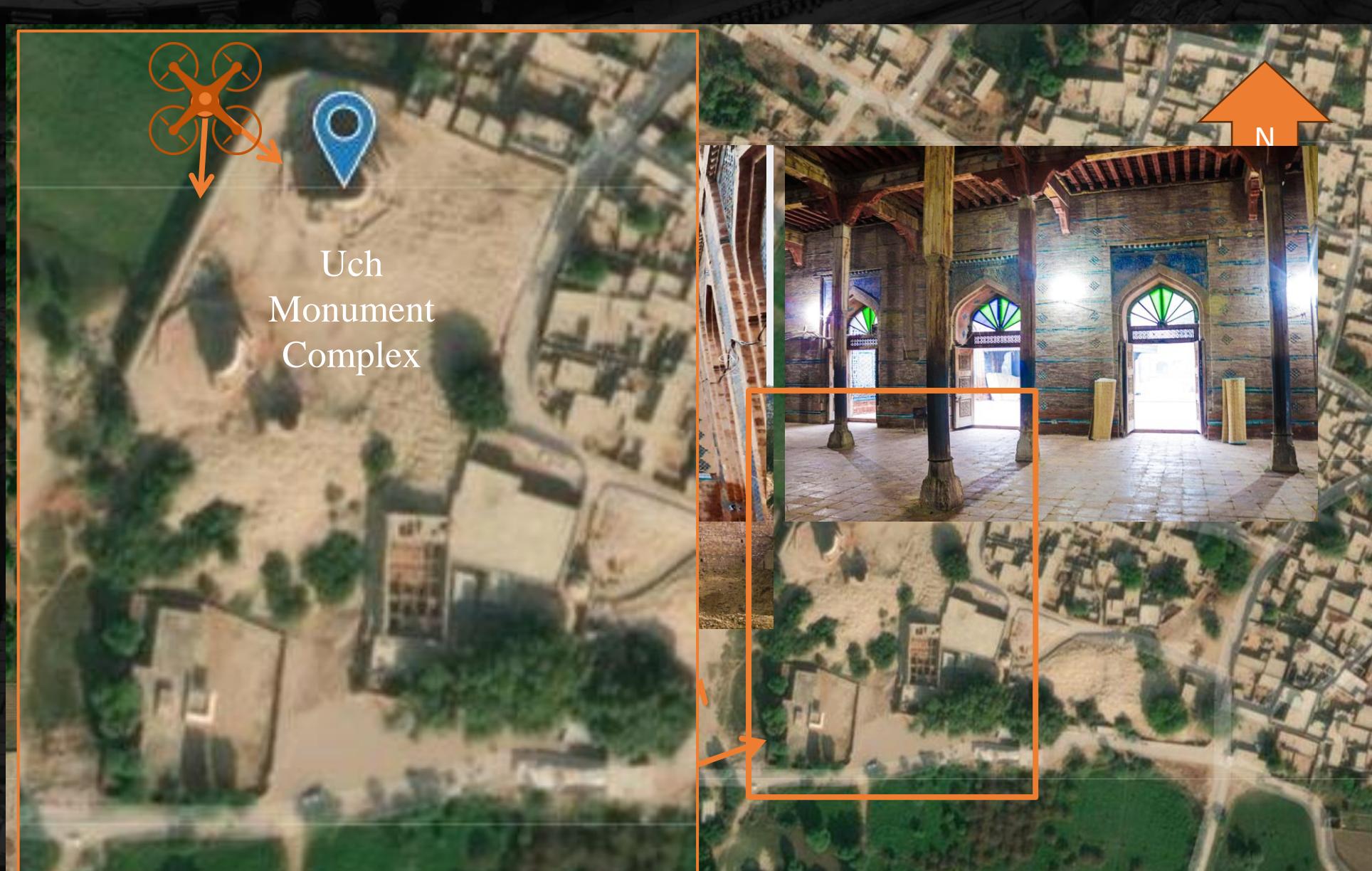
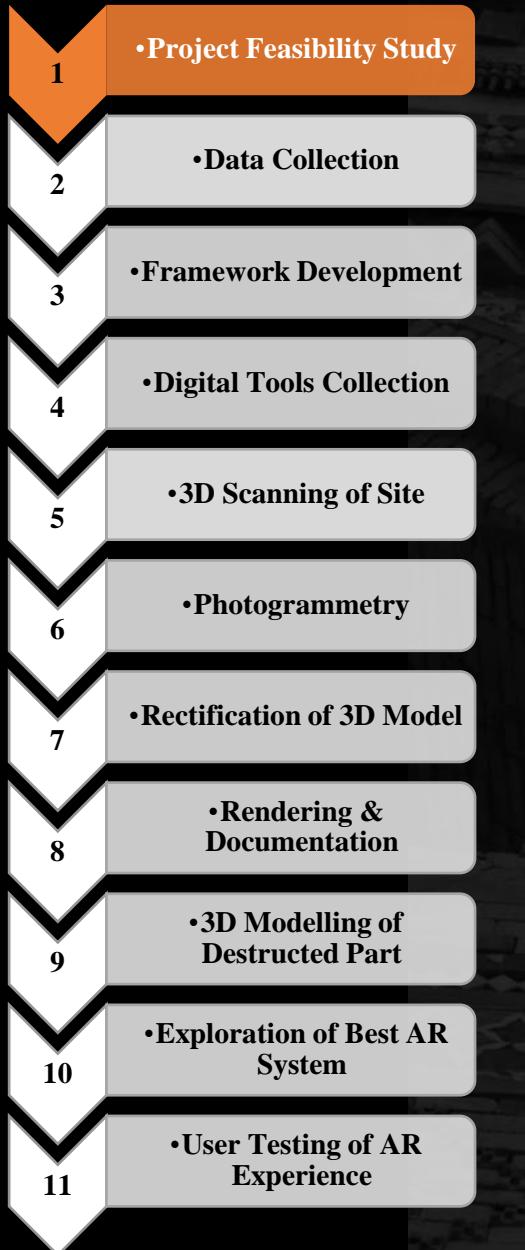
- Physical repair or hand reconstruction, can be costly, time-consuming
- Conventional Surveying can have errors and time consuming



RESEARCH OBJECTIVES

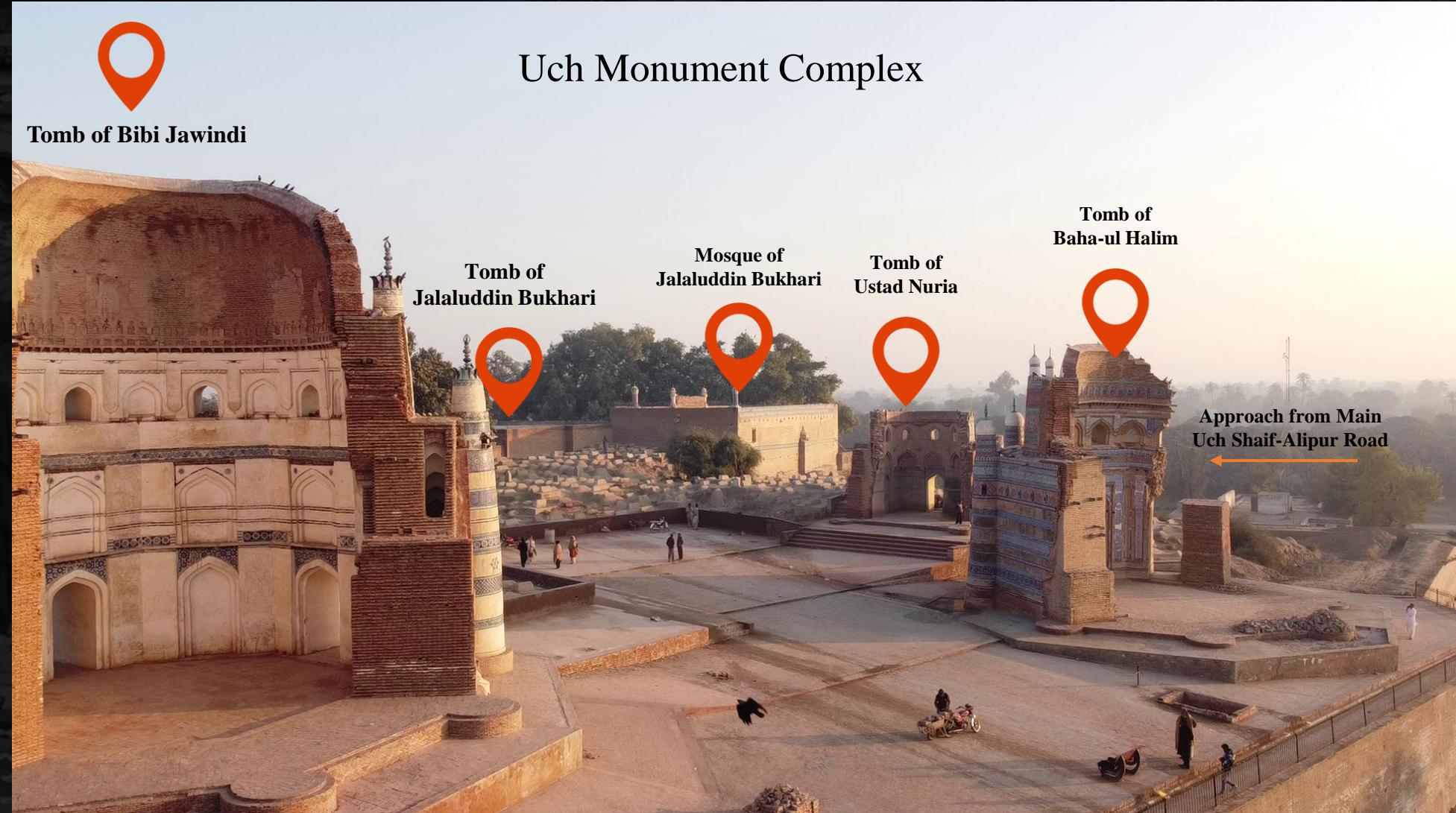
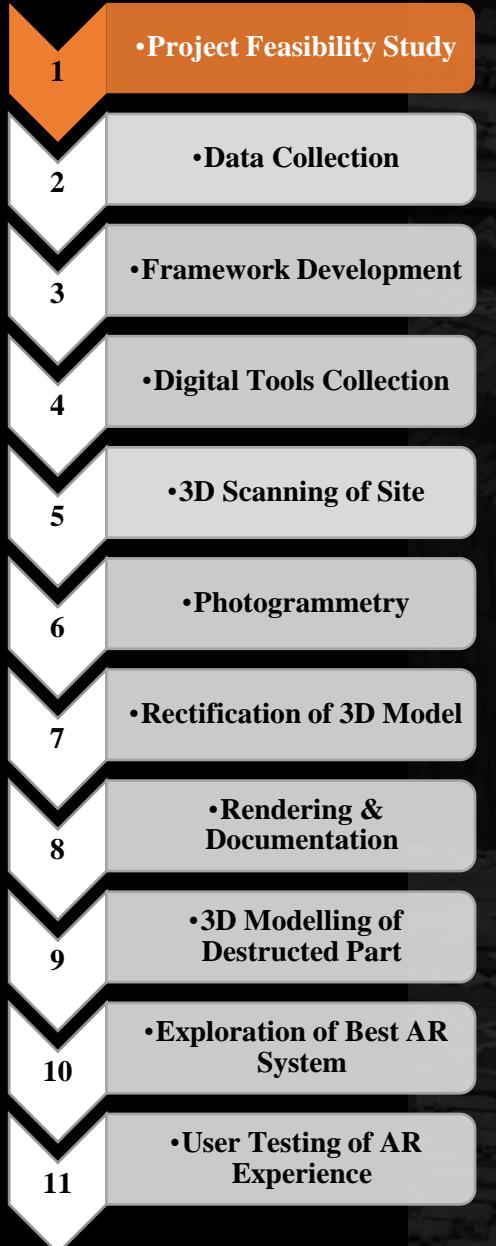
- To develop a digital reconstruction method of decayed architectural heritage sites with augmented reality.
- The digital reconstruction process should be more cost effective and accessible than already in-use expensive apparatus.
- The immersive experience of end product must be easily available and accessible to more users.

Methodology



Satellite View of Geolocation of Bibi Jawindi Complex Location at Uch Sharif from Sketch up Geolocation Data. (Source: Author).

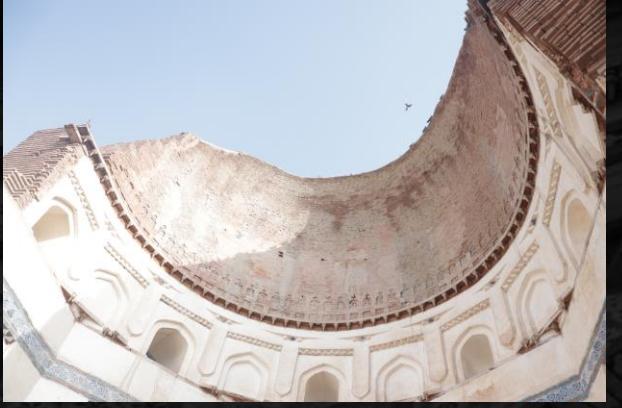
Methodology



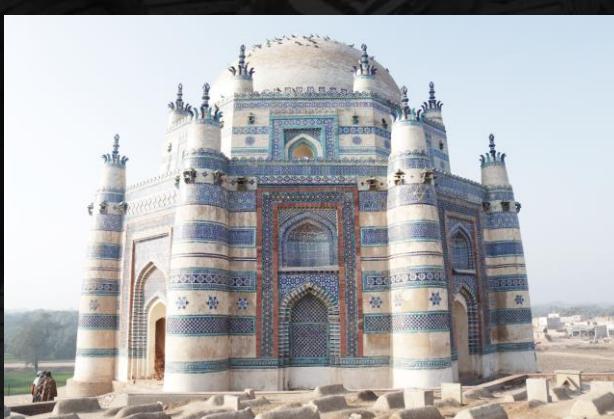
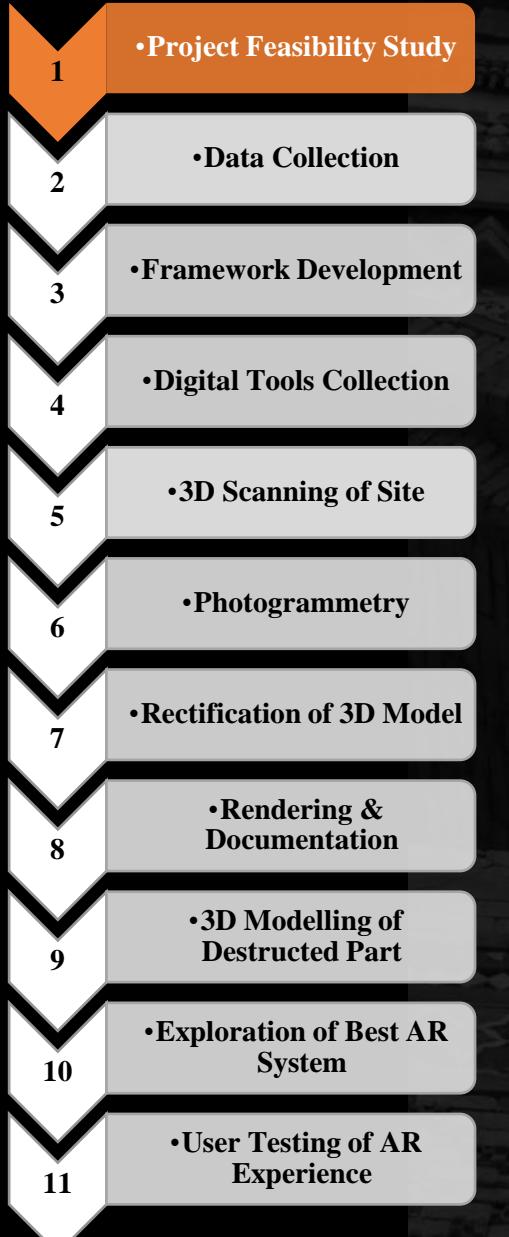
(Aerial View of Uch Monument Complex, Source: Ar. Abdullah Saeed)

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Methodology



Tentative list of the
UNESCO World Heritage
Sites

Research and Education; architectural techniques and artistic traditions of the region

Religious Importance; Bibi Jawindi, who is believed to be the great-granddaughter of a revered Sufi saint, Jahaniyan Jahangasht

SIGNIFICANCE
Tomb of Bibi Jawindi

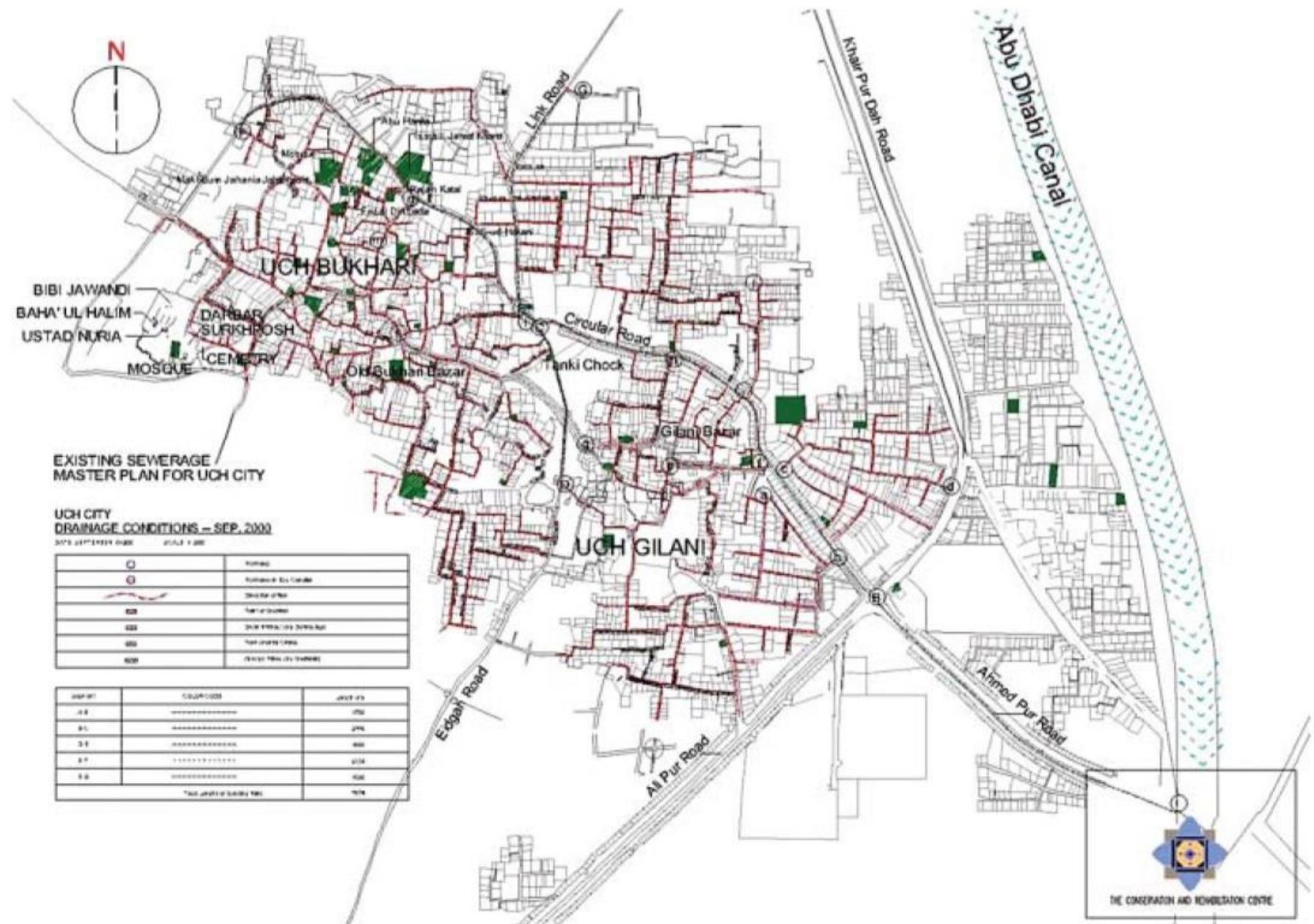
Tourist Attraction; tourists and travelers interested in exploring Pakistan's historical heritage

Cultural Heritage; the rich history and cultural diversity

Included in watch list of
100 endangered sites of
World Monuments Fund

Methodology

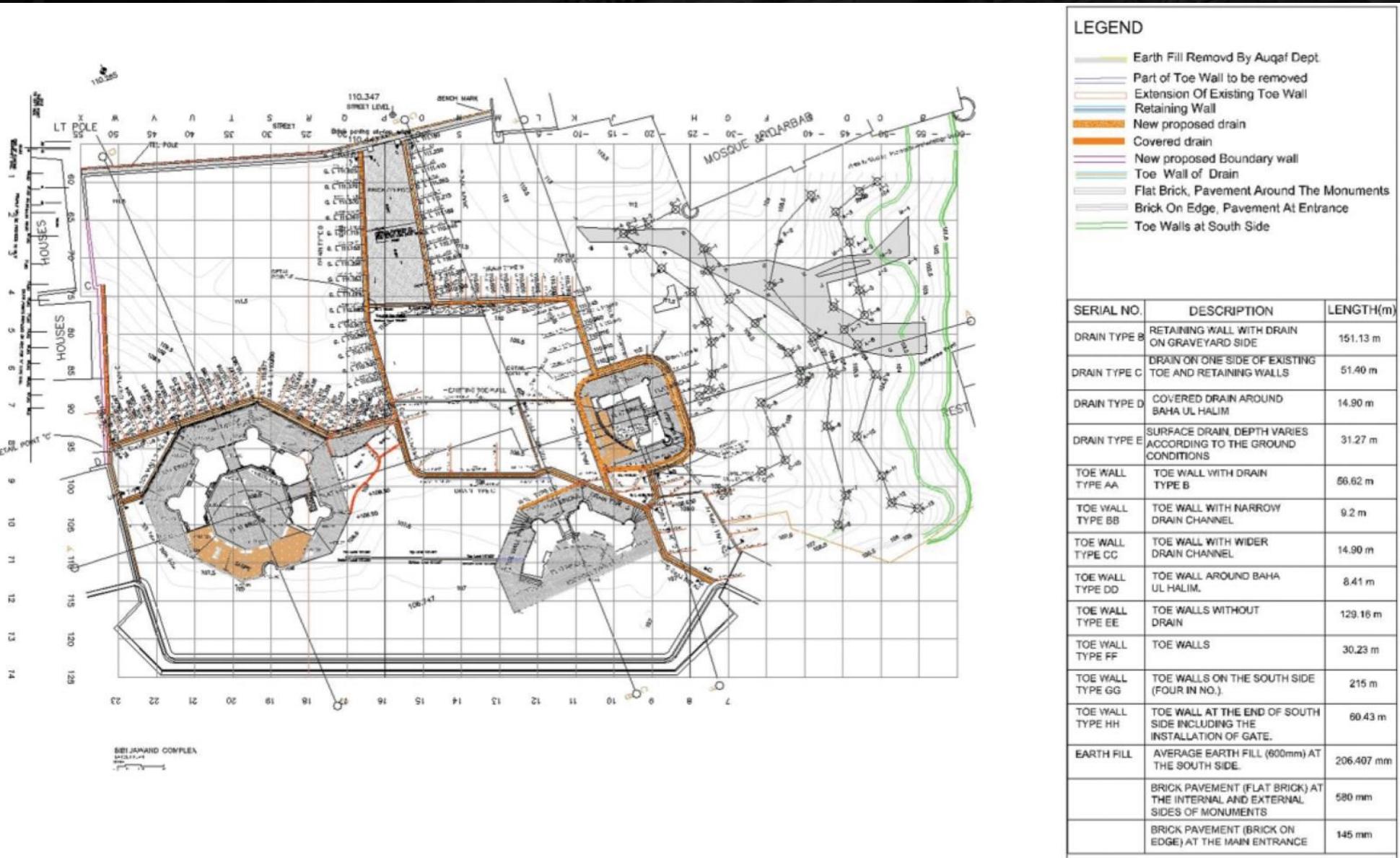
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Map of Uch city-wide drainage interventions designed (Source: Conservation and Rehabilitation Centre.)

Methodology

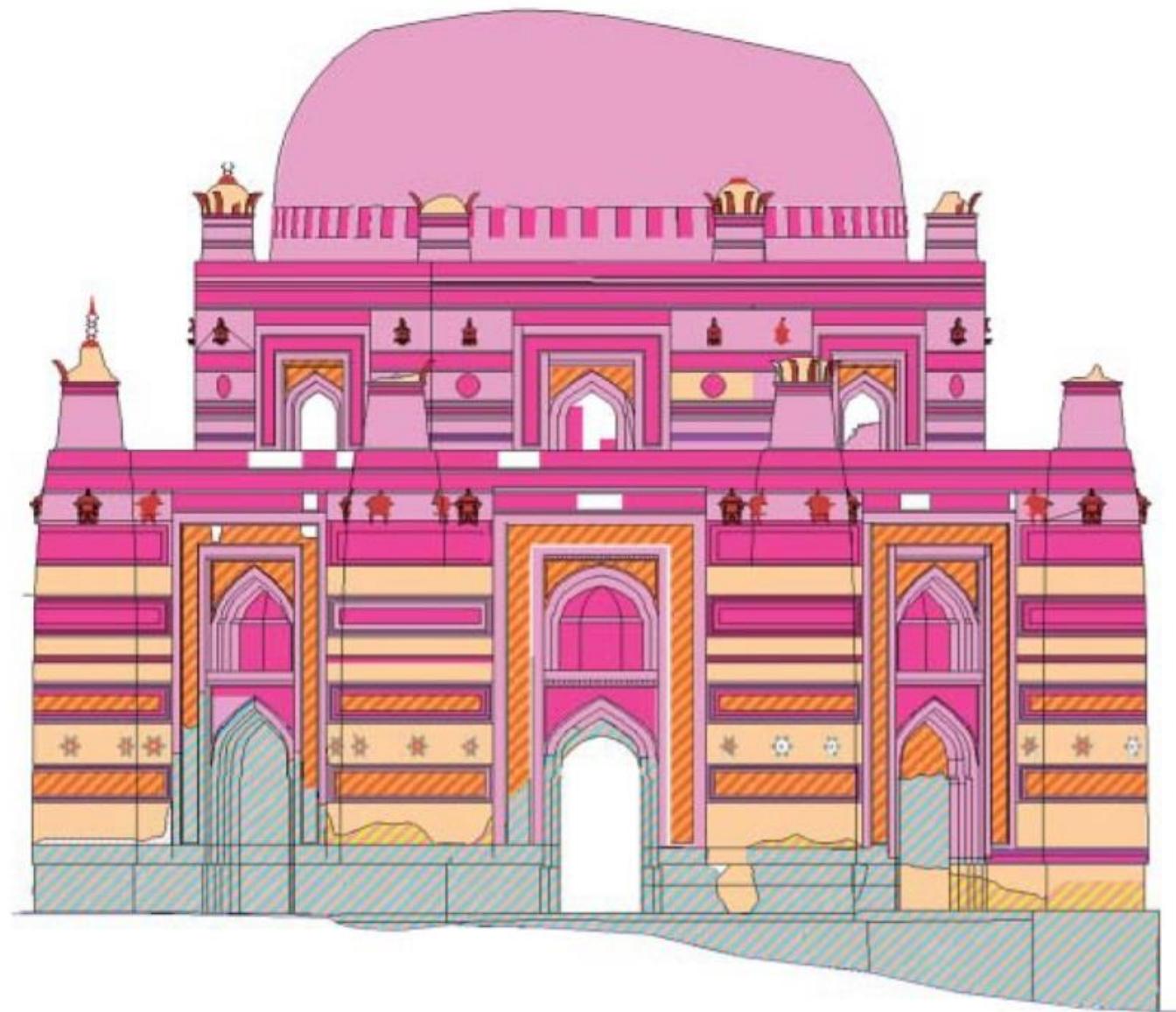
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Drainage study of site. (Source: Conservation and Rehabilitation Centre.)

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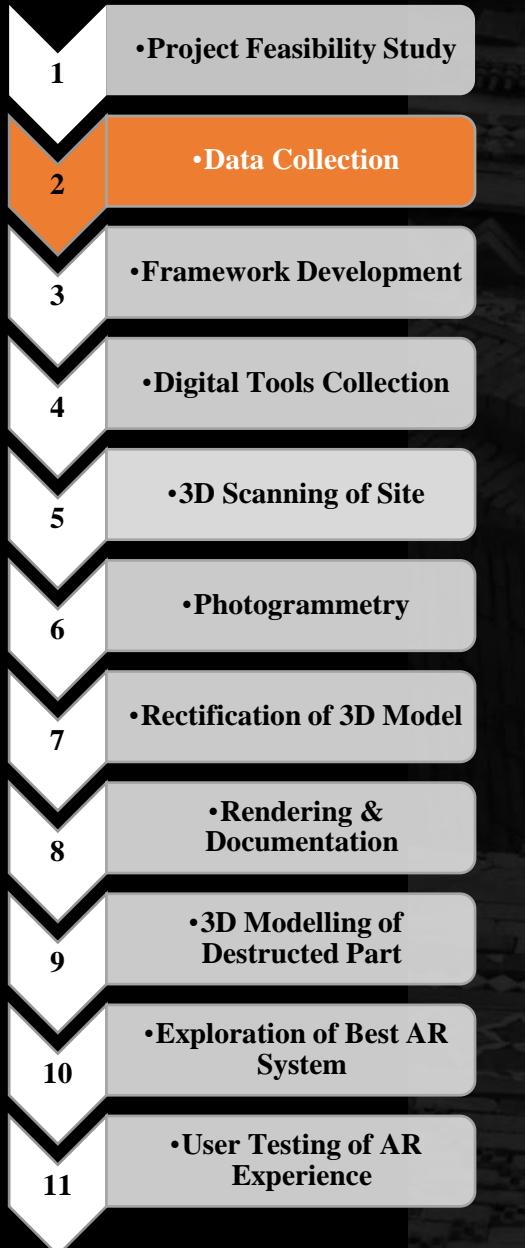


MATERIAL TYPES

- FIRED BRICK MODERN
- FIRED BRICK ORIGINAL
- EXTERIOR PLASTER
- INTERIOR PLASTER
- GYPSUM PLASTER
- MUD PLASTER
- CEMENT PLASTER
- GLAZED TERRACOTTA
- GLAZED MOSAIC
- GLAZED TILE
- CUT GLAZED BRICK
- TIMBER

An example of digital graphic materials mapping of Bibi Jawandi Mausoleum. (Source: Conservation and Rehabilitation Centre.)

Methodology



WEATHERING GROUP	ANNOTATION	CODE
RW	Rp	[Dark Red]
RW	Rp	[Dark Blue]
ROWD	Wg	[Orange]
ROWD	Wp	[Pink]
ROWD	Wg1	[Light Green]
ROWD	Wg2	[Orange]
ROWD	Wg3	[Purple]
VLB	Og1	[Light Green]
VLB	Og2	[Purple]
VLB	Og3	[Dark Blue]
VLB	D1	[Yellow]
G	Ppt1	[Grey]
C	Ct	[Light Blue]
C	Cp	[Orange]
VLB	Vb	[Red]
VLB	Vp	[Light Green]
VLB	U	[Purple]
VLB	Up	[Yellow]
VLB	Ig	[Yellow]
BPG	[Yellow]	
BI	[Green]	
CS SC SI	CS1	[Dark Blue]
CS SC SI	SCM1	[Light Green]
CS SC SI	SCM2	[Dark Blue]
CS SC SI	SCM3	[Light Blue]
CS SC SI	SCM4	[Cyan]
CS SC SI	SI	[Purple]

An example of digital graphic condition mapping of Bibi Jawandi Mausoleum. (Source: Conservation and Rehabilitation Centre.)

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Before



After



Before

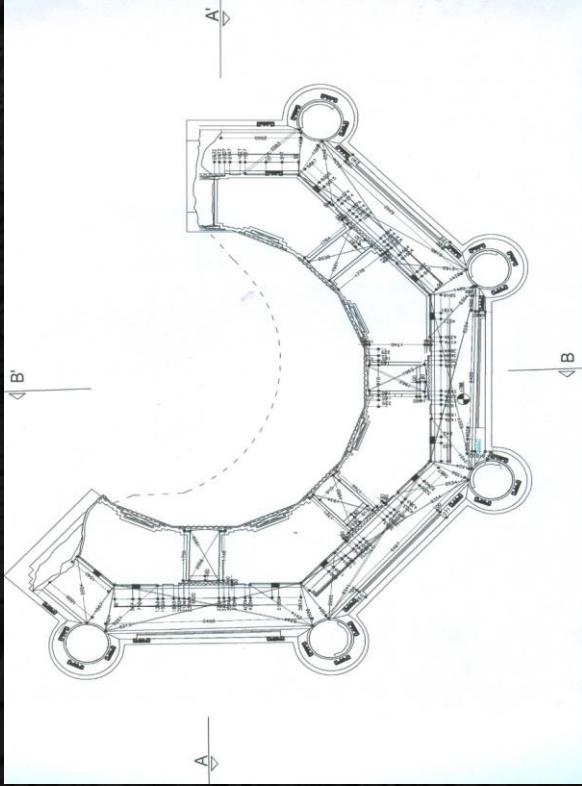
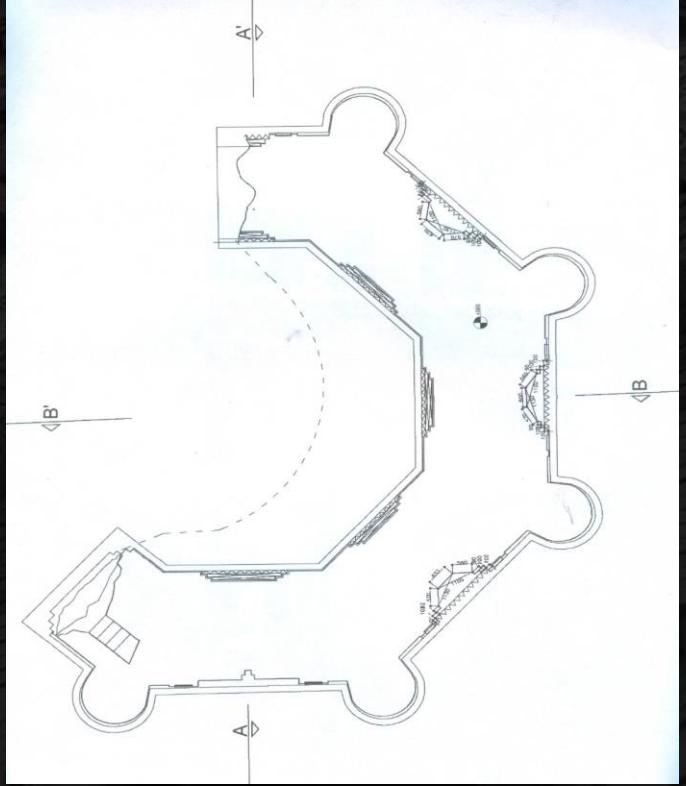
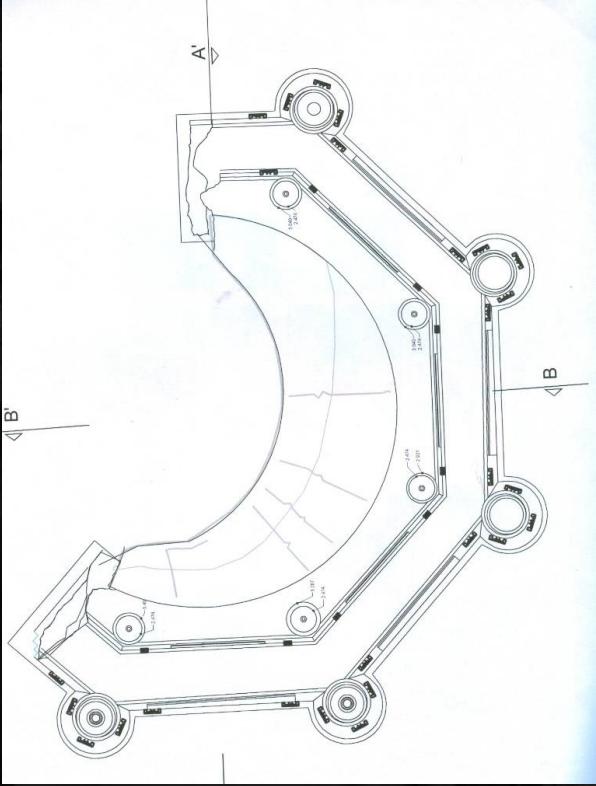


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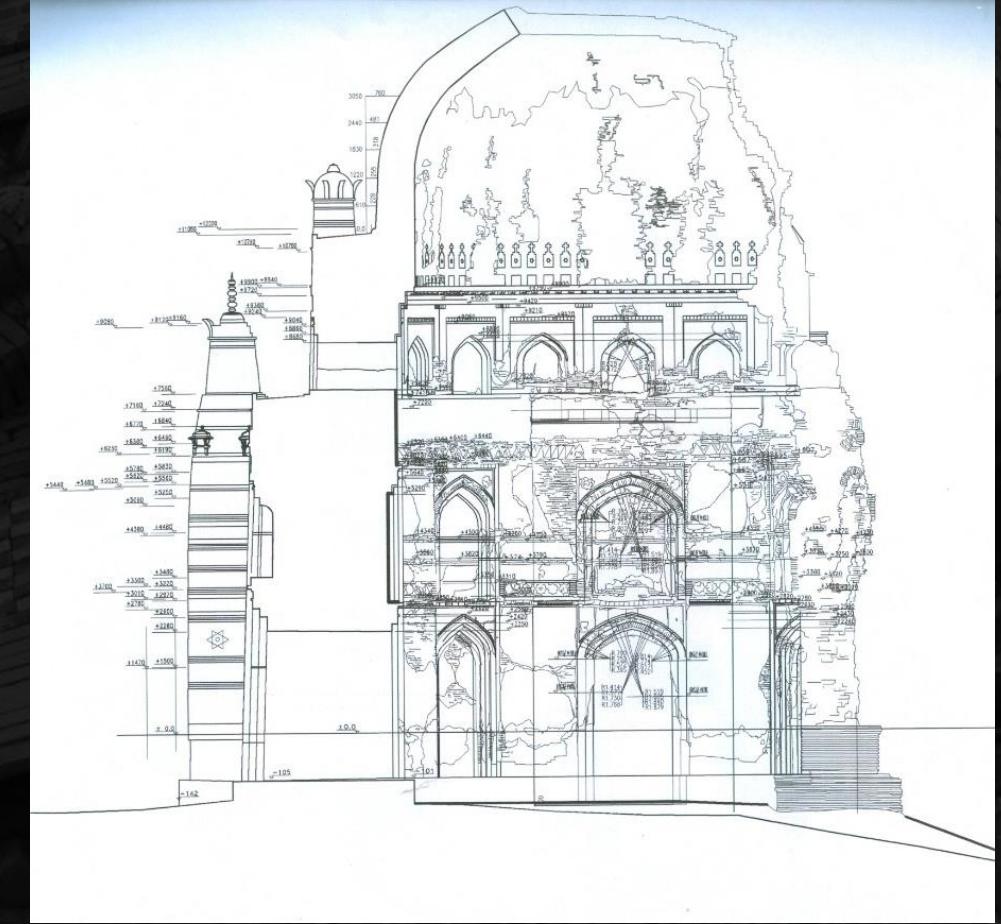
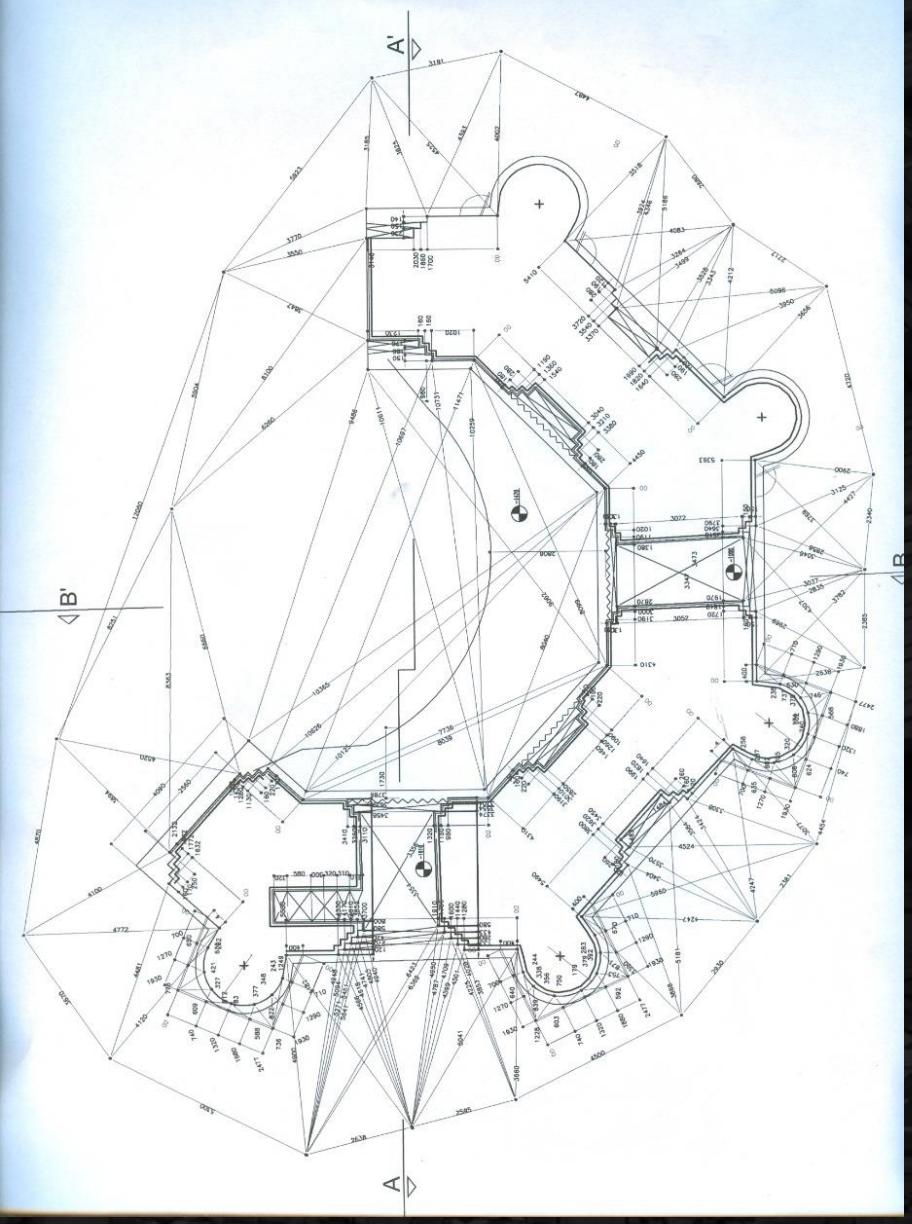
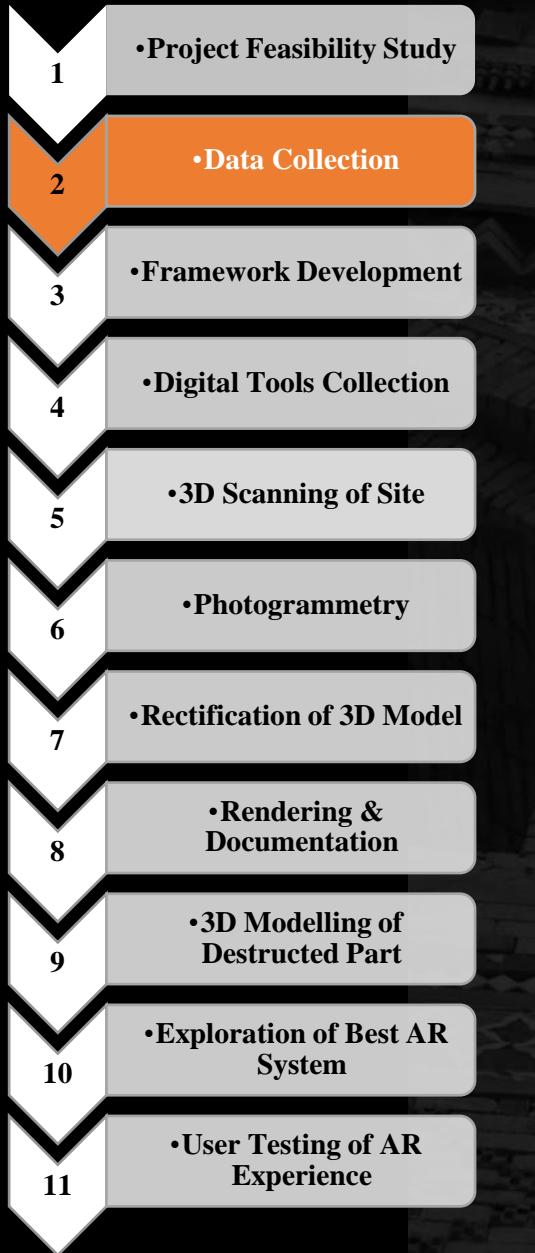
Rehabilitation & Conservation of the tomb by Archeology Directorate (Source: Tourism Department GOP)

Methodology

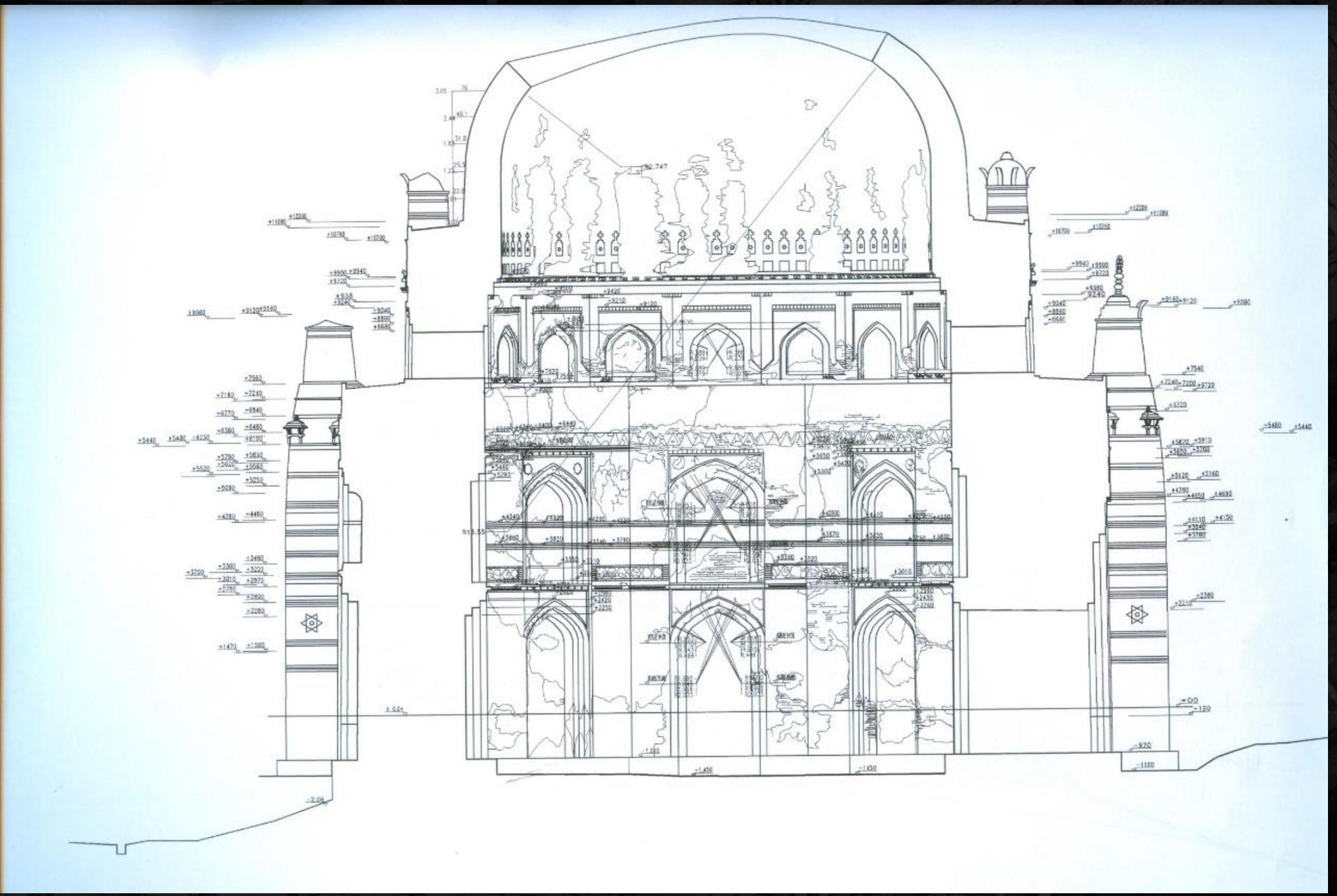
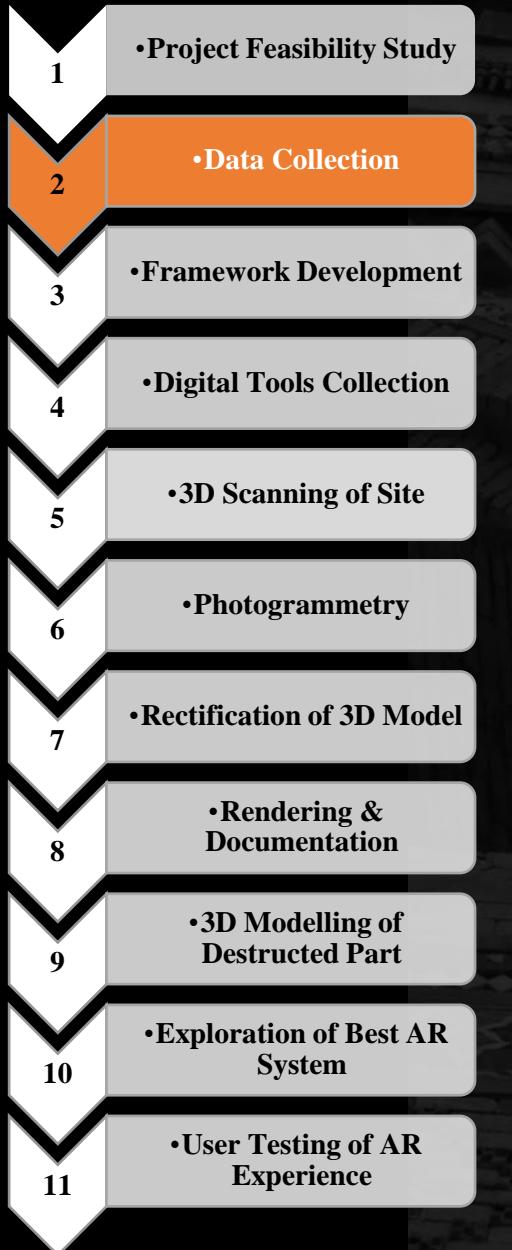
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Methodology



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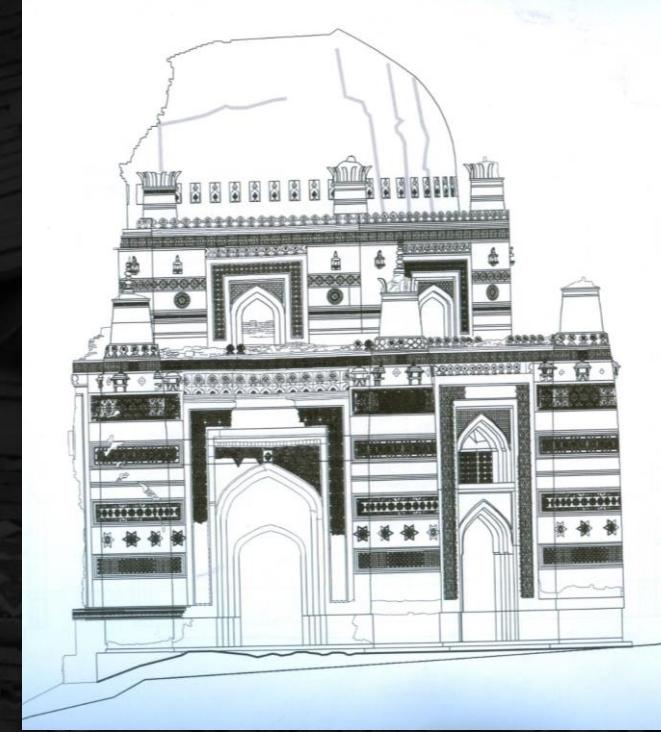
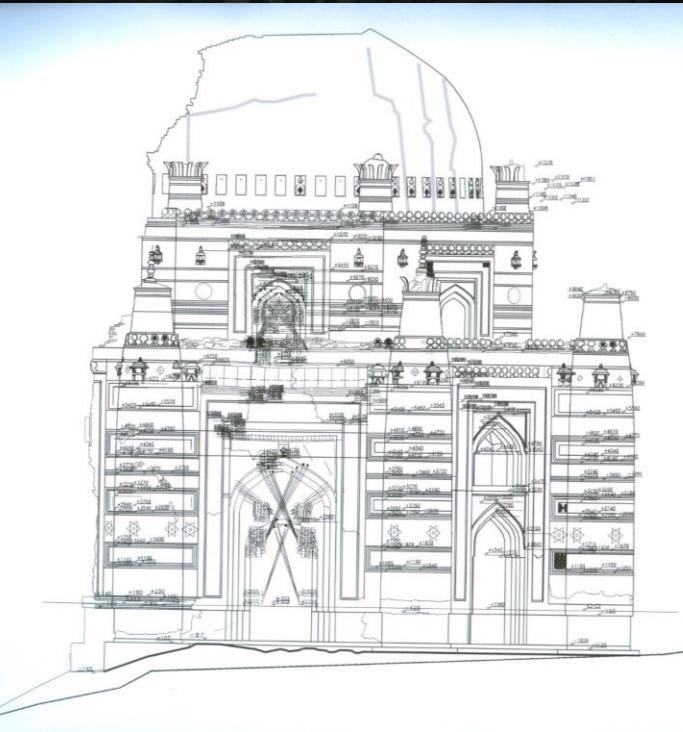
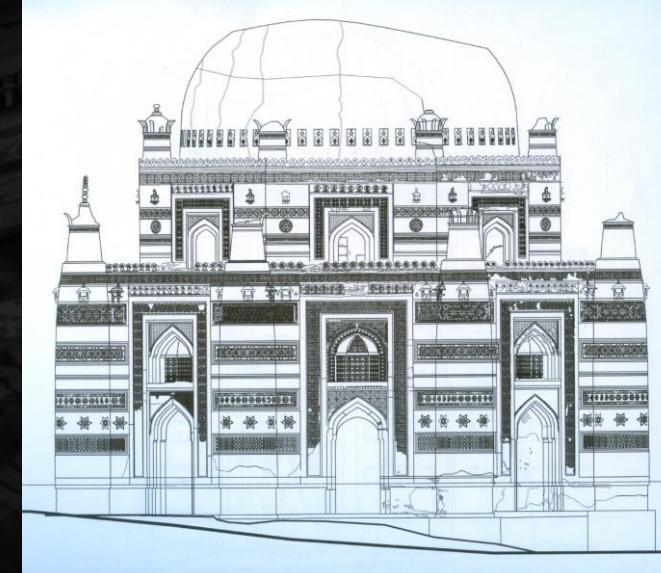
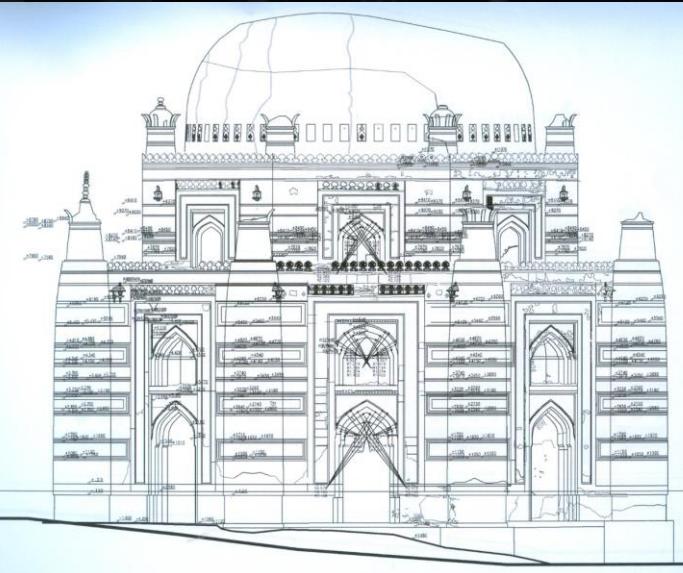
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Critical Analysis of Numerous Case Studies

3.1 3D Virtual Reconstruction of Funerary Lion Sculpture

(first half of the 1st century CE, Museo Lapidario Estense, Modena, Italy). Photo credit: Marianna Grandi



Damaged Sculpture

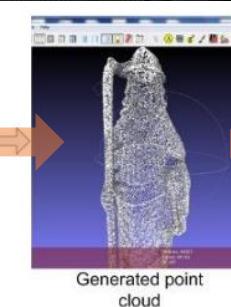
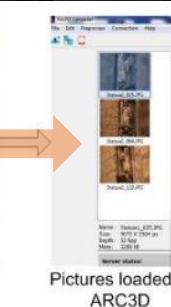


Digital Reconstruction of Sculpture



AR Scene (AR Easy Plugin)

3.2 Reconstruction of the Black Church outdoor sculpture using AR (Black Church, Brasov, Romania)



AR Scene (Instant Reality)

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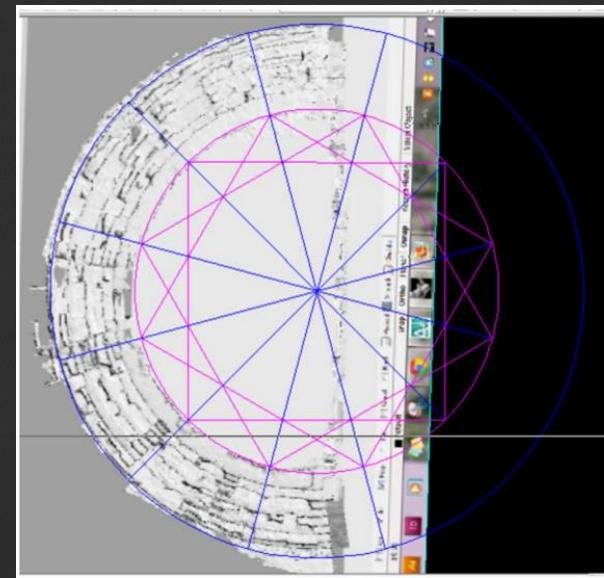
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Critical Analysis of Numerous Case Studies

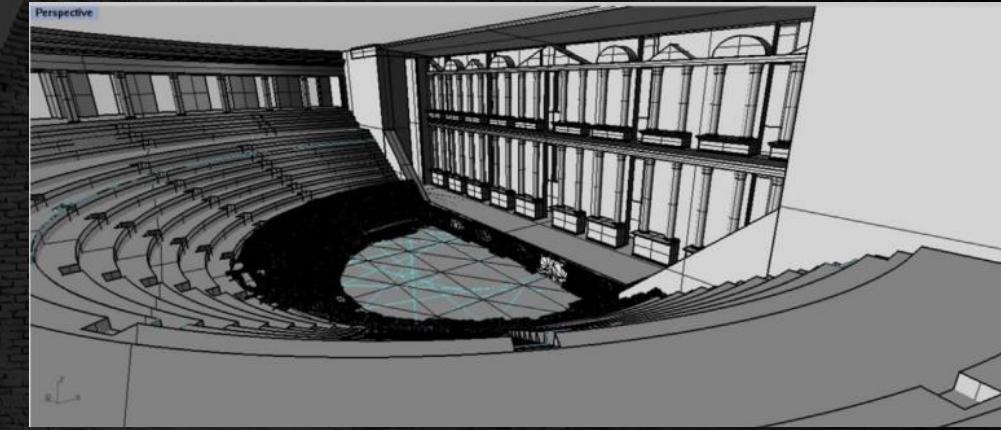
3.3 Hypothetical Reconstruction of the existing Roman Theater at Byblos



Byblos Theater superposed with Vitruvian Greek Theater construction lines.



Actual Site Image of Byblos Theater , Lebanon



Computer model of the augmented Byblos Roman Theater



Hypothesized model added and aligned on top the computerized model of the theater. (VR Oculus RIFT) 20

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High-Resolution Camera



Powerful Graphics
Computer System



Tripod



Android Smartphone
(AR Core Preferred)



Drone DJI Mavic Mini (Complete Kit)



Graphic Card (Min 4GB)



Large Storage Disk
(2 TB)

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OR



OR

ANY OTHER

Photogrammetry
Software System



OR



OR



OR



OR

ANY OTHER

3D Modelling
& Rendering
Software
Systems

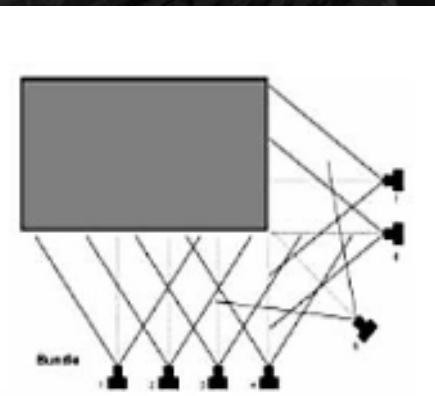
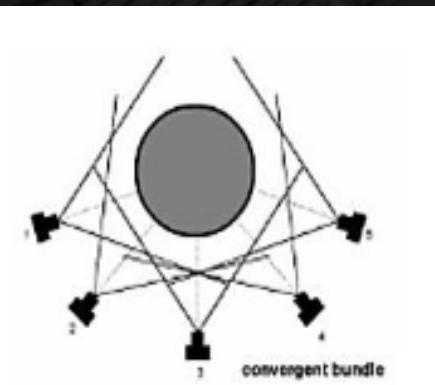
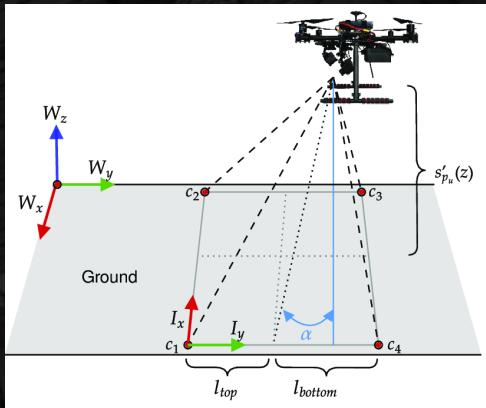
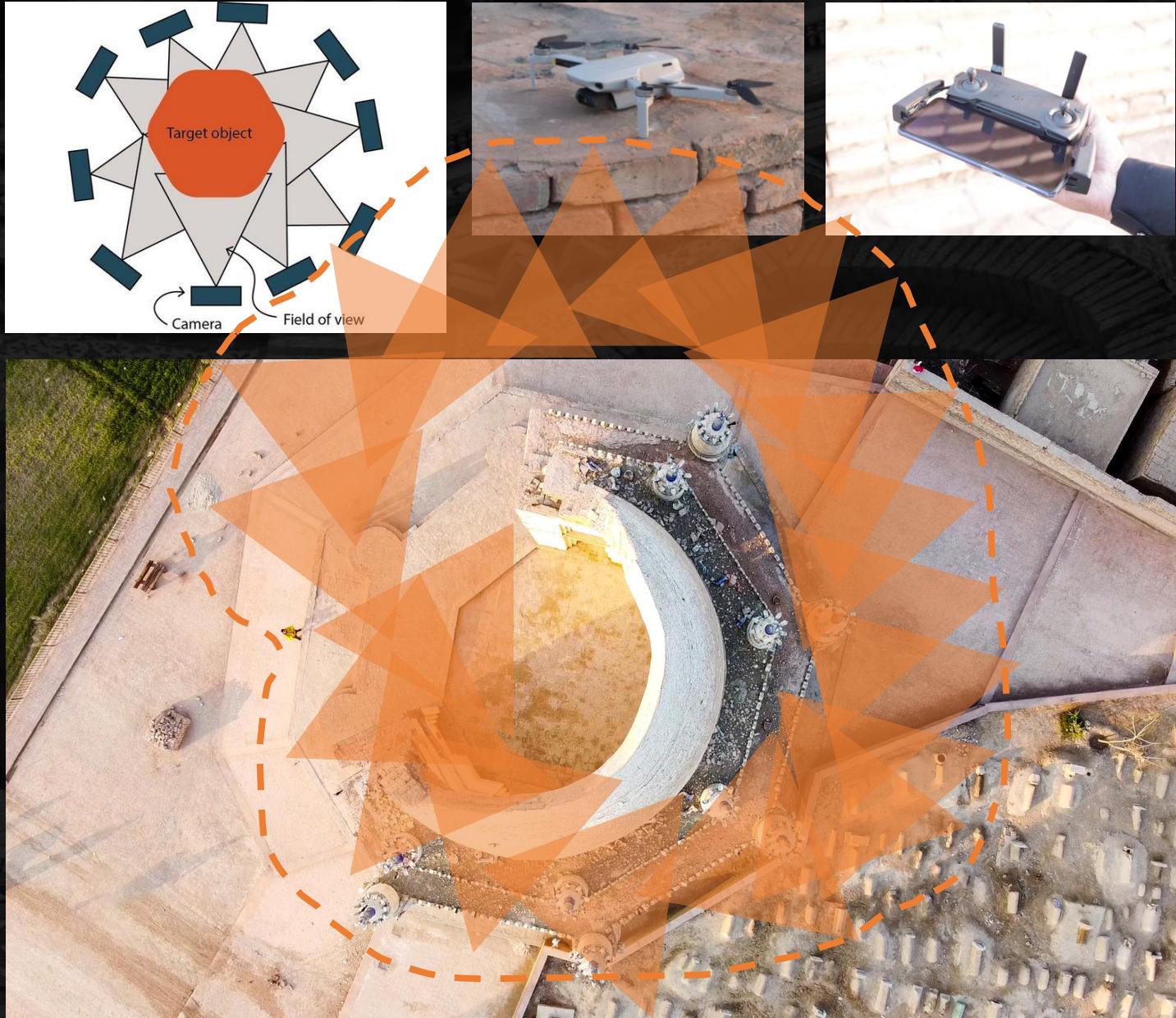


OR
ANY OTHER

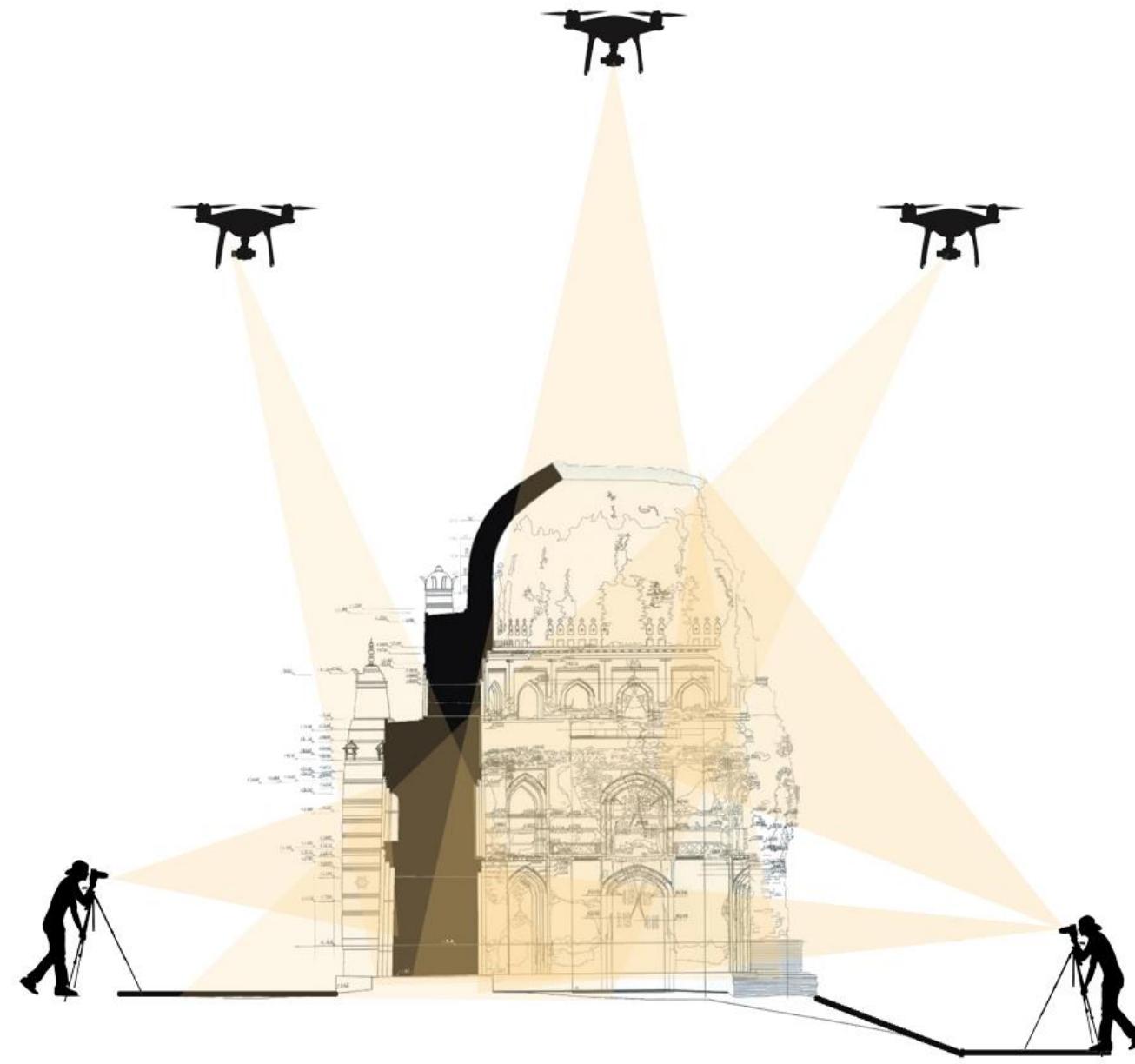
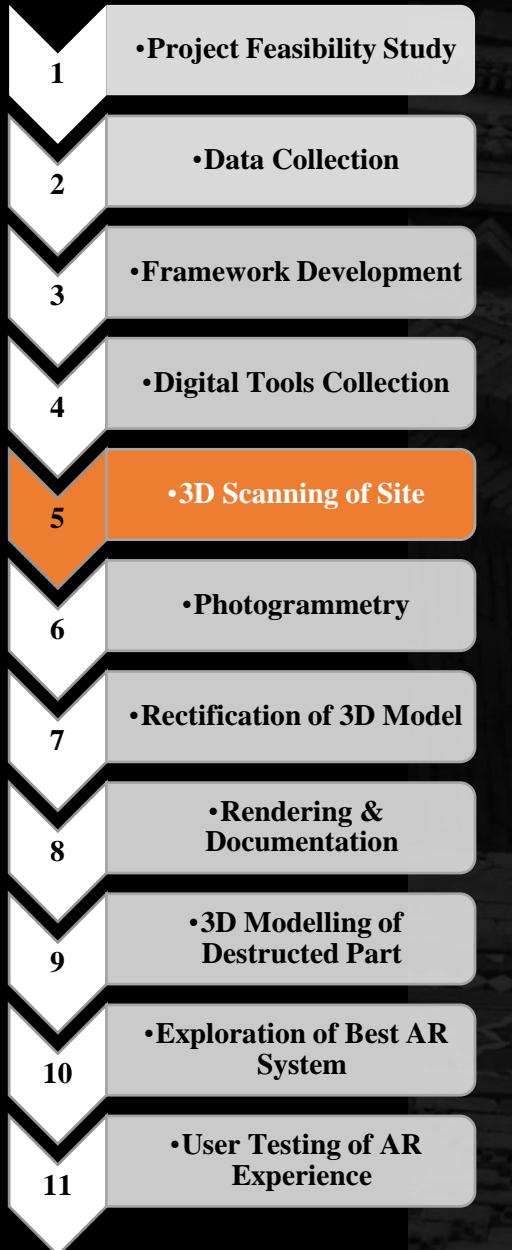
Augmented
Reality Software
Development Kit

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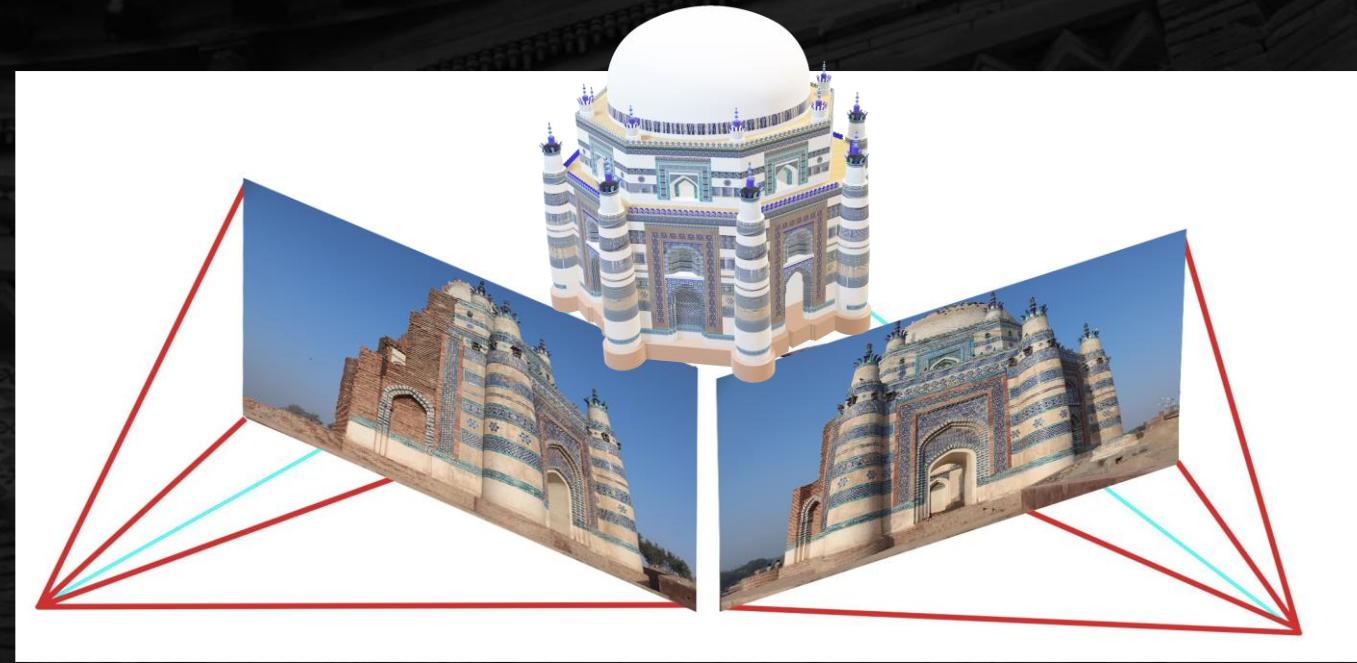


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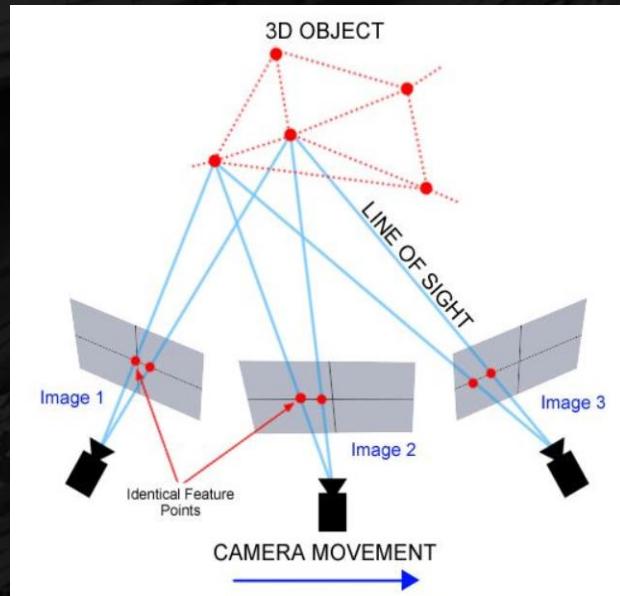
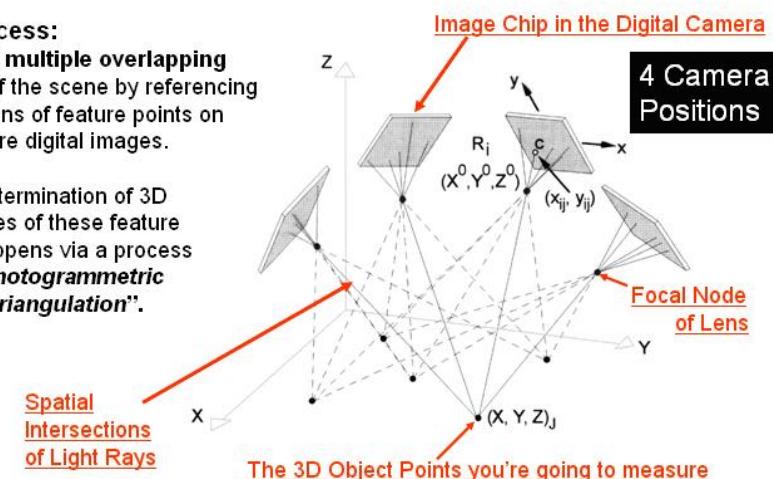


Close Range Photogrammetry (*inside and outside the camera*)

The Process:

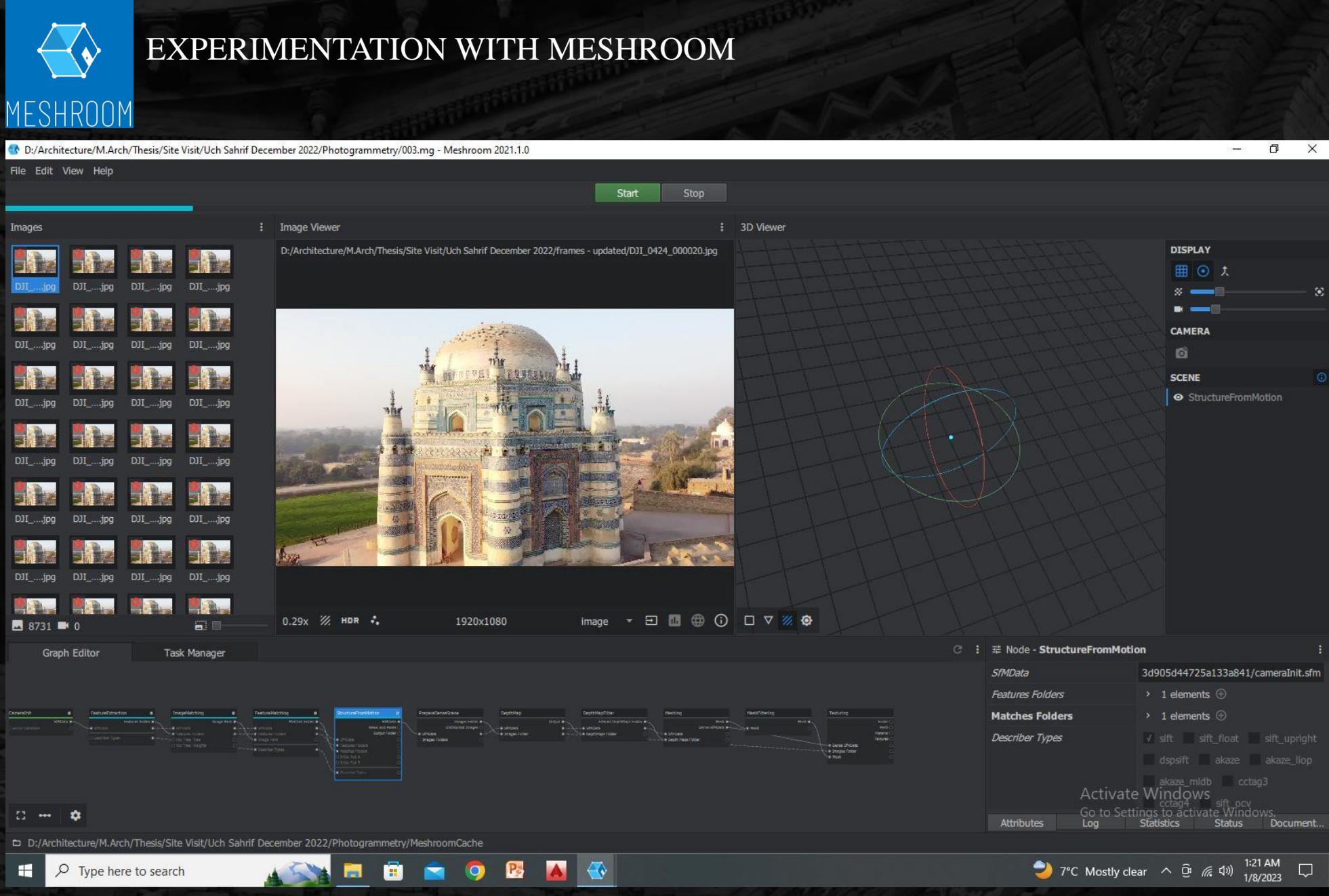
1. Record **multiple overlapping images** of the scene by referencing 2D positions of feature points on two or more digital images.

2. The determination of 3D coordinates of these feature points happens via a process called "**Photogrammetric Bundle Triangulation**".



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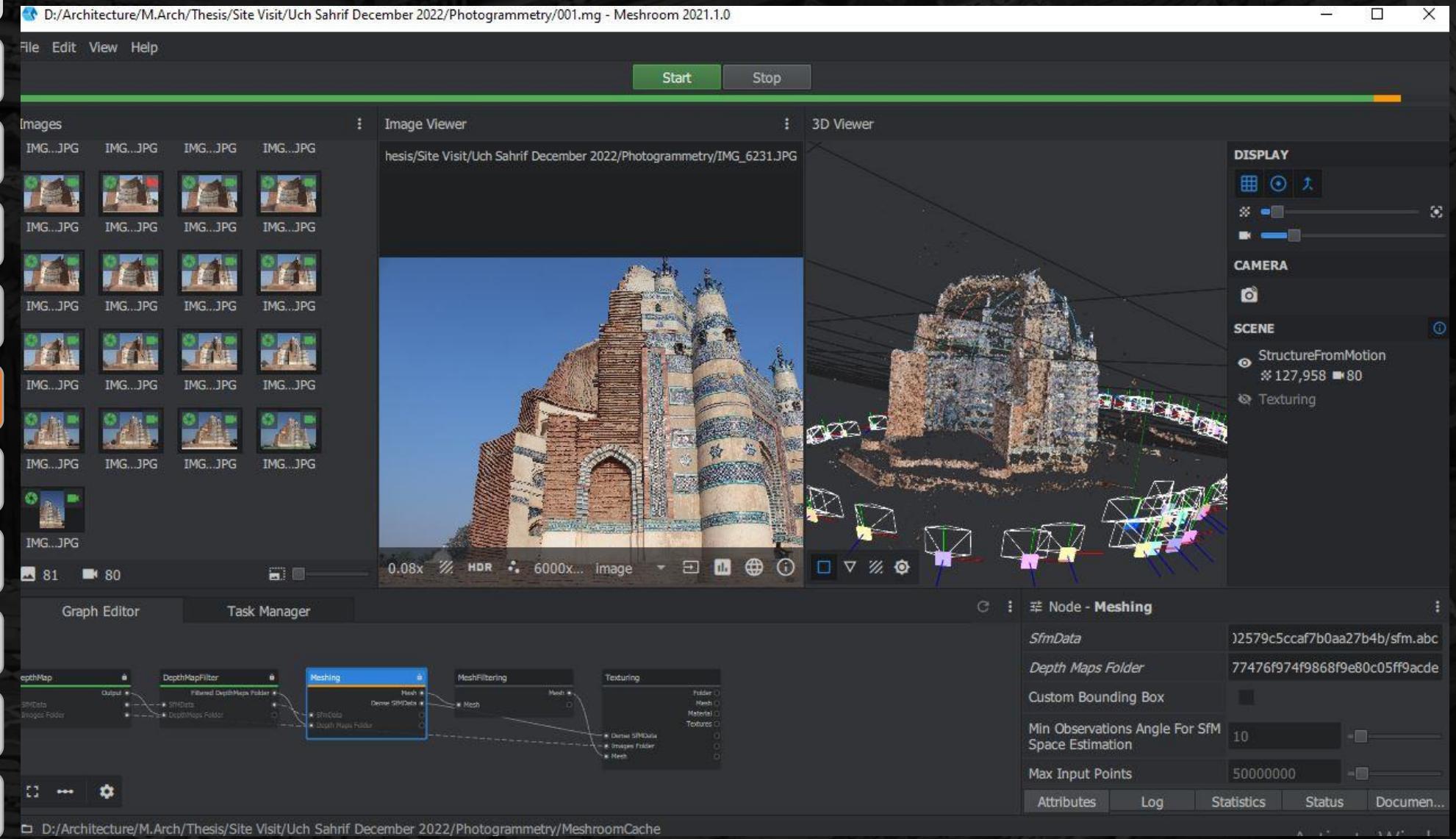


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EXPERIMENTATION WITH MESHROOM

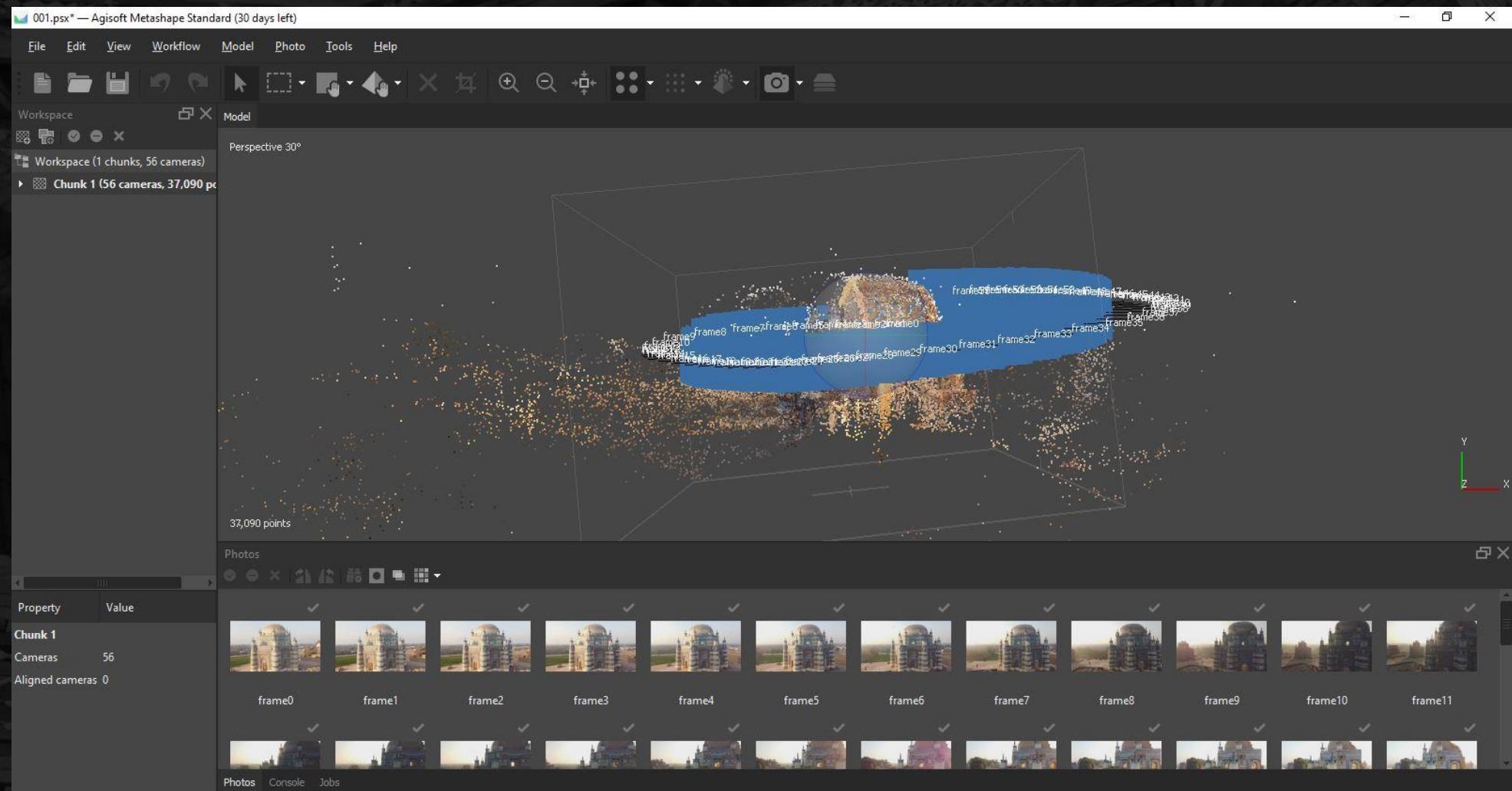


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EXPERIMENTATION WITH METASHAPE

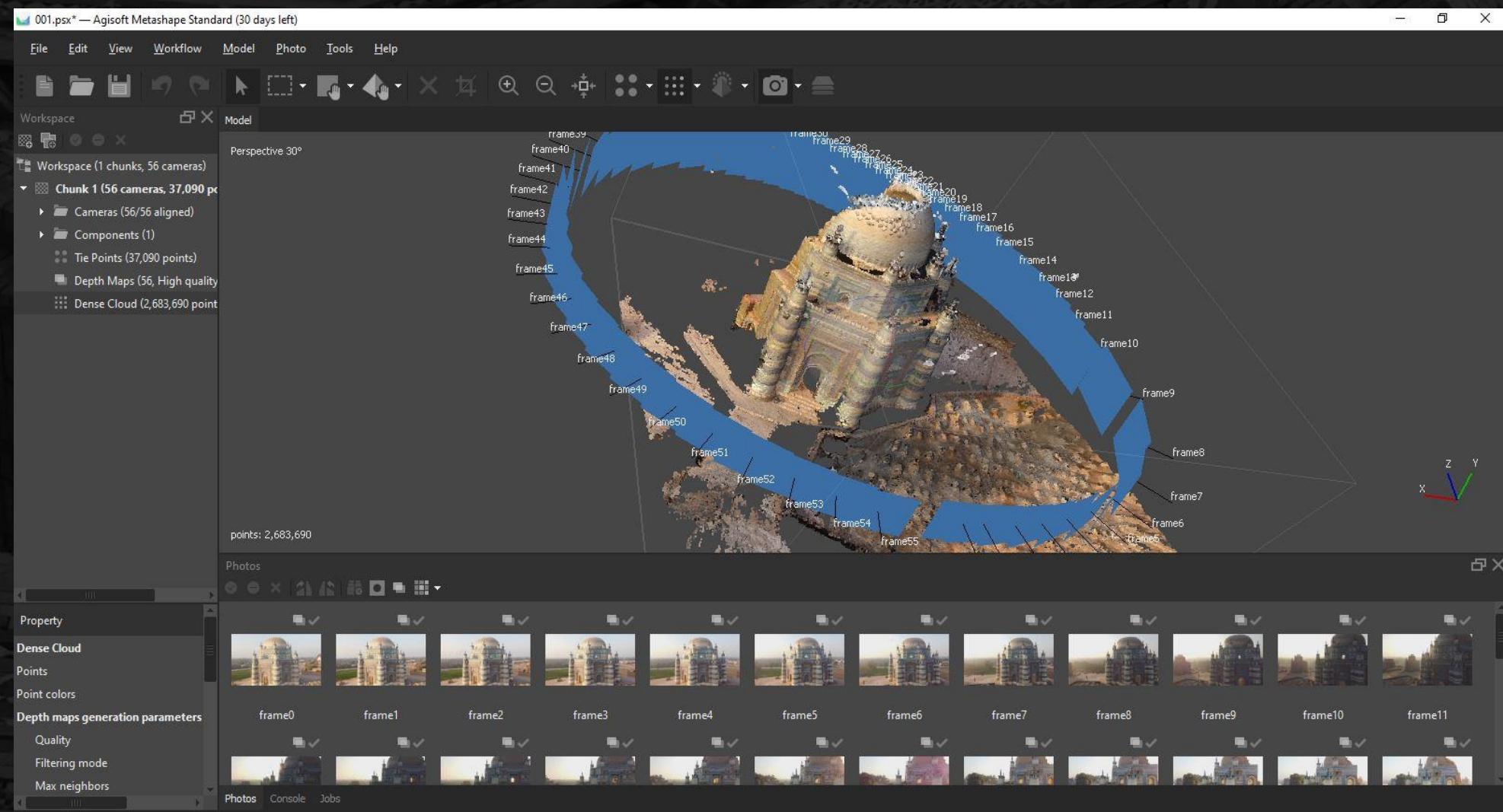


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EXPERIMENTATION WITH METASHAPE



Methodology



SURVEY DATA REPORT METASHAPE 22 JANUARY 2023

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6 •Photogrammetry

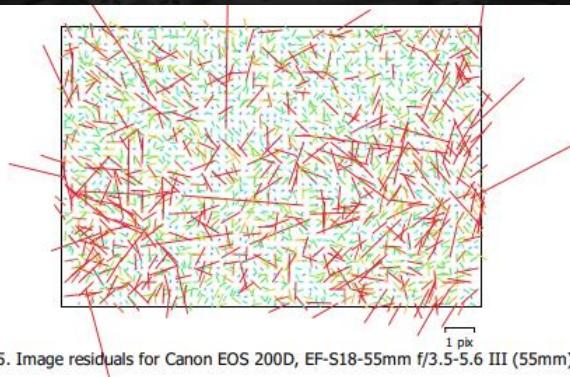
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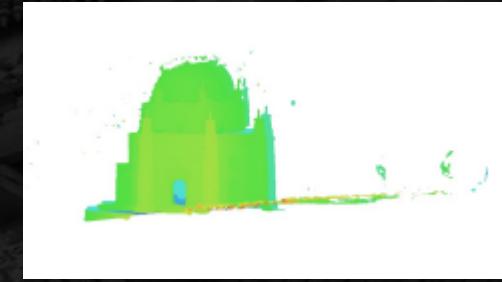
Canon EOS 200D, EF-S18-55mm f/3.5-5.6 III (55mm)

4 images

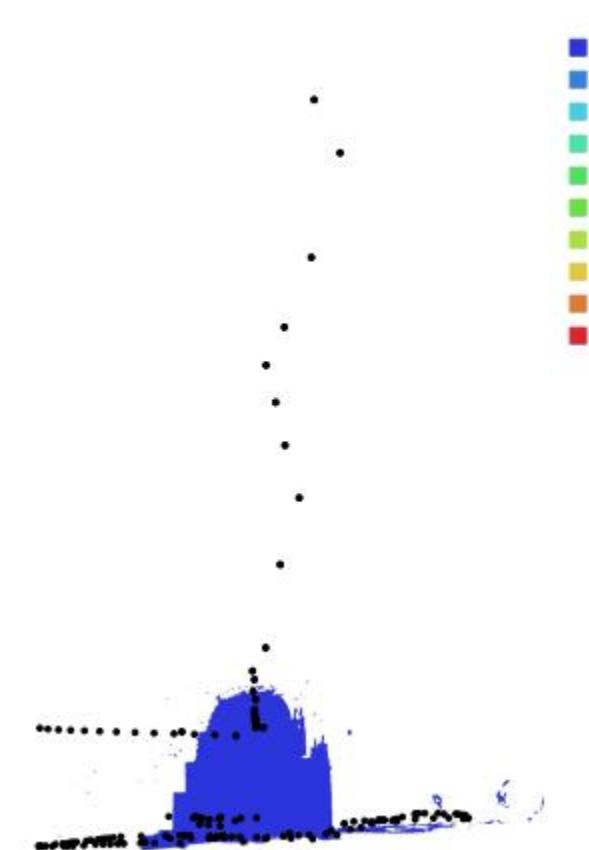
Type	Resolution	Focal Length	Pixel Size
Frame	6000 x 4000	55 mm	3.84 x 3.84 µm

Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F 14260.1	3.6	1.00	-0.07	-0.33	0.01	0.02	-0.00	0.01	0.06
Cx 144.647	5.5		1.00	0.36	0.10	-0.12	0.14	0.96	0.41
Cy 115.759	5.4			1.00	-0.04	-0.02	0.04	0.33	0.84
K1 0.0511681	0.0045				1.00	-0.96	0.89	0.11	0.05
K2 0.940296	0.15					1.00	-0.98	-0.13	-0.09
K3 -7.86259	1.5						1.00	0.14	0.11
P1 0.00303366	0.00018							1.00	0.41
P2 0.00479919	0.00014								1.00

Table 5. Calibration coefficients and correlation matrix.



Reconstructed digital elevation modeL



Camera locations and image overlap.

Number of images: 224 Camera stations: 223

Tie points: 84,306 Projections: 457,783

Reprojection error: 0.796 pix

Methodology



SURVEY DATA REPORT METASHAPE 22 JANUARY 2023

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General	Cameras Aligned cameras	224 223	Memory usage	9.31 GB
Point Cloud	Points RMS reprojection error Max reprojection error Mean key point size Point colors Key points Average tie point multiplicity	84,306 of 152,217 0.187196 (0.795969 pix) 0.56213 (49.3505 pix) 3.61551 pix 3 bands, uint8 No 6.47321	Date created	2023:01:16 20:18:18
Alignment parameters	Accuracy Generic preselection Reference preselection Key point limit Key point limit per Mpx Tie point limit Exclude stationary tie points Guided image matching Adaptive camera model fitting Matching time Matching memory usage Alignment time Alignment memory usage	High Yes No 40,000 1,000 4,000 Yes No No 3 minutes 52 seconds 531.18 MB 2 minutes 12 seconds 229.97 MB 2023:01:15 21:46:56 1.8.4.14856 17.43 MB	Software version	1.8.4.14856
Depth Maps	Count	189	File size	520.27 MB
Depth maps generation parameters	Quality Filtering mode Max neighbors Processing time Memory usage	High Mid 16 26 minutes 58 seconds 5.11 GB	Model	
Dense Point Cloud	Date created Software version File size	2023:01:16 19:43:57 1.8.4.14856 712.81 MB	Faces Vertices Vertex colors Texture	7,129,974 3,571,217 3 bands, uint8 8,192 x 8,192, 4 bands, uint8
Depth maps generation parameters	Quality Filtering mode Max neighbors Processing time Memory usage	High Mid 16 26 minutes 58 seconds 5.11 GB	Depth maps generation parameters	High Mid 16 26 minutes 58 seconds 5.11 GB
Dense cloud generation parameters	Processing time	34 minutes 20 seconds	Reconstruction parameters	Arbitrary Dense cloud Enabled No 12 minutes 40 seconds 7.99 GB
	Memory usage		Texturing parameters	Generic Mosaic 8,192 Yes Yes 2 minutes 7 seconds 3.08 GB 3 minutes 52 seconds 4.37 GB 2.61 GB 2023:01:16 20:40:23 1.8.4.14856 388.53 MB
			Mapping mode Blending mode Texture size Enable hole filling Enable ghosting filter UV mapping time UV mapping memory usage Blending time Blending memory usage Blending GPU memory usage	
			System	Agisoft Metashape Standard 1.8.4 build 14856 Windows 64 bit 15.95 GB AMD Ryzen 5 2600X Six-Core Processor GeForce GTX 1060 6GB

Methodology



RECTIFICATION WITH BLENDER REDUCING MESH SIZE, CLEANING MODEL, CONVERTING PLANAR GEOMETRY

1 •Project Feasibility Study

2 •Data Collection

3 •Framework Development

4 •Digital Tools Collection

5 •3D Scanning of Site

6 •Photogrammetry

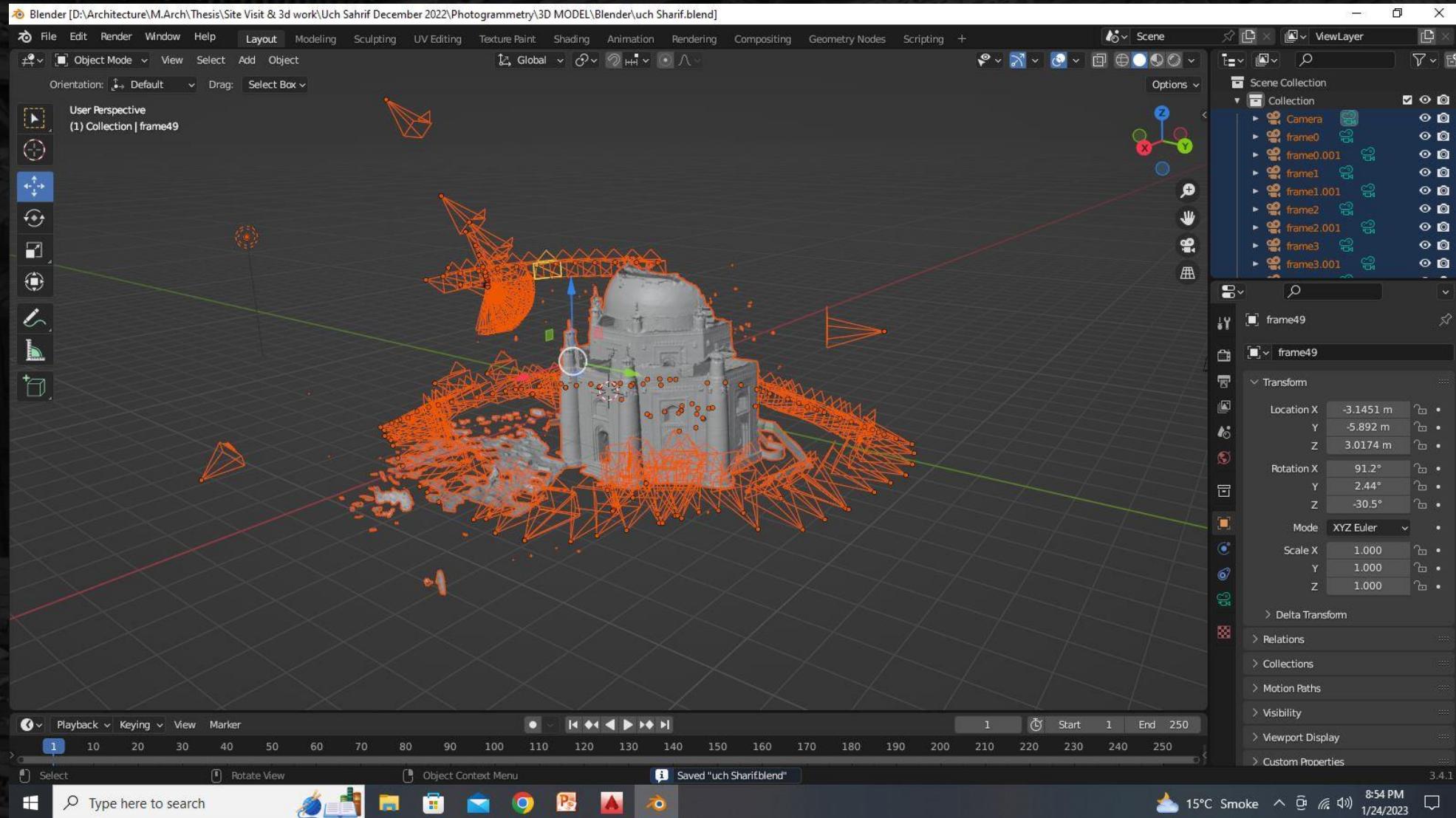
7 •Rectification of 3D Model

8 •Rendering & Documentation

9 •3D Modelling of Destructed Part

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11 •User Testing of AR Experience



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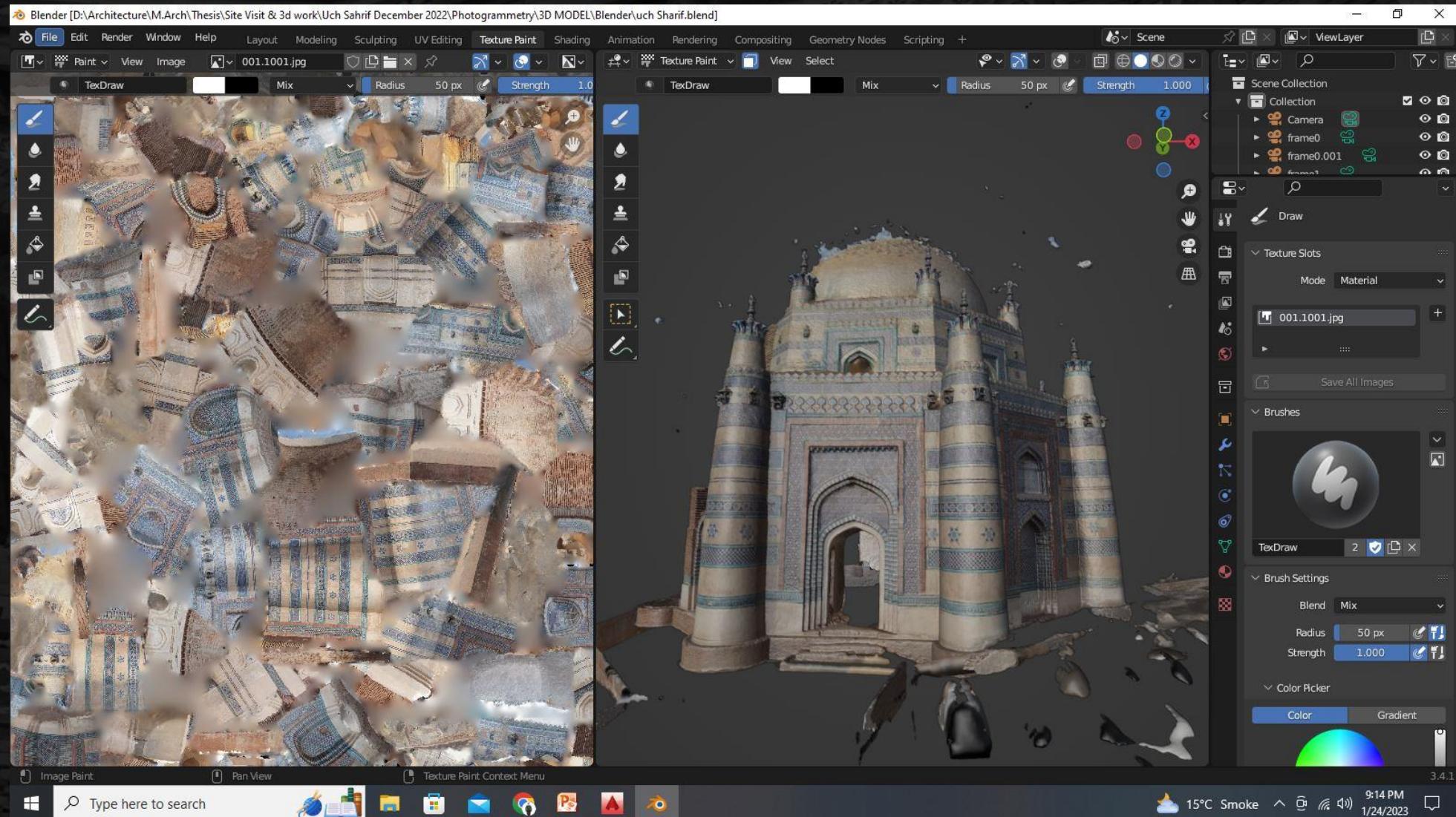
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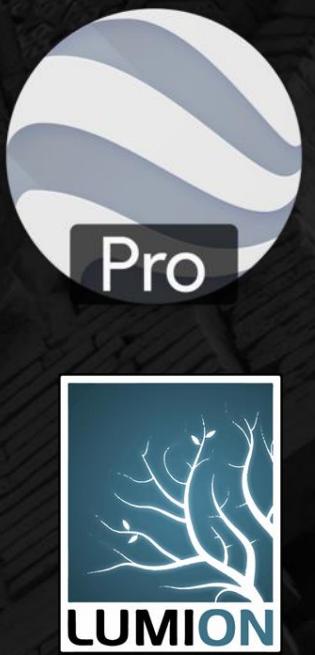
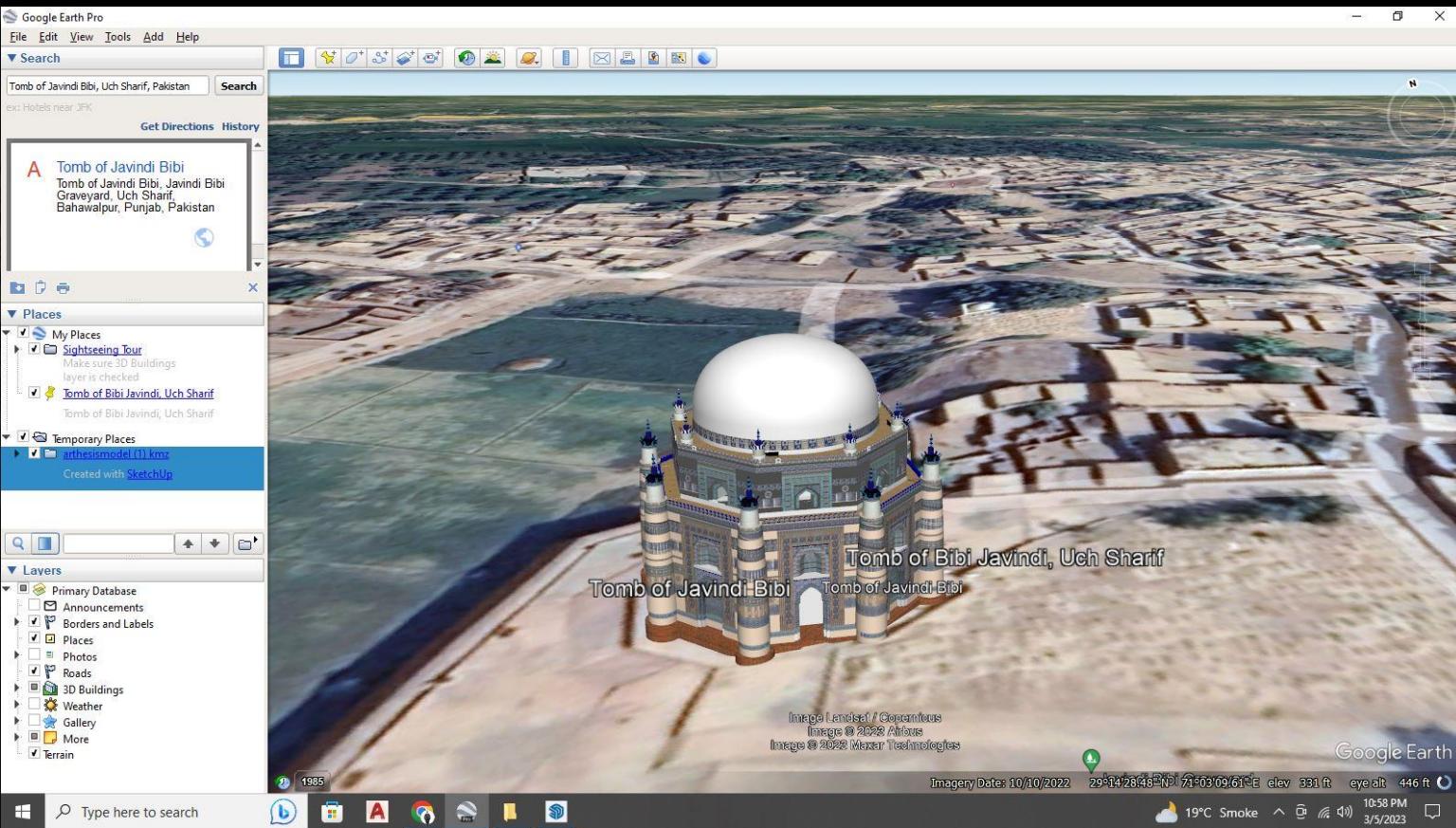
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•Exploration of Best AR
System

10

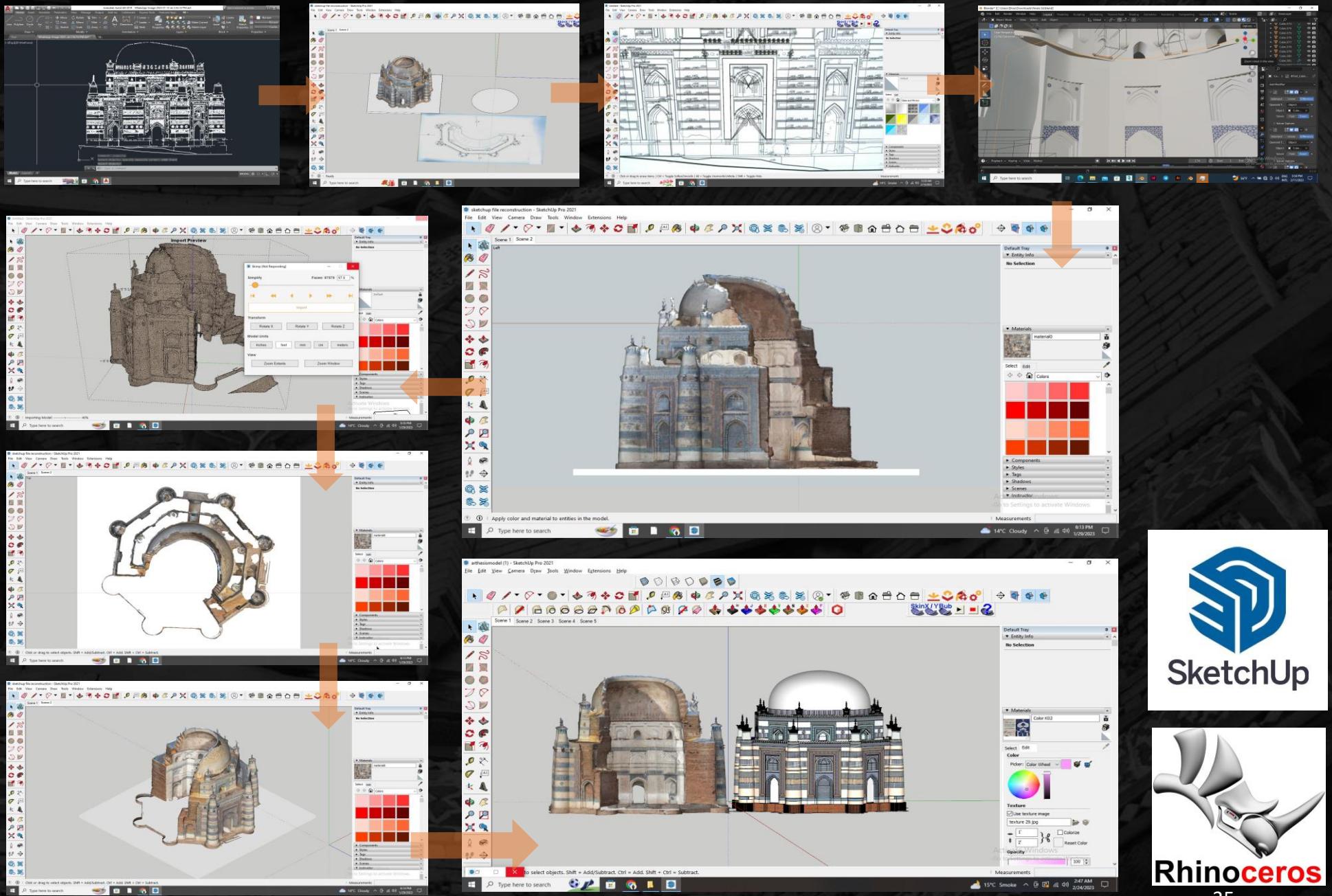
•User Testing of AR
Experience

11



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Rhino**ceros**

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	SDK	License	Supported Platforms	2D	3D	Geo Location	Cloud Support
Vuforia	Free		Android, iOS, UWP and Unity Editor	✓	✓	✗	✓
EasyAR	Free		Android, iOS, UWP, Windows, Mac and Unity Editor	✓	✗	✗	✗
Wikitude	Paid		Android, iOS, Smart Glasses	✓	✓	✓	✓
ARToolKit	Free		Android, iOS, Linux, Windows, MacOS and Smart Glasses	✓	✗	✗	✗
Kudan	Paid		Android, iOS, Unity Editor.	✓	✓	✗	✗
Layar	Paid		Android, iOS, BlackBerry	✓	✓	✓	✗
NyART.Kit	Free		Android, iOS	✓	✗	✗	✗

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SDK	License	Supported Platforms	2D	3D	Geo Location	Cloud Support
AUGMENTECTURE	Free	Android, iOS, UWP and Unity Editor	✓	✓	✗	✓
AUGIN	Free	Android, iOS, UWP, Windows, Mac and Unity Editor	✓	✗	✗	✗
ARLOOPA	Paid	Android, iOS, Smart Glasses	✓	✓	✓	✓
AR UNITE	Free	Android, iOS, Linux, Windows, MacOS and Smart Glasses	✓	✗	✗	✗
ARKIAPP	Paid	Android, iOS, Unity Editor.	✓	✓	✗	✗
FECTOR	Paid	Android, iOS, BlackBerry	✓	✓	✓	✗
AR VIEWER	Free	Android, iOS	✓	✗	✗	✗

Methodology

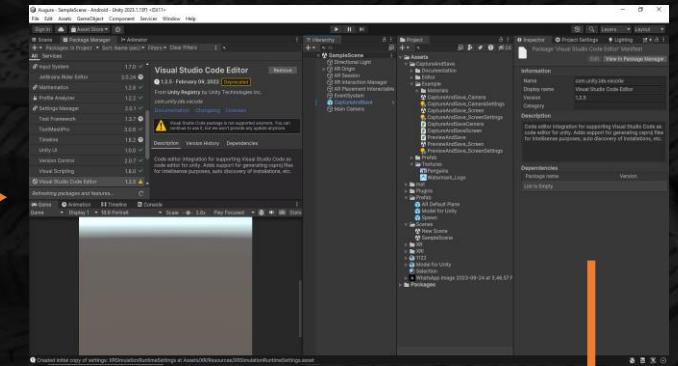
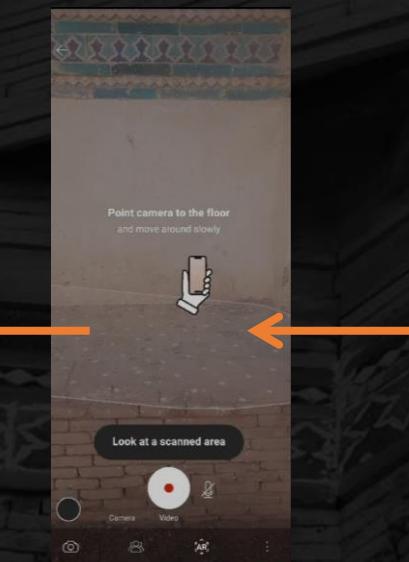
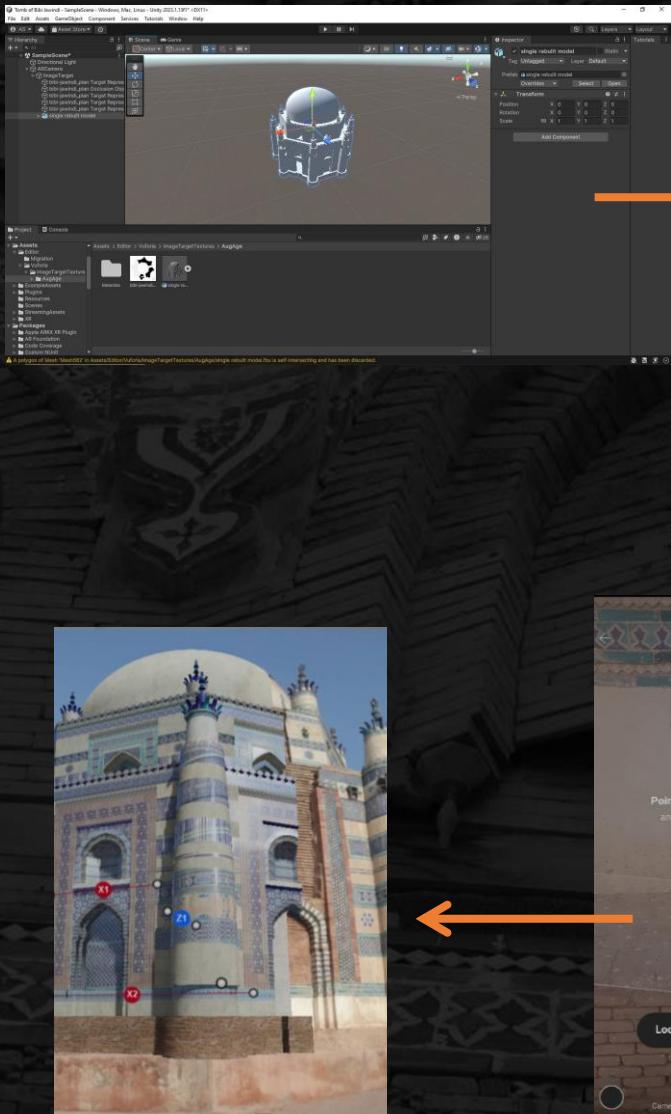
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	SDK	License	Supported Platforms	2D	3D	Geo Location	Cloud Support
1	AFTER EFFECTS	Free	Android, iOS, UWP and Unity Editor	✓	✓	✗	✓
2	VUFORIA	Free	Android, iOS, UWP, Windows, Mac and Unity Editor	✓	✗	✗	✗
3	UNITY FOUNDATION AR	Free	Android, iOS, Smart Glasses, Mac, Windows,	✓	✓	✓	✓

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```
// Attempts to remove an <see cref="ARAnchor"/>
// <summary>
// <param name="anchor">The anchor you wish to remove.</param>
// <returns>
// <c>True</c> if the anchor was successfully removed.
// <c>False</c> usually means the anchor is not longer tracked by the system.
// </returns>
[Obsolete("Call Destroy() on the " + nameof(ARAnchor) + " component to remove it. (2020-10-06)")]
public bool RemoveAnchor(ARAnchor anchor)
{
    if (enabled)
        throw new InvalidOperationException("Cannot create an anchor from a disabled anchor manager.");
    if (subsystem == null)
        throw new InvalidOperationException("Anchor manager has no subsystem. Enable the manager first.");
    if (anchor == null)
        throw new ArgumentNullException(nameof(anchor));
    if (subsystem.TryRemoveAnchor(anchor.trackableId))
    {
        DestroyPendingTrackable(anchor.trackableId);
        return true;
    }
    return false;
}

etc...
```

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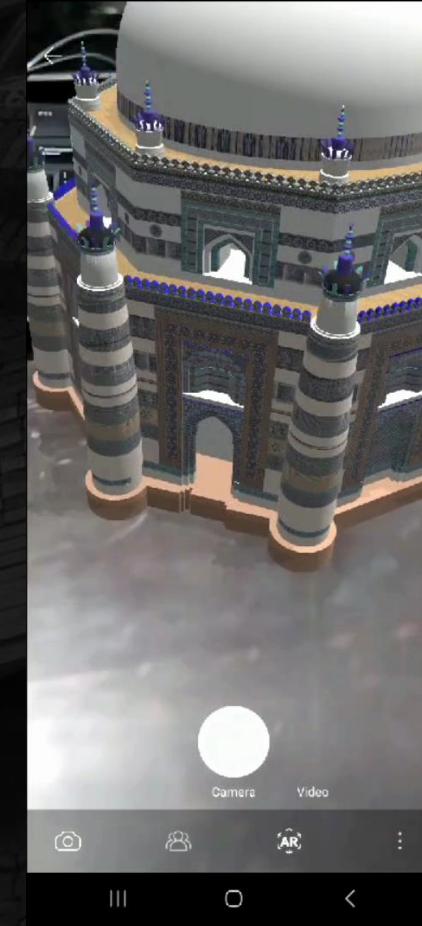
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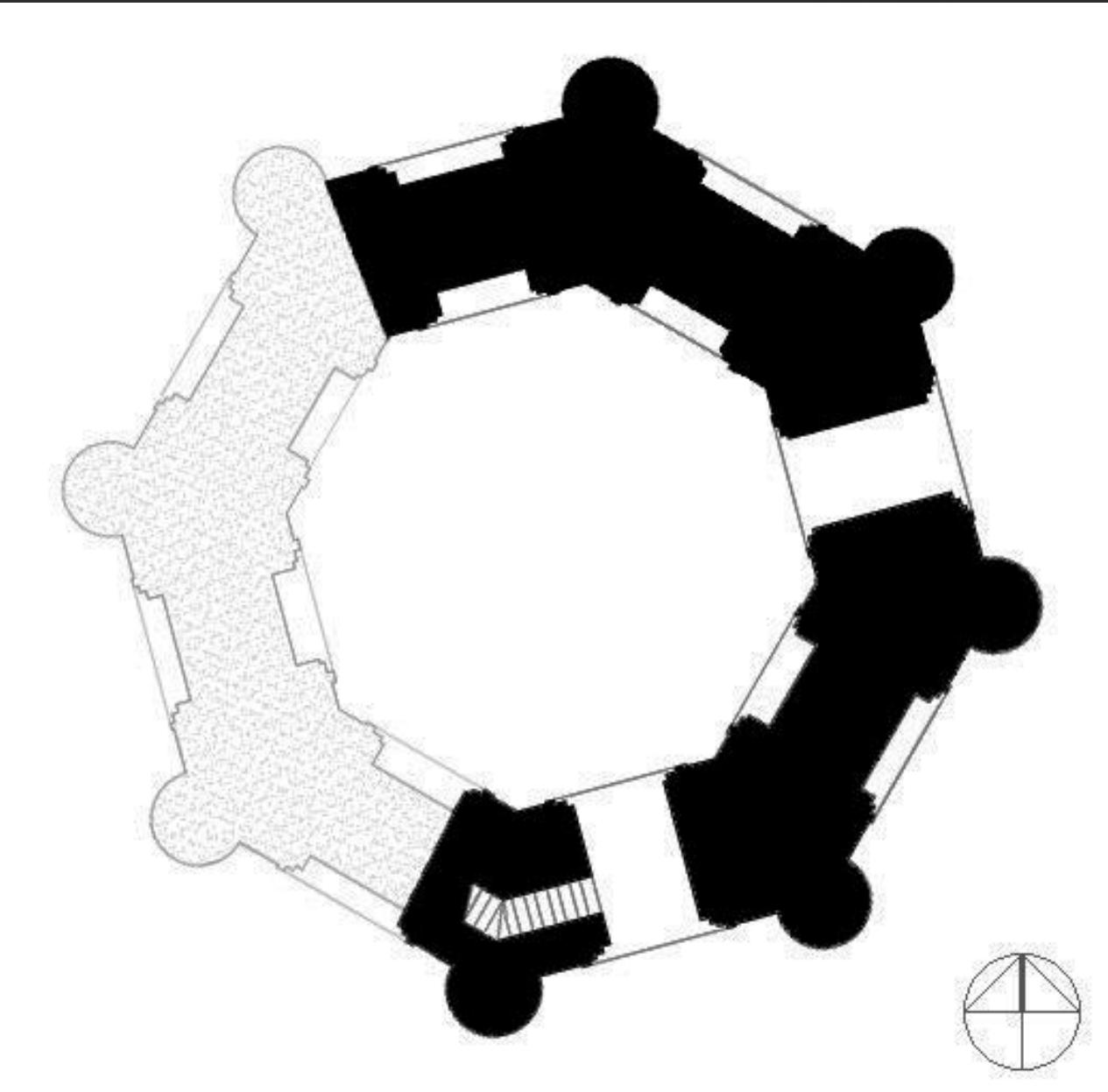
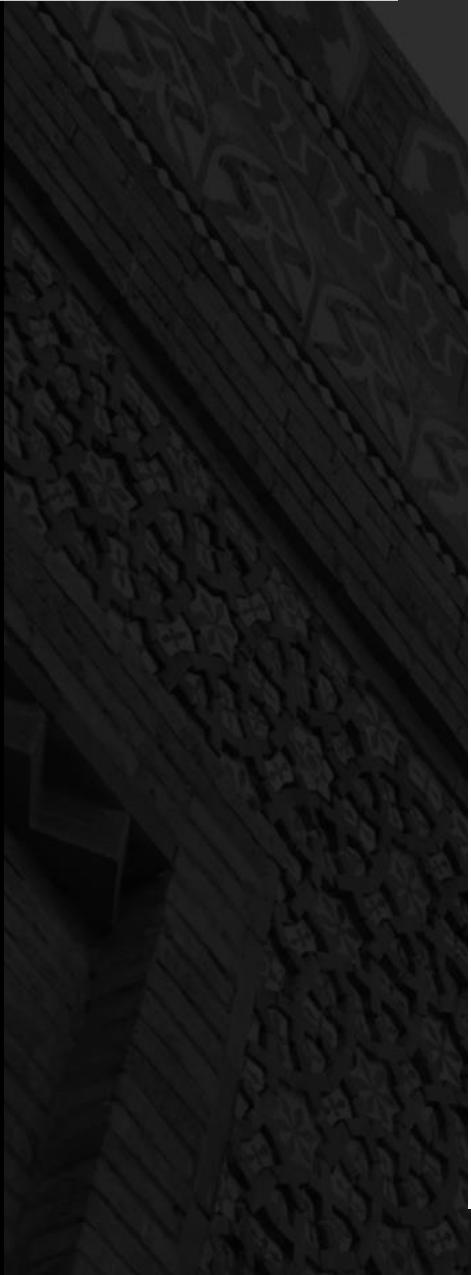
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Results

- Accurate 3D Model
- Augmented Reality Application
- Marker less Tracking
- Realistic Visualization
- Interactive Features

AR PLAN OF TOMB



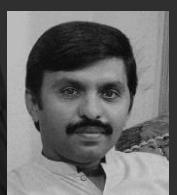
Future Work

- The preservation of the region's cultural heritage can benefit from the digital restoration of Bibi Jawindi's tomb.
- The AR application can serve as an educational tool for students and researchers interested in Islamic art and architecture.
- The digital restoration of the tomb may draw additional visitors to the area. The AR app can improve the overall visitor experience and raise interest in the regional cultural assets.
- Using the digital reconstruction, historians and archaeologists can examine the tomb's historical setting. Researchers can learn more about the cultural and historical significance of the tomb and its function in the local community.
- The digital reconstruction project has the potential to bring together academics from various fields, including historians, architects, and artists, to work together and advance the AR application.
- Gateway towards Holograms, Mixed Reality, and 3d Para;;ex.
- A Global Cloud documentations platform can be generated.

Acknowledgements

The author expresses gratitude to the advisor, Dr. Munazzah Akhtar, the committee members, colleagues, friends, parents, and organizations for their invaluable support, guidance, and encouragement throughout their academic journey, as well as for the data and resources provided.

“People who helped me throughout my experimentation process”



Questions ?

**“Just as bricks build walls, augmented reality constructs
immersive experiences, brick by digital brick”**

Thank You

for being such an attentive and wonderful audience.