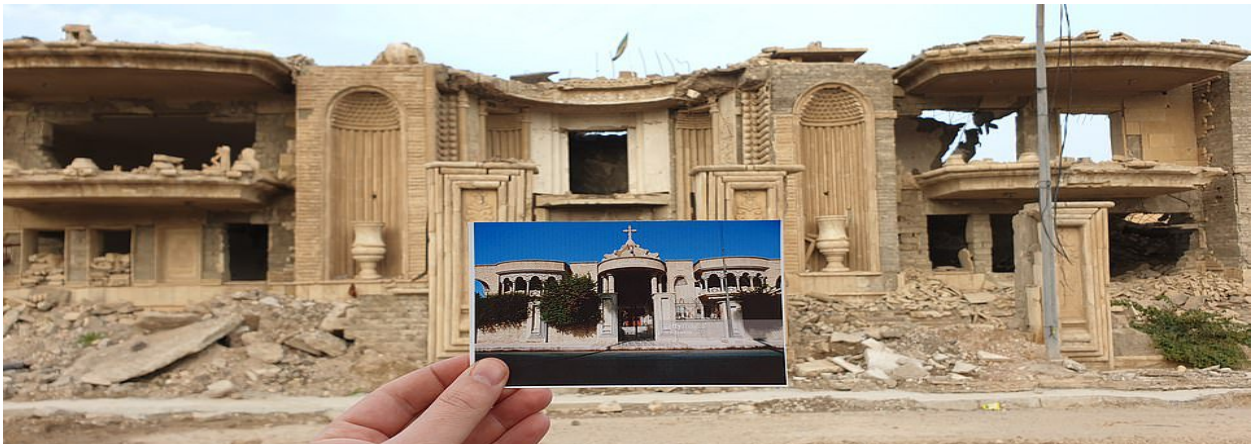
Preserving History in Pixels: The Power of 3D Imaging for Art & Culture

Cultural heritage is the story of human civilization. It is embodied in ancient monuments, priceless artifacts, and historic sites that tell tales of bygone eras. Yet, these treasures face threats ranging from natural disasters and environmental degradation to human conflict and neglect. Today, technology is stepping in to safeguard our legacy. Among the most transformative technologies is 3D scanning , a method that digitally captures the geometry, texture, and detail of heritage assets with stunning precision. In this blog, we explore how 3D scanning is not only preserving our cultural heritage but also enabling its digital reconstruction and restoration.

The Urgency of Cultural Heritage Preservation

Across the globe, cultural artifacts and historic sites are at risk. Consider the devastation caused by conflicts or natural calamities: in places like Mosul, heritage sites have been damaged or lost forever.

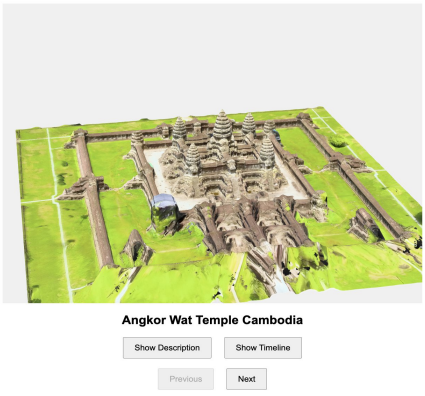


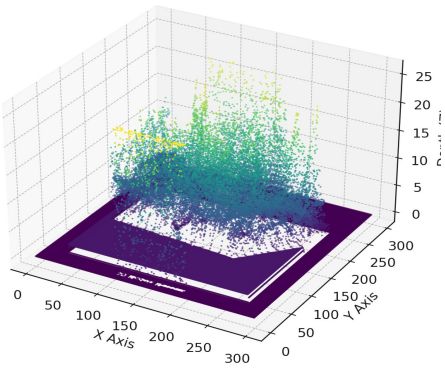
Preservation efforts have traditionally relied on photographs, manual measurements, and even plaster casts methods that can be invasive, time-consuming, and often incomplete. Digital preservation, by contrast, offers a non-contact, precise alternative. By creating a high-resolution digital replica of an object or site, experts can archive every detail, monitor degradation over time, and even use the data to guide physical reconstruction efforts.

The Role of 3D Scanning in Heritage Preservation

3D scanning technology has several key advantages:

- **Non-contact and Safe:** Using lasers or structured light, 3D scanners capture detailed geometry without touching the object. This is crucial when dealing with fragile artifacts.
- **High Resolution:** Modern scanners can record minute details—down to microns capturing not only the overall shape but also subtle textures and surface variations.
- **Digital Archiving:** The resulting digital models can be stored indefinitely, ensuring that even if the original is damaged, the digital surrogate remains available.
- **Facilitating Restoration and Reconstruction:** High-quality scans serve as precise blueprints. They can guide restorers in reconstructing damaged structures or producing exact replicas through 3D printing.





Our Project: A Pipeline for 3D Scan Analysis and Reconstruction

Journey: From Raw Data to Actionable Insights

In our project, we set out to develop a comprehensive pipeline for processing hundreds of 3D scanned models stored in a folder named **My3DModels**. The primary goal was to transform raw scan data into actionable insights that could guide restoration and reconstruction efforts for fragile cultural artifacts and historical sites.

1. Metadata Extraction and Analysis

Our first step was to build an automated process to extract key metadata from each 3D model. Using advanced tools, we captured critical details such as:

- **Asset Information:** Version, generator details, and overall file properties.
- **Scene Complexity:** Counts of scenes, nodes, and meshes present in each model.
- **Material and Extension Data:** A list of extensions used, which can reveal the complexity of the scan and any additional processing (such as compression or advanced shading) applied during the digital capture.

This metadata provided us with a quantitative basis to compare the quality and level of detail across the entire collection of scans. For example, models with higher numbers of meshes and nodes generally indicated a more detailed capture essential for accurate digital reconstruction and restoration.

Final 3D Model Metadata Report

This report summarizes key metrics and quality assessments for the 3D models in the My3DModels folder.

Summary Statistics

	Filename	Asset Version	Asset Generator	Number of Scenes	Number of Nodes	Number of Meshes	Number of Materials	Number of Animations	Number of Textures	Number of Images	Number of Buffers	Extensions Used	Extensions Required	Count_Extensions_Used	Cluster	PCA1	PCA2	Quality Score	Quality Score Normalized	V
count	205	205	205	205.0	205.000000	205.000000	205.000000	205.000000	205.000000	205.000000	205.0	205	205	205.000000	205.000000	2.050000e+02	2.050000e+02	205.000000	205.000000	0.
unique	205	1	30	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	4	2	NaN	NaN	NaN	NaN	NaN	NaN	N
top	The_Morning_Room.glb	2.0	pygltflib@v1.16.3	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	[]	[]	NaN	NaN	NaN	NaN	NaN	NaN	N
freq	1	205	130	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	179	203	NaN	NaN	NaN	NaN	NaN	NaN	N
mean	NaN	NaN	NaN	1.0	46.497561	23.046780	3.785366	0.029268	4.707317	4.707317	1.0	NaN	NaN	0.126829	0.282927	-5.199093e-17	-2.166289e-17	67.273171	0.025587	N
std	NaN	NaN	NaN	0.0	145.328833	64.788476	11.181777	0.219451	11.811518	11.811518	0.0	NaN	NaN	0.333596	0.677330	1.861671e+00	1.217472e+00	209.171243	0.081996	N
min	NaN	NaN	NaN	1.0	3.000000	1.000000	1.000000	0.000000	0.000000	0.000000	1.0	NaN	NaN	0.000000	0.000000	-7.944668e-01	-4.045672e+00	2.000000	0.000000	N
25%	NaN	NaN	NaN	1.0	10.000000	3.000000	1.000000	0.000000	1.000000	1.000000	1.0	NaN	NaN	0.000000	0.000000	-5.726539e-01	-2.045915e-01	12.000000	0.003920	N
50%	NaN	NaN	NaN	1.0	18.000000	9.000000	1.000000	0.000000	1.000000	1.000000	1.0	NaN	NaN	0.000000	0.000000	-4.436237e-01	-6.133375e-02	25.000000	0.009016	N
75%	NaN	NaN	NaN	1.0	38.000000	19.000000	2.000000	0.000000	4.000000	4.000000	1.0	NaN	NaN	0.000000	0.000000	-2.621631e-01	1.305822e-01	52.000000	0.019600	N
max	NaN	NaN	NaN	1.0	1741.000000	812.000000	100.000000	2.000000	98.000000	98.000000	1.0	NaN	NaN	1.000000	2.000000	1.460168e+01	1.431422e+01	2553.000000	1.000000	N

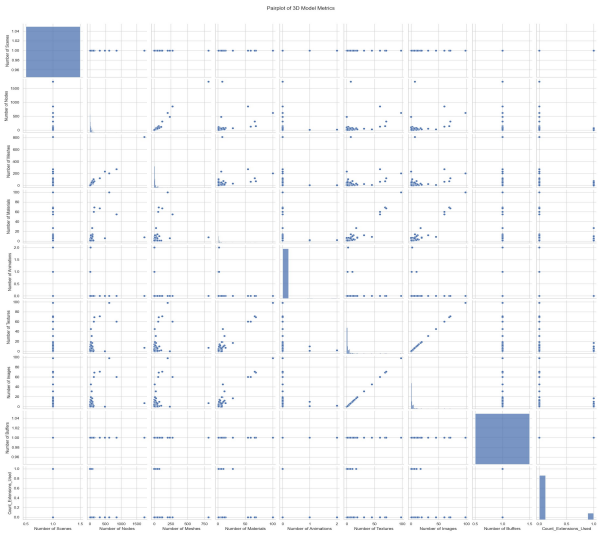
Detailed Model Data

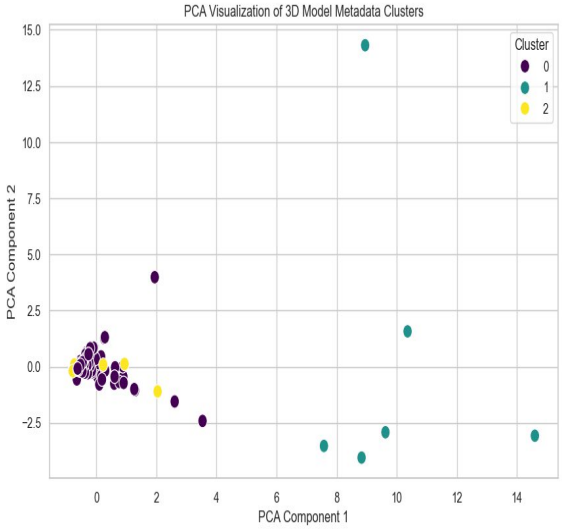
Filename	Asset Version	Asset Generator	Number of Scenes	Number of Nodes	Number of Meshes	Number of Materials	Number of Animations	Number of Textures	Number of Images	Number of Buffers	Extensions Used	Extensions Required	Count_Extensions_Used	Cluster	PCA1	PCA2	Quality Score	Quality Score Normalized
The_Morning_Room.glb	2.0	pygltflib@v1.16.3	1	30	13	1	0	1	1	1	[]	[]	0	0	-0.529978	0.112773	43.0	0.016372
angkor_wat_temple_cambodia.glb	2.0	Sketchfab-12.68.0	1	27	23	1	0	1	1	1	[]	[]	0	0	-0.465713	0.199260	50.0	0.018816
terracotta_warrior.glb	2.0	Sketchfab-13.93.0	1	11	7	1	0	3	3	1	[]	[]	0	0	-0.422523	-0.126692	18.0	0.006272
parthenon_-_acropolis_athens_greece.glb	2.0	Sketchfab-12.68.0	1	13	8	2	0	2	2	1	[]	[]	0	0	-0.451730	-0.079912	21.0	0.007448
Cathedral.glb	2.0	pygltflib@v1.16.3	1	70	33	2	0	4	4	1	[]	[]	0	0	-0.003810	0.286469	103.0	0.038592
14th_century_great_wall.glb	2.0	Sketchfab-12.65.0	1	16	12	1	0	1	1	1	[KHR_materials_unlit]	[]	1	2	-0.703115	-0.042150	14.0	0.004704
Church_of_St.glb	2.0	pygltflib@v1.16.3	1	38	17	1	0	1	1	1	[]	[]	0	0	-0.468194	0.184009	55.0	0.020776
Apollo_Belvedere.glb	2.0	pygltflib@v1.16.3	1	6	1	1	0	5	5	1	[]	[]	0	0	-0.298429	-0.310390	7.0	0.001960
Rick_Roll_Bridge.glb	2.0	pygltflib@v1.16.3	1	44	20	1	0	1	1	1	[]	[]	0	0	-0.436856	0.237436	64.0	0.024304
Coptic_prayer_book.glb	2.0	pygltflib@v1.16.3	1	10	2	1	0	4	4	1	[]	[]	0	0	-0.366974	-0.232244	12.0	0.003920
westminster_abbey.glb	2.0	Sketchfab-15.24.0	1	19	15	3	0	3	3	1	[KHR_materials_unlit]	[]	1	2	-0.422033	-0.152194	17.0	0.005880
Vendetta_Mask.glb	2.0	pygltflib@v1.16.3	1	21	8	1	0	0	0	1	[]	[]	0	0	-0.643616	0.090072	29.0	0.010584
Helmet_with_Beaked_Visor.glb	2.0	pygltflib@v1.16.3	1	26	11	1	0	1	1	1	[]	[]	0	0	-0.530870	0.077155	37.0	0.013720
chichen_itza_pyramid_3d_reconstruction.glb	2.0	Sketchfab-12.68.0	1	4	1	1	0	1	1	1	[KHR_materials_unlit]	[]	1	2	-0.791850	-0.198222	2.5	0.000196
Harlech_Castle_Wales_-_UNESCO_World_Heritage.glb	2.0	pygltflib@v1.16.3	1	10	2	1	0	1	1	1	[]	[]	0	0	-0.819650	-0.075160	12.0	0.003920
Coelophysis.glb	2.0	pygltflib@v1.16.3	1	6	1	1	0	1	1	1	[]	[]	0	0	-0.835330	-0.100934	7.0	0.001960
Gurley_Burt_Solar_Transit_-_Circa_1907.glb	2.0	pygltflib@v1.16.3	1	17	4	3	0	14	14	1	[]	[]	0	0	0.593169	-0.755091	21.0	0.007448
Mexico_City_Metropolitan_Cathedral.glb	2.0	pygltflib@v1.16.3	1	62	29	4	0	4	4	1	[]	[]	0	0	0.043552	0.170433	91.0	0.034888
ruin_on_top_of_meteora.glb	2.0	Sketchfab-12.68.0	1	14	12	1	0	2	2	1	[]	[]	0	0	-0.472839	-0.013155	26.0	0.009408
Hintze_Hall.glb	2.0	pygltflib@v1.16.3	1	92	44	3	0	4	4	1	[]	[]	0	0	0.155869	0.460967	136.0	0.052528
Marly_-_Louvre_Museum_Low_Definition.glb	2.0	pygltflib@v1.16.3	1	11	3	1	0	1	1	1	[]	[]	0	0	-0.811621	-0.061334	14.0	0.004704
Protoceratops_andrewsi_NHMW-GEO_20150404001.glb	2.0	pygltflib@v1.16.3	1	28	12	2	0	2	2	1	[]	[]	0	0	-0.391626	0.019203	40.0	0.014896
Ship_in_a_bottle.glb	2.0	pygltflib@v1.16.3	1	28	8	8	0	19	19	1	[]	[]	0	0	1.286794	-1.050713	36.0	0.013328
The_Armoury.glb	2.0	pygltflib@v1.16.3	1	34	15	1	0	1	1	1	[]	[]	0	0	-0.489086	0.146391	49.0	0.018424
excavation_of_the_medina_calatrava_la_vieja.glb	2.0	Sketchfab-16.59.0	1	56	54	1	0	1	1	1	[]	[]	0	0	-0.228253	0.619909	110.0	0.042336
neuschwanstein_castle_bavaria_germany.glb	2.0	Sketchfab-12.66.0	1	73	69	1	0	1	1	1	[]	[]	0	0	-0.105586	0.835288	142.0	0.054880
The_Rosetta_Stone.glb	2.0	pygltflib@v1.16.3	1	16	6	1	0	1	1	1	[]	[]	0	0	-0.583100	-0.011890	22.0	0.007840
sydney_opera_house_sydney_australia.glb	2.0	Sketchfab-14.96.0	1	54	50	1	0	1	1	1	[KHR_materials_specular]	[]	1	2	-0.405620	0.483247	52.0	0.019600
School_Anime.glb	2.0	pygltflib@v1.16.3	1	32	14	6	0	5	5	1	[]	[]	0	0	0.060233	-0.195863	46.0	0.017248
Estances_de_la_Casa_Gassia.glb	2.0	pygltflib@v1.16.3	1	38	17	1	0	1	1	1	[]	[]	0	0	-0.468194	0.184009	55.0	0.020776
notre_dame_cathedral__work_in_progress.glb	2.0	Sketchfab-12.66.0	1	4	2	1	0	1	1	1	[KHR_materials_unlit]	[]	1	2	-0.786638	-0.188378	3.0	0.000392
Sculpture_Bust_of_Ridzs_Loewenfeld.glb	2.0	pygltflib@v1.16.3	1	7	1	1	0	2	2	1	[]	[]	0	0	-0.549487	-0.149313	8.0	0.002352
St_Pancras_New_Church_Crypt.glb	2.0	pygltflib@v1.16.3	1	44	20	1	0	1	1	1	[]	[]	0	0	-0.436856	0.237436	64.0	0.024304
model_of_pompeii_in_naples_archaeological_museum.glb	2.0	Sketchfab-15.1.0	1	40	38	2	0	2	2	1	[KHR_materials_unlit]	[]	1	2	-0.376002	0.233605	39.0	0.014504
Granite_head_of_Amenemhat_III.glb	2.0	pygltflib@v1.16.3	1	12	4	2	0	8	8	1	[]	[]	0	0	0.032158	-0.437437	16.0	0.005488

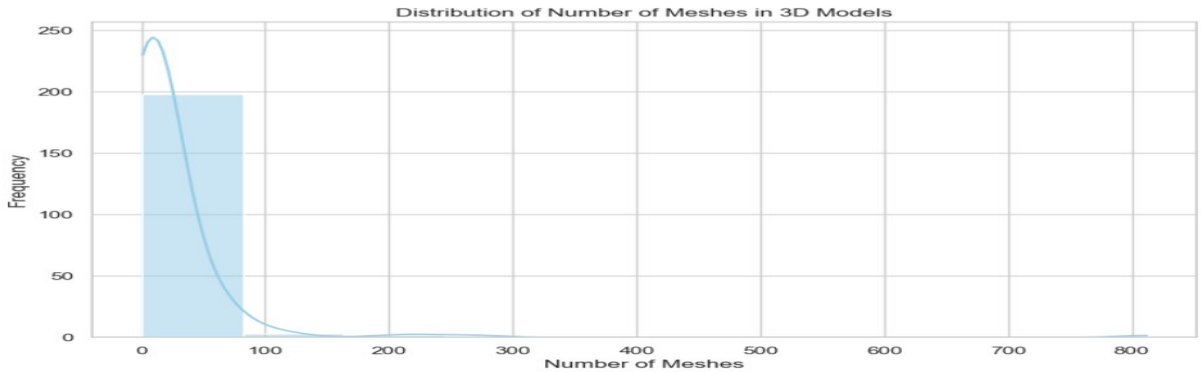
2. Clustering and Quality Scoring

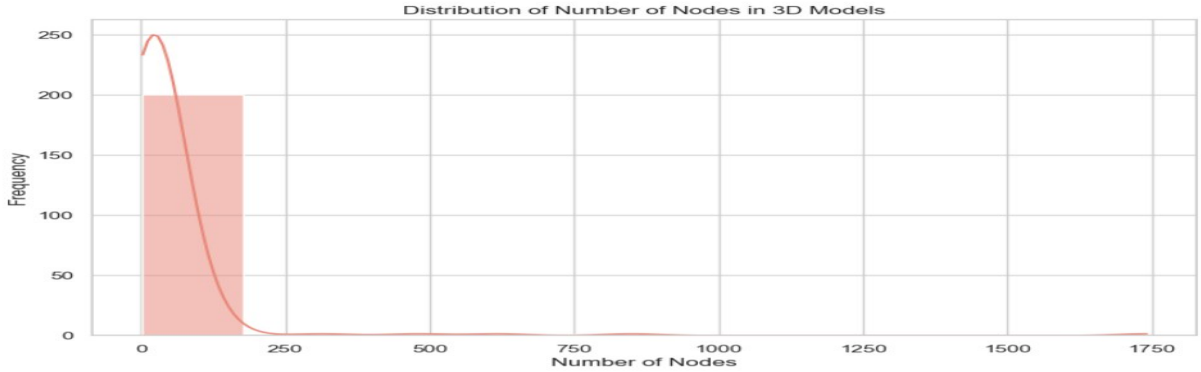
To further our analysis, we developed a quality metric by combining several metadata features. This “quality score” was designed to indicate the level of detail in a scan while accounting for any additional processing complexity. By normalizing this score, we were able to rank our models on a scale from 0 to 1, with higher scores suggesting higher-quality scans.

Through clustering techniques, we identified groups of models that shared similar characteristics. This analysis enabled us to quickly pinpoint which models were ideal candidates for reconstruction or further preservation work. In practical terms, this means that heritage experts can now prioritize those scans that capture the finest details of an artifact or historical site.







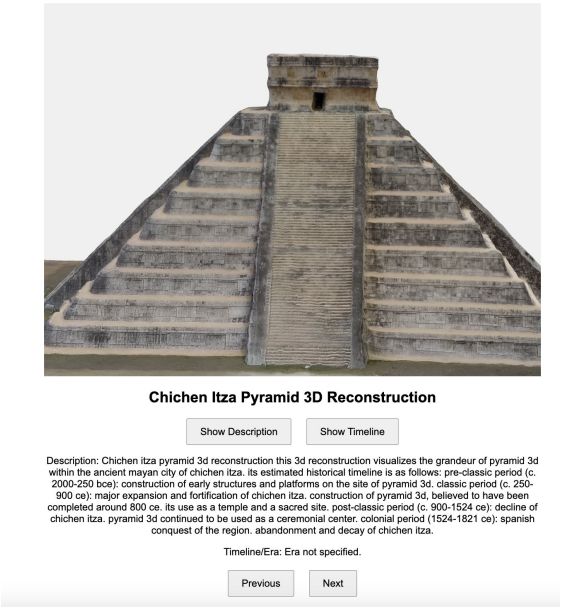


3. Interactive Visualization and Dashboard

One of the most exciting outcomes of our project was the development of an interactive dashboard. This dashboard served several critical functions:

- **Filtering and Comparison:** Users could adjust a slider to filter models based on their normalized quality score. This interactive filtering allowed us to quickly identify the best candidates among dozens of models.
- **Detailed Metadata View:** With a few clicks, users could view the full metadata of each model—revealing insights into the number of meshes, nodes, and any advanced scanning techniques applied.
- **3D Model Viewing:** An integrated 3D viewer enabled real-time, interactive exploration of each model. By rotating, zooming, and inspecting the digital scans, experts and enthusiasts alike could closely examine the fine details of historical artifacts without any physical risk to the originals.

This combination of interactive filtering and 3D visualization bridges the gap between raw data and practical application, making the digital documentation of cultural heritage not only more accessible but also more actionable.



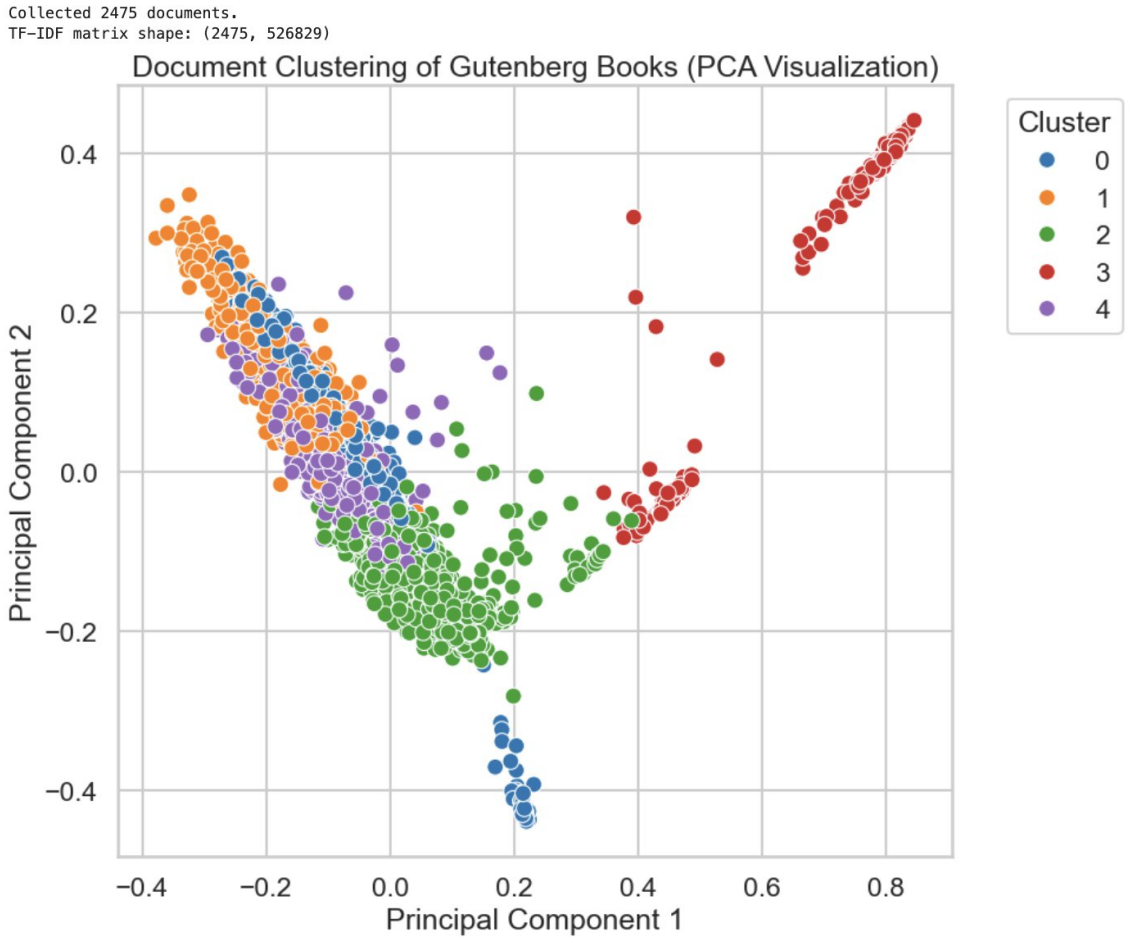
4. Prototyping a Reconstruction Pipeline

Understanding that the ultimate goal of digital preservation is to support physical restoration and reconstruction, we prototype a preliminary reconstruction pipeline. This pipeline focuses on:

- **Pre-Processing:** Assessing each model's quality (such as vertex count and overall detail) to determine whether it meets the necessary threshold for reconstruction.
- **Exporting for Reconstruction:** Converting high-quality scans into widely used formats (for example, OBJ files) that can be seamlessly imported into reconstruction software or 3D printing workflows.

- **Guiding Restoration Efforts:** Providing detailed digital blueprints that restoration experts can use to plan and execute physical reconstructions, ensuring that every intricate detail is faithfully reproduced.

These can be expanded to include books and historical literature which we can classify and cluster based on the context they share.



The Impact on Cultural Heritage Preservation

Our project is more than a technical exercise it represents a paradigm shift in how we preserve and interact with cultural heritage. High-quality 3D scans not only create digital archives that serve as permanent records of our past but also empower restoration and reconstruction efforts. By combining rigorous data analysis with interactive visualization, we can better understand which scans capture the essence of an artifact and ensure that the most detailed, faithful digital replicas guide our restoration projects.

Our work builds on the foundations that by integrating quantitative quality assessments, interactive dashboards, and prototype reconstruction pipelines into a comprehensive digital preservation framework we can actually preserve our history.

Conclusion

In an era where our cultural heritage faces unprecedented challenges, 3D scanning offers a lifeline capturing every detail of our history with precision and care. Our project illustrates a complete workflow: from extracting and analyzing metadata to filtering for quality, preparing models for reconstruction, and envisioning immersive digital experiences. This work not only safeguards our past but also paves the way for innovative restoration and educational opportunities in the future.

By harnessing the power of modern 3D scanning and digital reconstruction, we can ensure that the rich legacy of our cultural heritage endures for generations to come.