

Digital Twin Technology for Circular Heritage Restoration: Kremna Propylon

CA23117 - CIRCUL'ARTs

WG4 - Innovation through creative and circular technologies

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Kremna

Kremna is an ancient city in Turkey.
Its name comes from the Greek word for "cliff."

This name is perfect because the city is built at 1,200 meters above sea level on a very steep mountain.

It has a famous **Propylon** (a monumental gate)

There are many ancient cisterns underground to hold water.





Problem

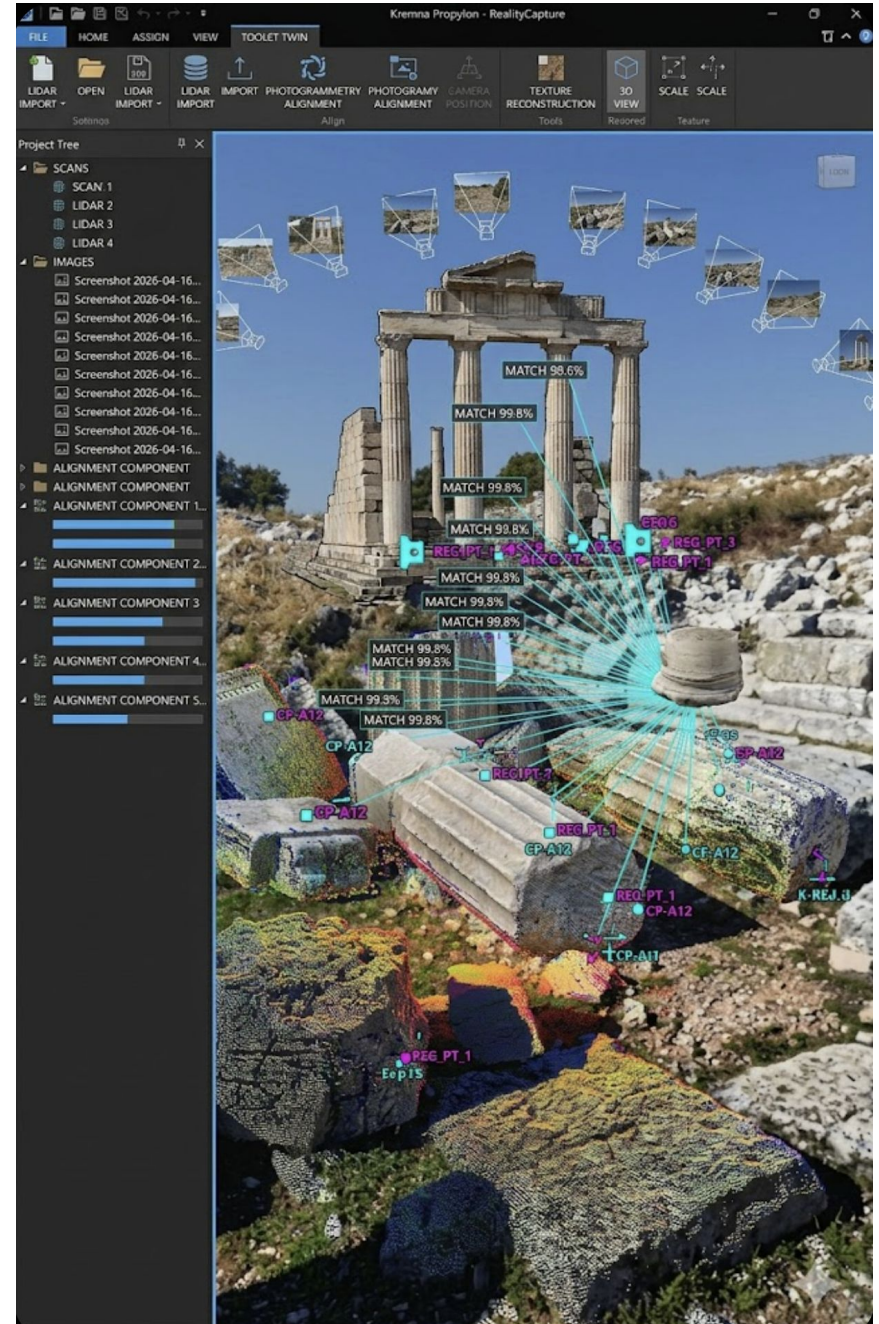
- **Difficult Terrain:** Narrow, steep paths make transporting heavy machinery (like large cranes) expensive.
- **Seasonal Limits:** Harsh weather conditions at high altitudes make on-site work impossible for several months of the year.
- **Structural Risk:** The presence of ancient cisterns directly beneath the Propylon area limits the weight and duration a crane can remain on-site.
- **Time & Labor:** Traditional restoration is time-consuming and labor-intensive.

Workflow

- **Data Acquisition (UAV + Sensors)**
- UAV (drone) surveys:
 - High-resolution imagery (for photogrammetry)
 - LiDAR scanning (for precise geometry)
- Ground Control Points (GCPs) for millimeter accuracy

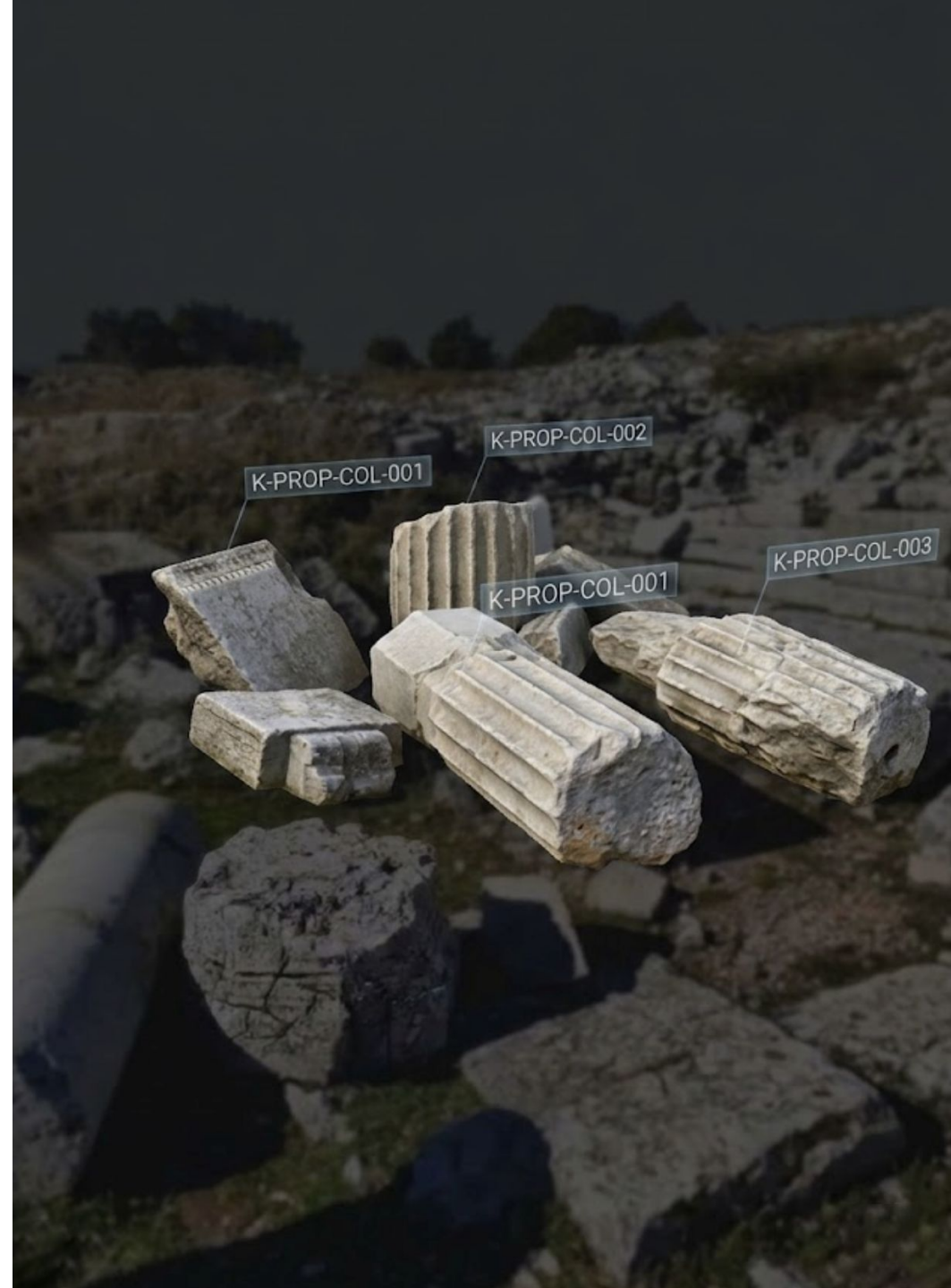
Workflow

- **Data Processing**
- **Photogrammetry:**
 - Dense point cloud generation
 - Mesh (3D surface model)
- **LiDAR integration:**
 - Geometry validation
 - Filling missing data
- **Output:**
 - High-precision 3D site model



Workflow

- **Stone Segmentation & Identification**
- Each stone block:
 - Digitally segmented
 - Assigned a unique ID
- Feature extraction:
 - Dimensions
 - Surface characteristics
 - Fracture edges and connection clues

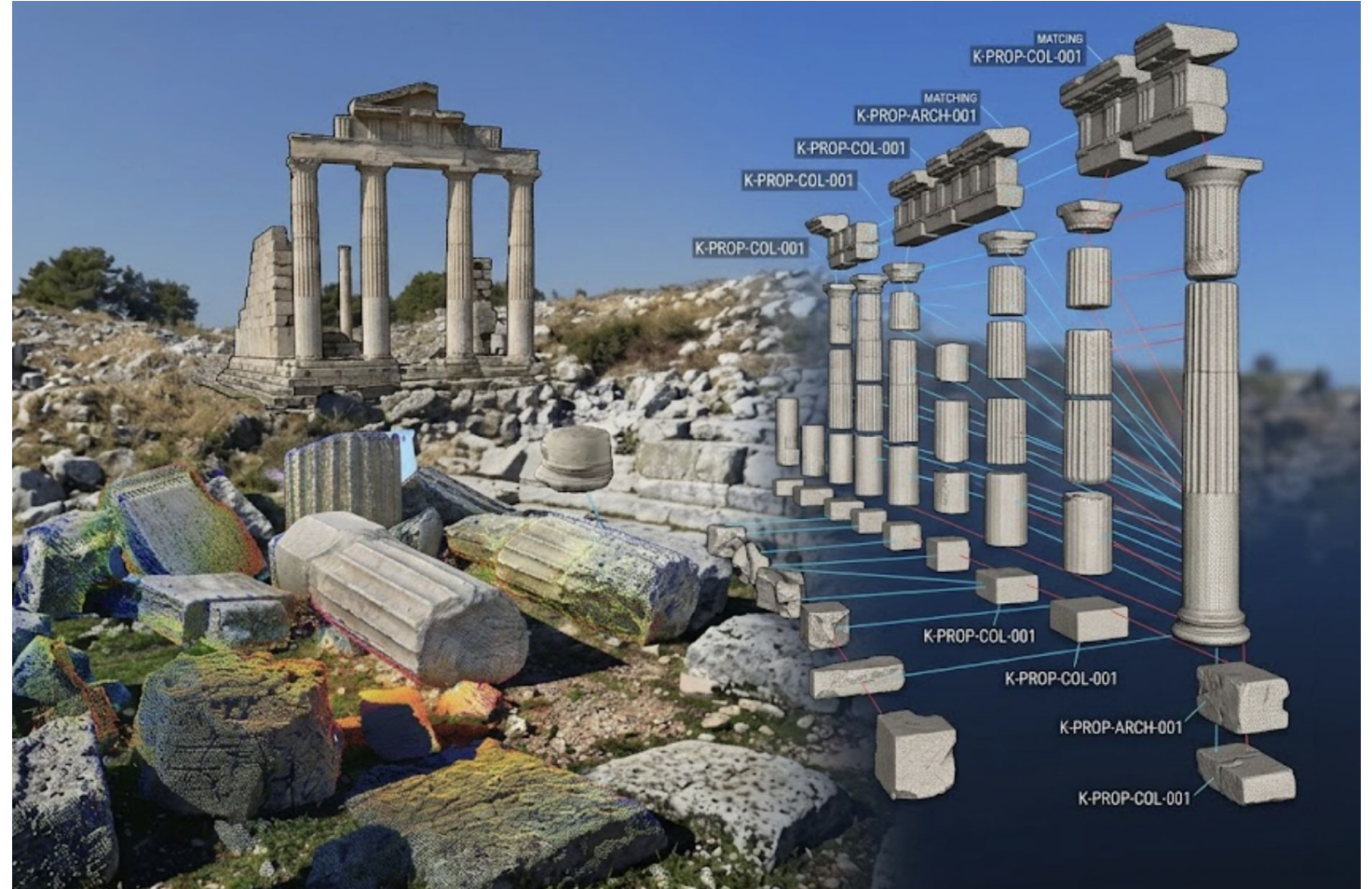


Workflow

The Virtual Assembly: Aligning column drums and architraves in a 3D environment .

Load Distribution: Simulating the structural integrity of the gate before a single stone is lifted.

Cistern Protection: Calculating the exact crane positions and movements to ensure the underground cisterns never reach a "critical load" point.



Economic & Safety Impact

- **Crane Time Reduction:** Instead of renting a crane for months for "trial and error," the crane is called only for the final, pre-planned assembly.
- **Cost Savings:** Significant reduction in daily rental fees and logistics.
- **Worker Safety:** Minimizing the time workers spend on high-risk cliff edges and under heavy suspended loads.

Conclusion & Future of Circular Heritage

- **Sustainable Restoration:** Utilizing 100% of original material by finding their place digitally.
- **Remote Collaboration:** Experts from around the world can assist in the restoration without needing to fly to the site.
- **Legacy:** The Digital Twin remains as a permanent record for future maintenance.

AI-Powered Pattern Recognition for Structural Matching

- **Pattern Recognition Algorithms:** Utilizing AI to analyze the unique fracture patterns, textures and mineral grains of every broken stone surface.
- **Geometric Matching:** AI can compare thousands of broken edges simultaneously to find the exact 3D match (Positive/Negative fit) with high probability.

AI-Powered Pattern Recognition for Structural Matching

- **Automated Classification:** AI automatically categorizes fragments as "Column Drum," "Architrave," or "Cornice" based on learned architectural features of the Roman period.
- **Error Elimination:** AI detects mismatches that are invisible to the human eye, preventing structural instability before the physical lifting begins.

Thank you for your attention!

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