

# Post-Disaster 3D Modeling of a Collapsed City: Citadel of Bam, Iran

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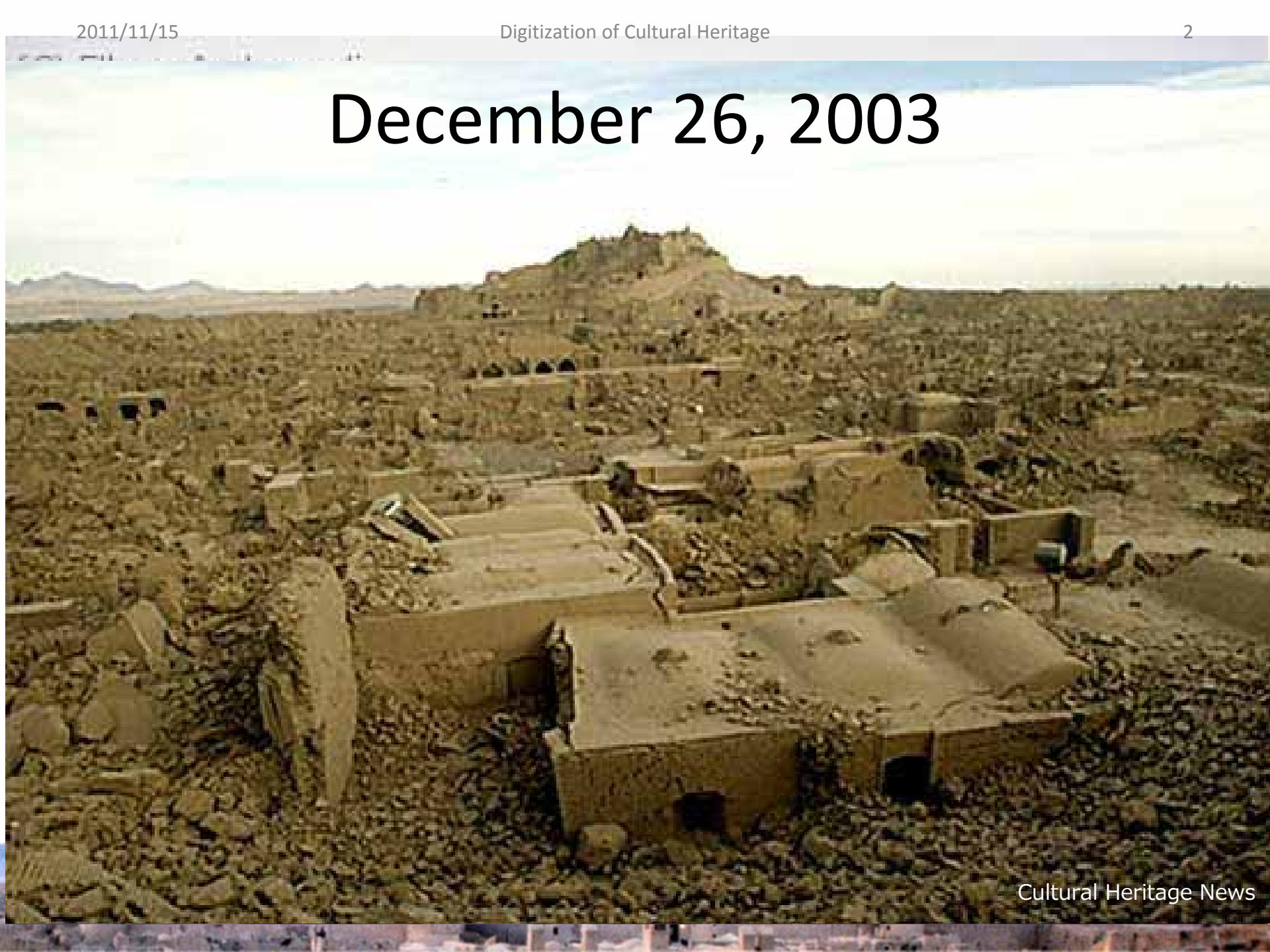
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<http://dsr.nii.ac.jp/bam/>



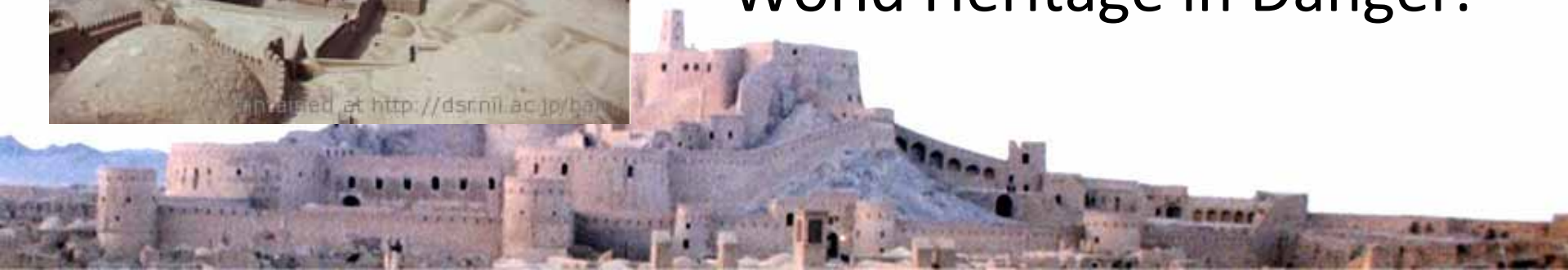
# December 26, 2003



# Citadel of Bam

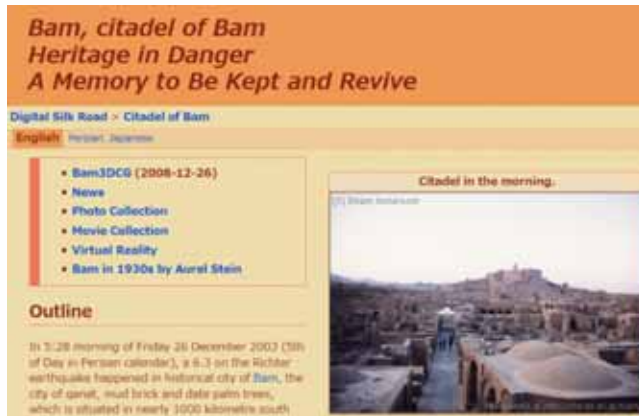


- One of the biggest mud brick complex in the world.
- Most of the citadel was collapsed by the quake.
- One year later, “Bam and its Cultural Landscape” was inscribed on the list of World Heritage in Danger.



# Project History

December 31, 2003



January 2004



April – June, 2006

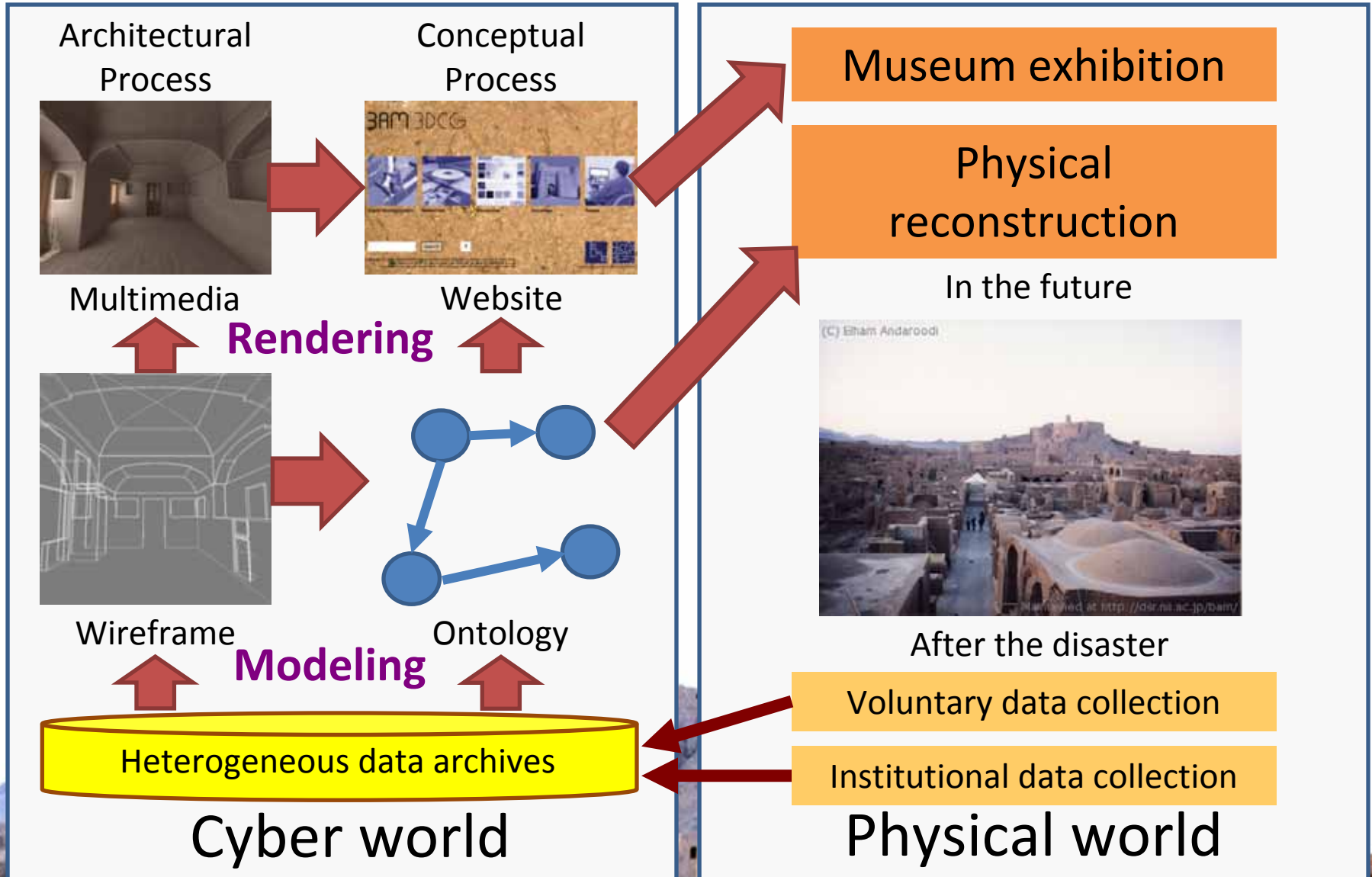


December 26, 2008



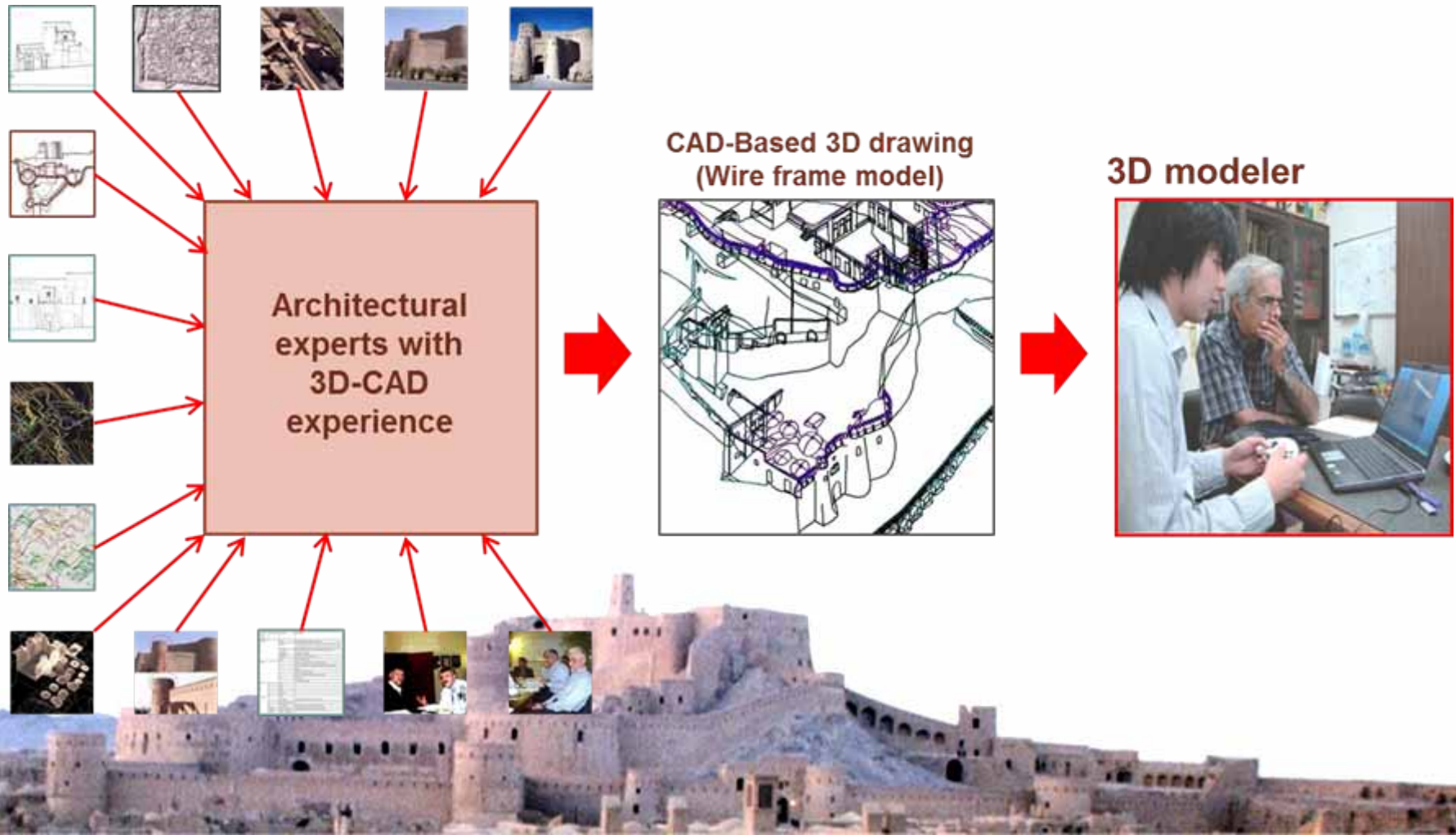


# Project Framework



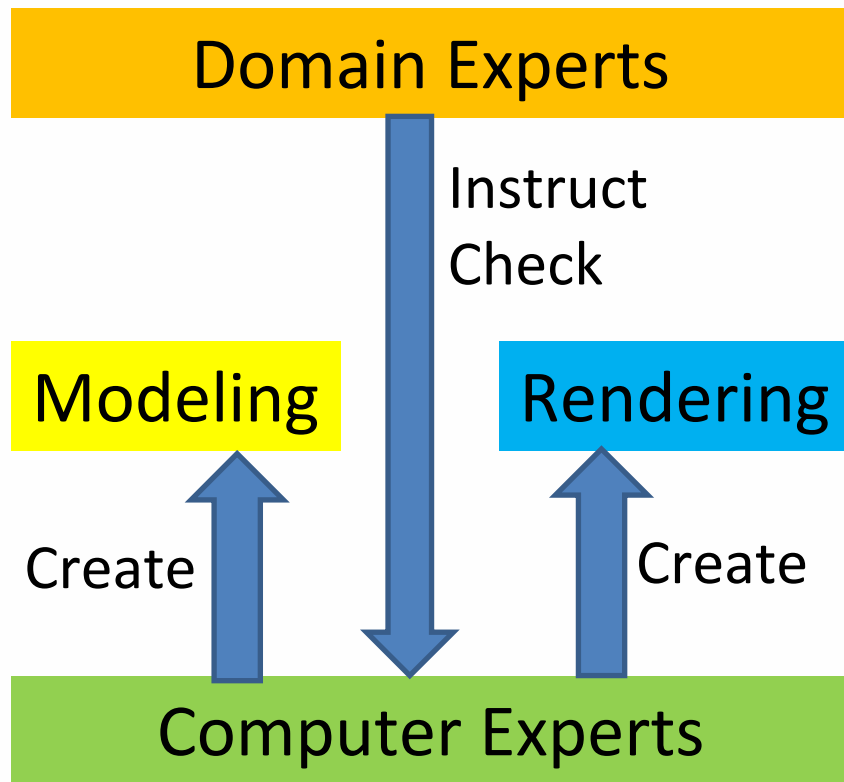
# Integration of Heterogeneous Data

**Estimating missing information is a critical problem!**

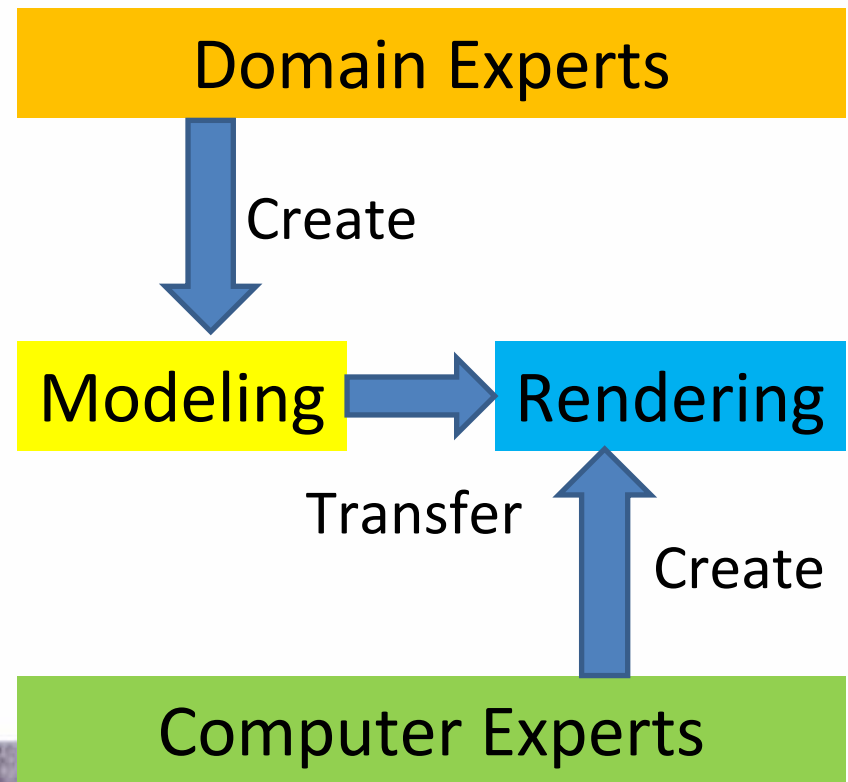


# Comparison of Workflow

## 1<sup>st</sup> Phase (bad)



## 2<sup>nd</sup> Phase (good)



# Architectural Modeling and Rendering

## Modeling

- Experts should model the structure.
- Model is created by a CAD tool (AutoCAD).
- The output is wireframe models.
- Accuracy is important.

## Rendering

- Experts should render the appearance.
- Model is rendered by a 3D CG tool (3ds max).
- The output is multimedia content.
- Appearance is important.



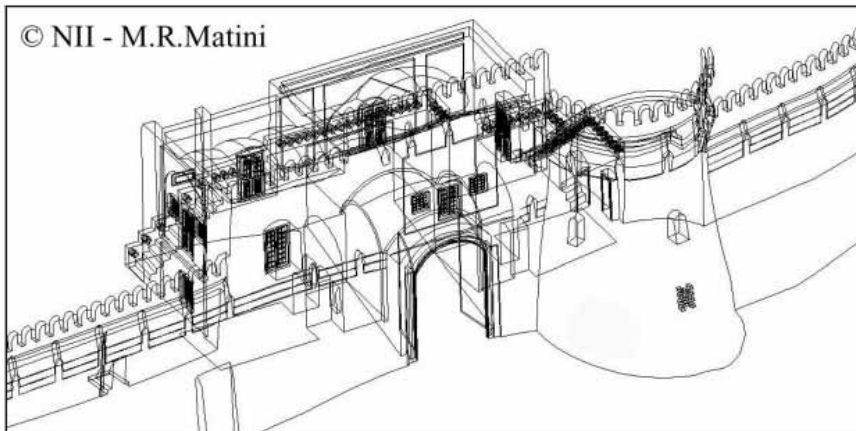


# Collaboration of Experts

- **Domain experts** (e.g. architects) focus on the accuracy of models.
- **Computer experts** (e.g. CG engineers) focus on the usefulness of systems and outputs.
- **Separation of modeling and rendering** is more efficient because of the division of roles.
- Similar to the separation of model / view in software engineering (modular design).



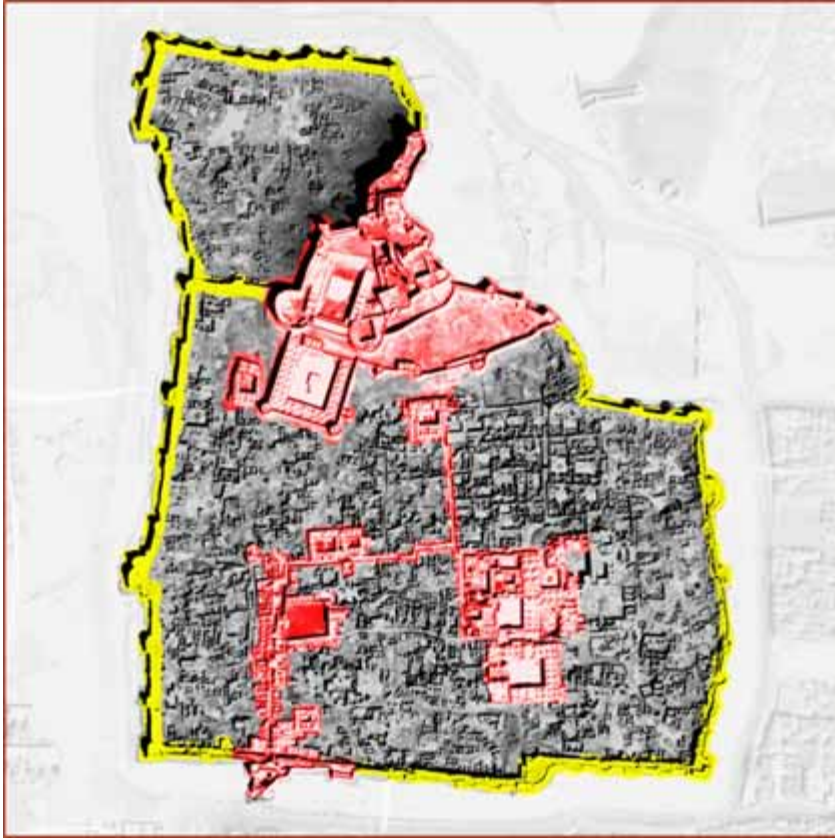
# Architectural Process



- A 3D model accurate enough for physical reconstruction.
- Accuracy includes appropriateness as Persian architecture.
- New data cannot be measured in a post-disaster reconstruction.



# Requirement of Accuracy

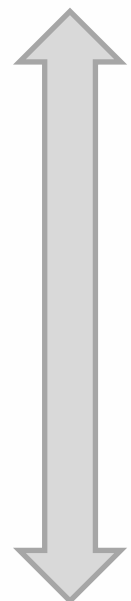


Original image: Digital Globe

- **High**
- **Moderate**
- **Low**

Accurate

Manual



Inaccurate Automatic

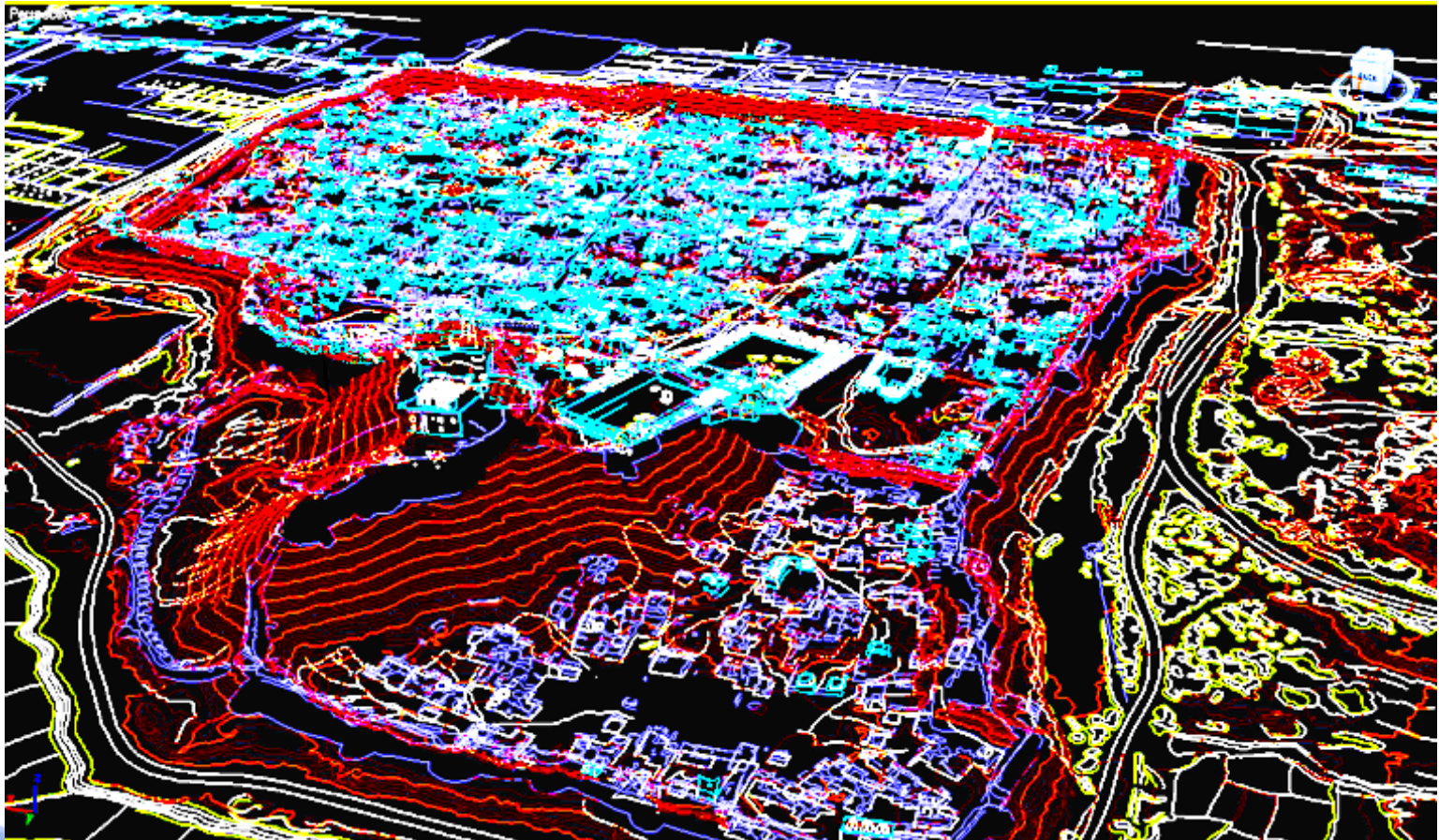
**Good balance between  
accuracy and cost**





# Photogrammetric Map

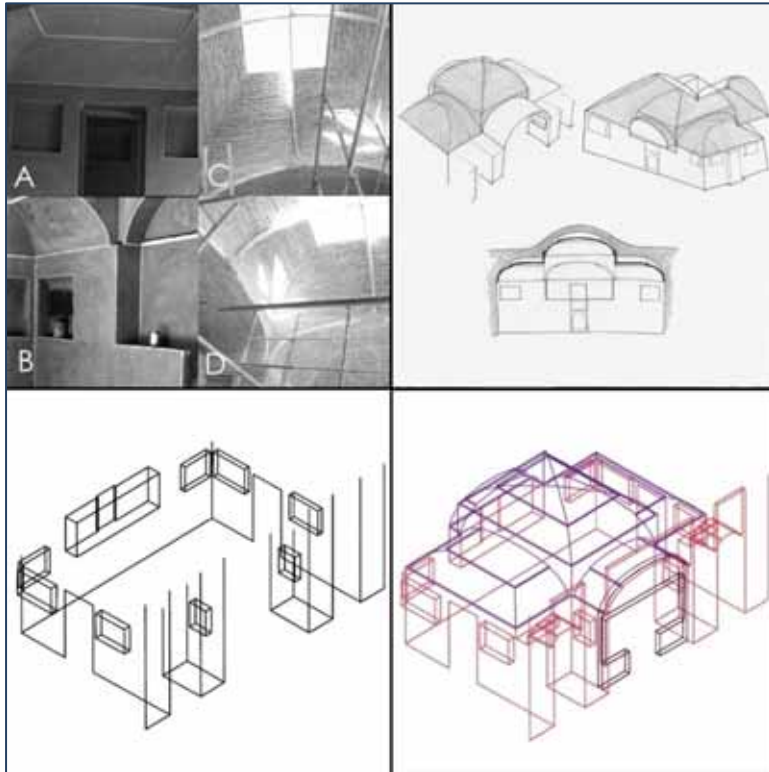
Rough reference of the shape and location.



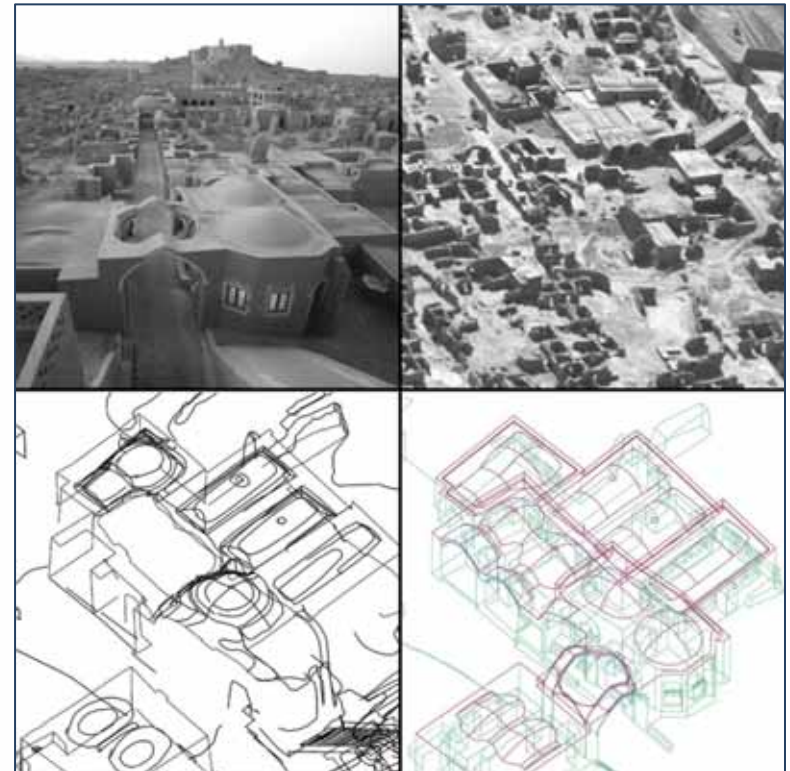
IFCA Project (By Prof. Adle), NCC, ICHHTO



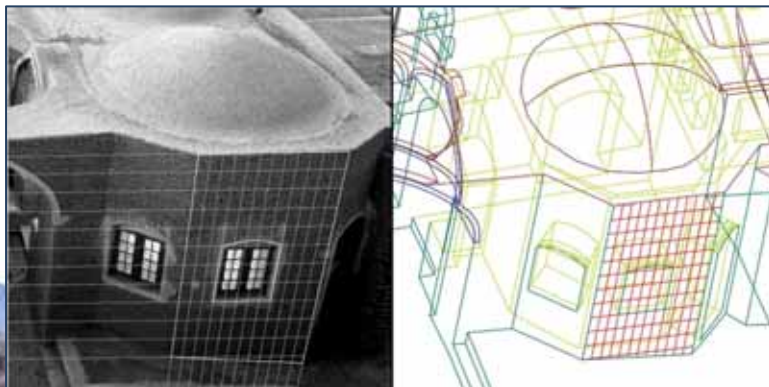
## 1. Geometrical modification



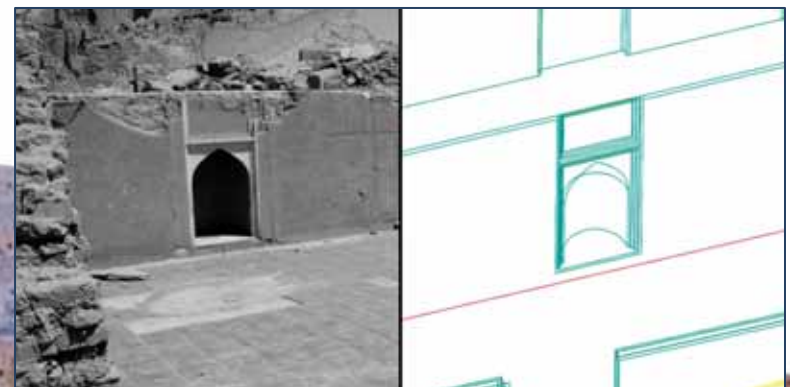
## 2. Structural modification



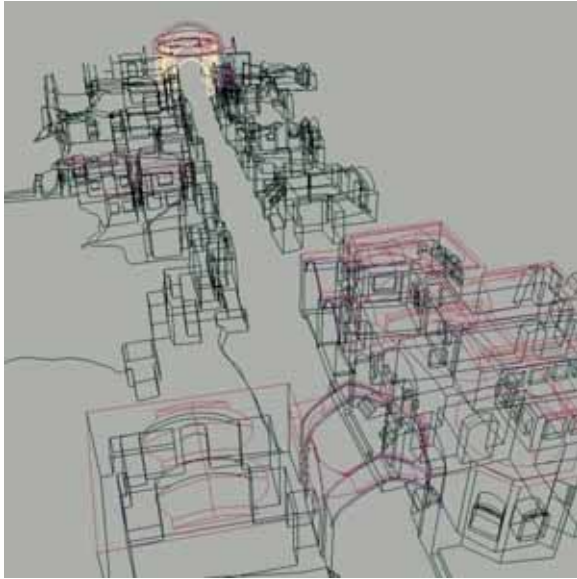
## 3. Proportional modification



## 4. Details

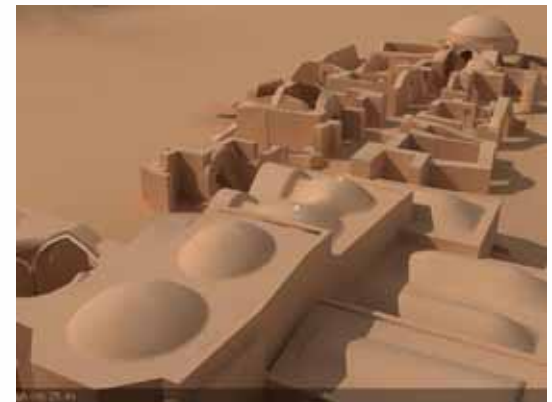
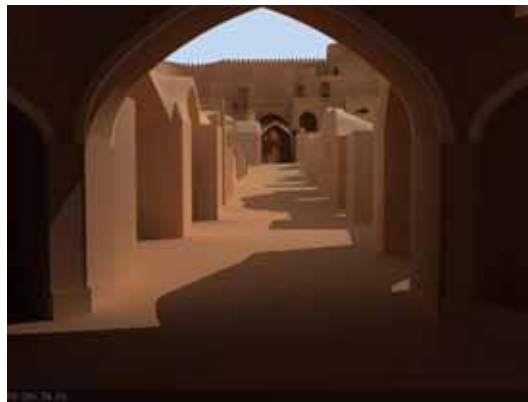
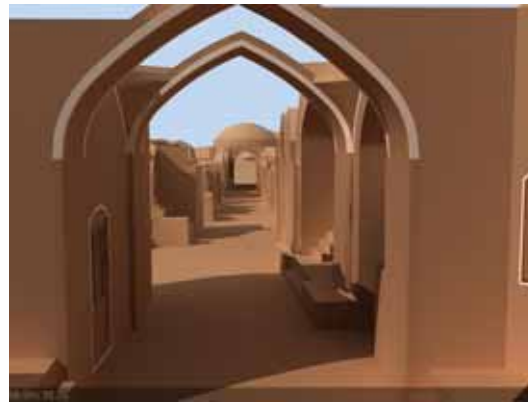


# Rendering of Exterior Space



CAD-based 3D drawing:  
Dr. M.R. Matini (NII)

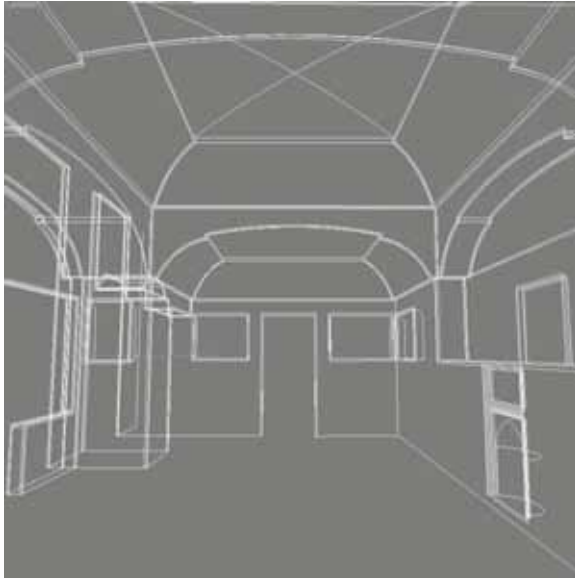
3D modelers:  
Global Information and Telecommunication  
Institute (GITI), Waseda University, Tokyo



one part of Bazaar



# Rendering of Interior Space



CAD-based 3D drawing:  
Dr. M.R. Matini (NII)

3D modelers:  
Raazahang, University of Tehran, Iran



one room of Sistani house

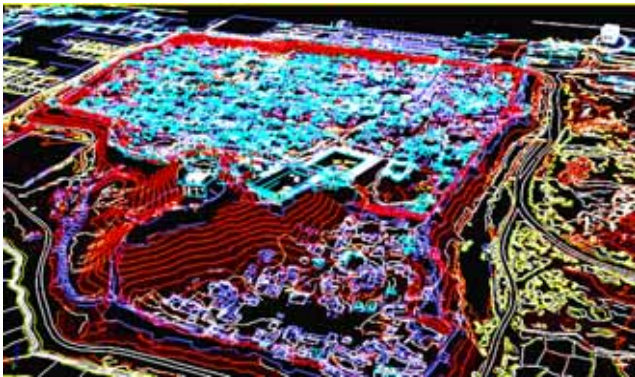




# Semi-Automatic Modeling

## Photogrammetric Map

IFCA Project (By Prof. Adle), NCC, ICHHTO



## Photographs

From experts and tourists



Overlay

Structure



Texture



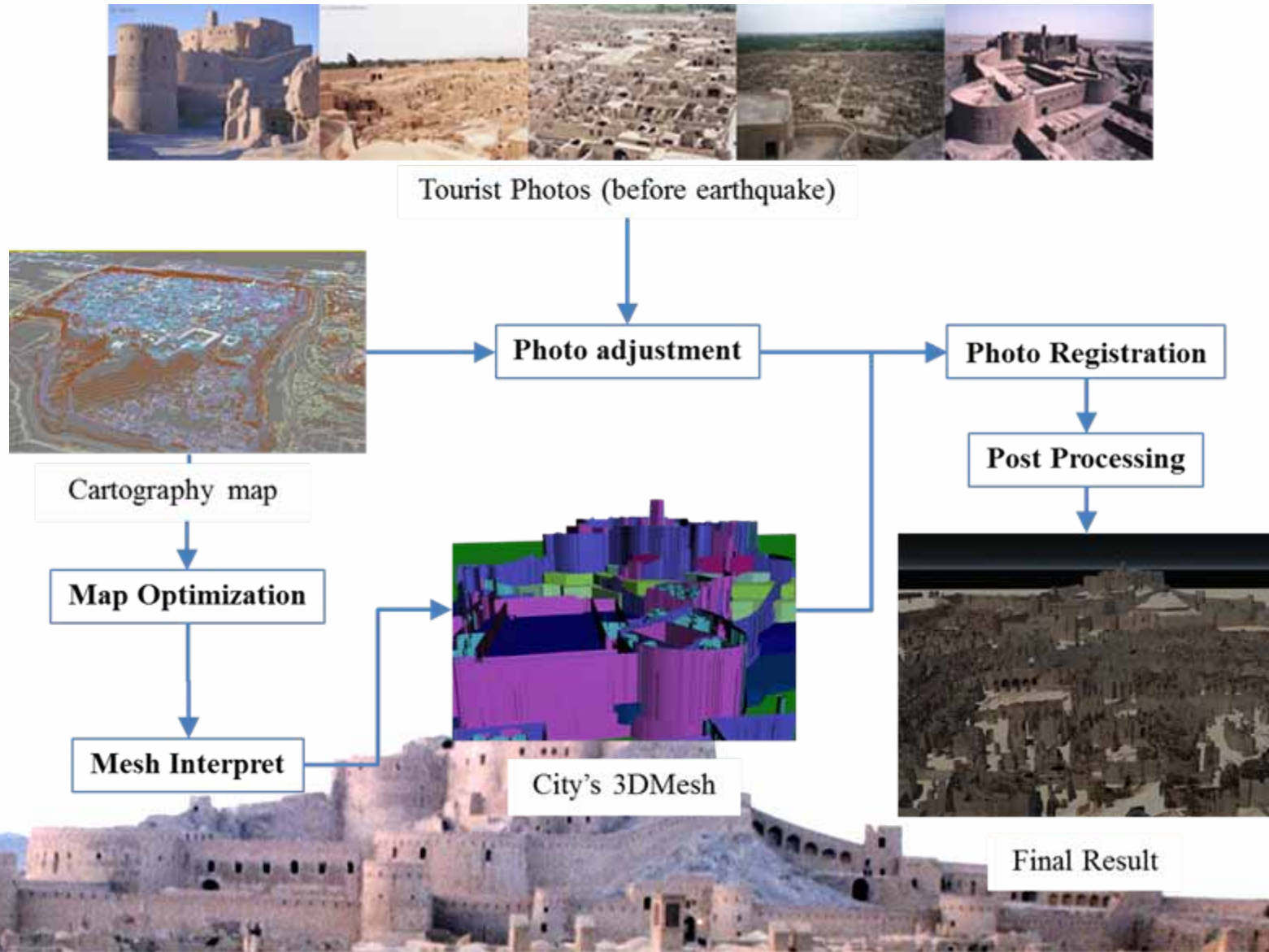
Simple 3D Model

Work by Mr. Natchapon Futragoon





# Workflow



# Automatic Modeling



Laser scanning

Image: Wikipedia



New data cannot be captured from now!



Structure from Motion

Image: Building Rome in a Day



# Multiple Images or Videos



Using point correspondences and projective geometry fails due to the lack of photographs, variety of cameras, and temporal change due to renovation.



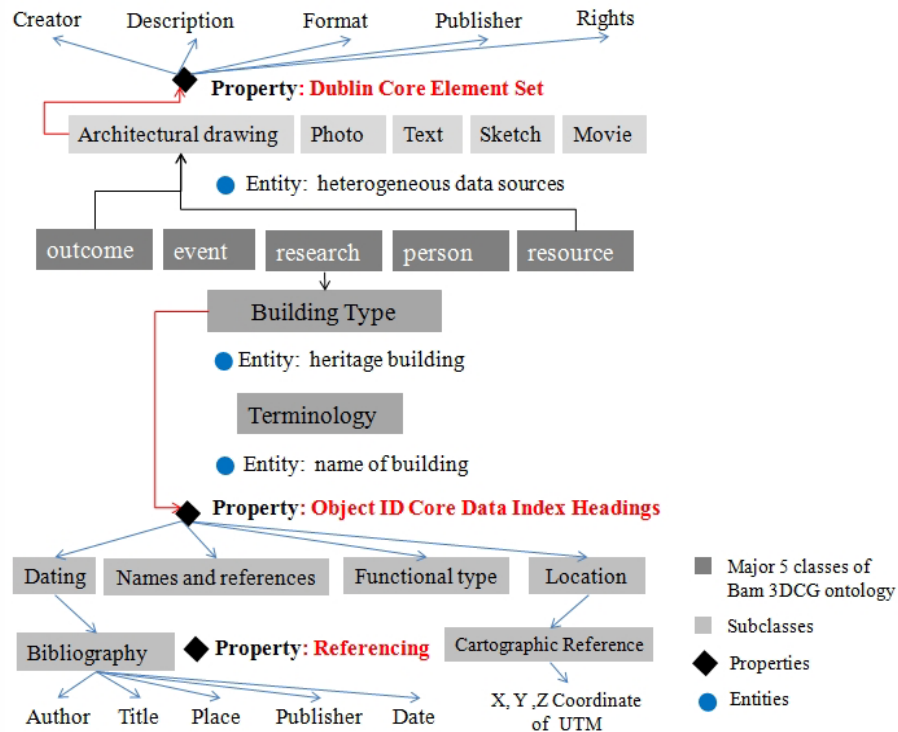
7-minute video taken from a helicopter by NHK in 1981 has potential for the automatic reconstruction of a 3D model, but not yet completed.



Work by Mr. Tiago da Silva



# Conceptual Process

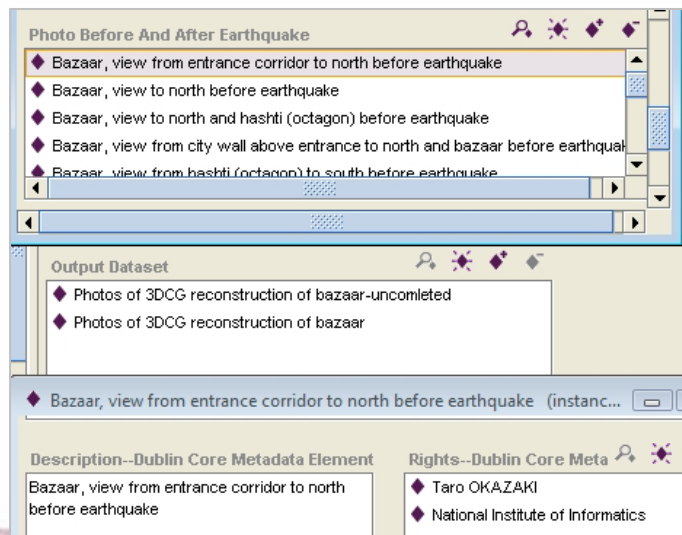
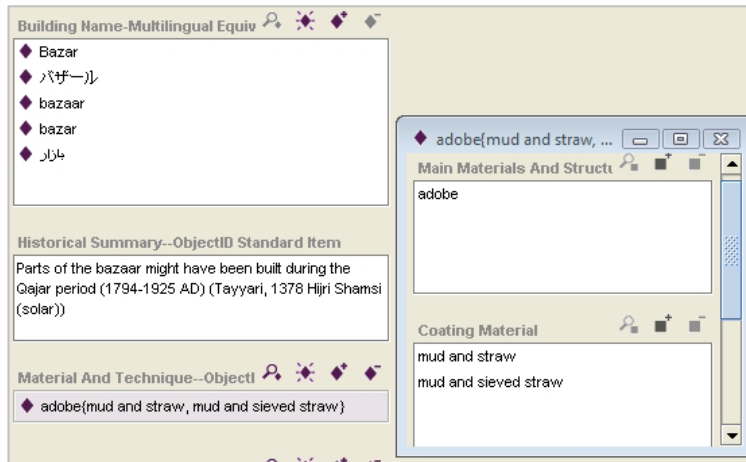


- 3D models represent the structure  $\Leftrightarrow$  **conceptual models represent the knowledge.**
- Two models are made separately, but could be linked in the future to realize the 3D semantic database of Bam.





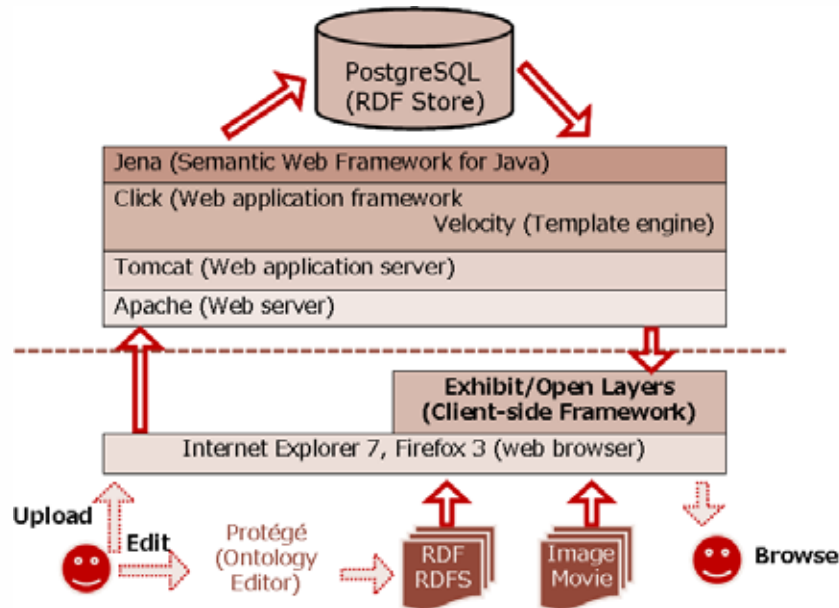
# Conceptual Modeling



- Conceptual modeling is about **representing relationship of concepts using ontology.**
- Multilingual ontology represents typology of buildings.
- Input and output data is annotated with concepts.



# Conceptual Rendering



- Conceptual rendering is about **storing and visualizing conceptual models**.
- Concepts are stored in RDF (Resource Description Framework)
- Website is automatically generated from RDF.

# Summary

- **Architectural modeling** produced a number of 3D models with enough accuracy for virtual and physical reconstruction of the Citadel of Bam.
- **Workflow for modeling and rendering** is crucial for the efficient generation of multimedia content.
- **Conceptual modeling** developed Bam3DCG ontology for representing many kinds of project-related data.
- **Conceptual rendering** developed automatic website generation system based on RDF.



# Future Work

- Semi-automatic modeling of remaining parts to make the 3D model of the whole city.
- Interactive rendering of 3D models through the Internet (Web) while protecting original 3D models from users.
- Linkage between architectural and conceptual models for the 3D semantic database of Bam.





# Last Words for March 11

- Cultural heritage was lost again on March 11.
- Post-disaster reconstruction start suddenly without preparation. How is it possible to be well-prepared for future disasters?
- **Short-term response** focuses on raising awareness and starting data collection activity.
- **Long-term response** focuses on reviving memories as the symbol of the community.



# Software

- Architectural Modeling
  - Computer-aided design (AutoCAD)
- Architectural Rendering
  - Computer graphics / virtual reality (3ds Max)
- Conceptual Modeling
  - Ontology editor (Protégé)
- Conceptual Rendering
  - Semantic Web framework (Jena)



# References

- Asanobu KITAMOTO, Elham ANDAROODI, Mohammad Reza MATINI, Kinji ONO, "Post-Disaster Reconstruction of Cultural Heritage: Citadel of Bam, Iran", Jinmonkon 2011, pp. (in press), 2011-12
- Elham ANDAROODI, Asanobu KITAMOTO, "Architectural Heritage Online: Ontology-Driven Website Generation for World Heritage Sites in Danger", Digital Heritage: Proceedings of Euromed 2010 (3rd International Euro-Mediterranean Conference), Lecture Notes in Computer Science (LNCS) 6436, M. Ioannides (Eds.), pp. 277-290, Springer-Verlag, doi:10.1007/978-3-642-16873-4, 2010-11 (Best Paper Award)
- Natchapon Futragoon, Asanobu KITAMOTO, Elham ANDAROODI, Mohammad Reza MATINI, Kinji ONO, "3D Reconstruction of a Collapsed Historical Site from Sparse Set of Photographs and Photogrammetric Map", ACCV Workshop on e-Heritage 2010, 2010-11
- Mohammad Reza MATINI, Alireza EINIFAR, Asanobu KITAMOTO, Kinji ONO, "Digital 3D Reconstruction Based on Analytic Interpretation of Relics; Case Study: Bam Citadel", Proceedings of the 22nd International Symposium on Digital Documentation, Interpretation & Presentation of Cultural Heritage (CIPA 2009), 2009-10
- Kinji ONO, Elham ANDAROODI, Alireza EINIFAR, Nobuaki ABE, Mohammad Reza MATINI, Olivier BOUET, Frank CHOPIN, Takashi KAWAI, Asanobu KITAMOTO, Asaka ITO, Eskandar MOKHTARI, Saeed EINIFAR, Seyyed Mohammad BEHESHTI, Chahryar ADLE, "3DCG Reconstitution and Virtual Reality of UNESCO World Heritage in Danger: the Citadel of Bam", Progress in Informatics, No. 5, pp. 99-136, 2008-03





# Acknowledgment

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- Digital Silk Road Project
  - <http://dsr.nii.ac.jp/>
- Bam Project
  - <http://dsr.nii.ac.jp/bam/>
- Bam3DCG
  - <http://dsr.nii.ac.jp/Bam3DCG/>

