

State of the Art and Challenges in Crowd Sourced Modeling

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Views of the world



- Street-side panoramas
- Photo-based exploration
- 3D Landmarks

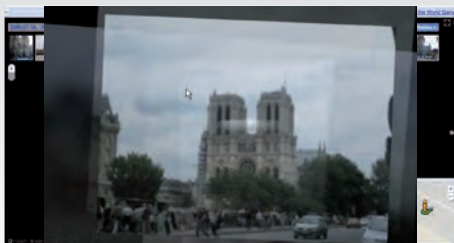
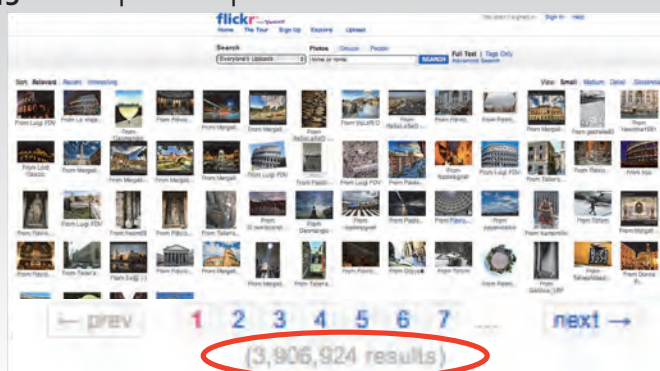


Photo Realistic World Model



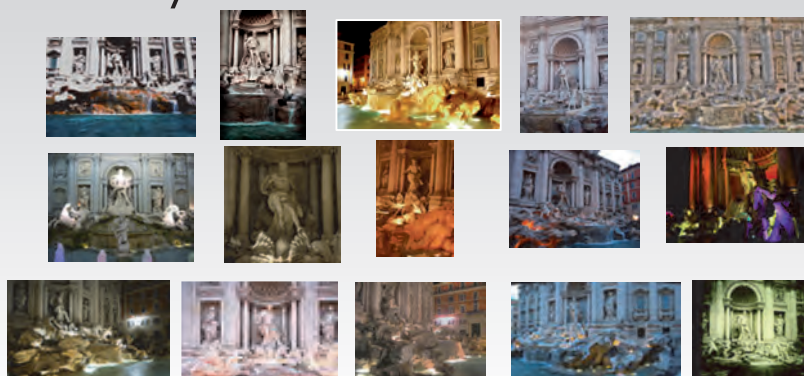
Reconstruction from Photos

- Image acquisition: Volunteers?
- Yes millions!
- **45 Billion** photos uploaded in 2010



Challenges for Reconstruction

- Scalability/Speed
- Variety of cameras

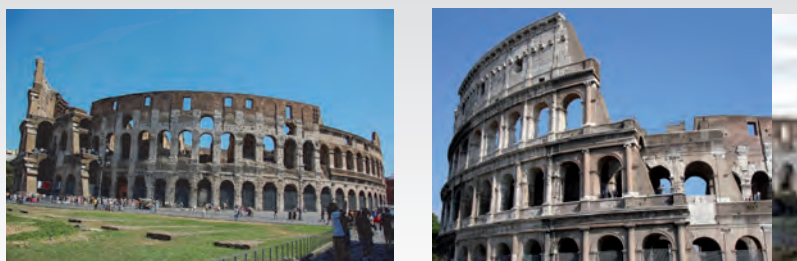


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Challenges for Reconstruction

- Scalability/Speed
- Variety of cameras
- Appearance variability



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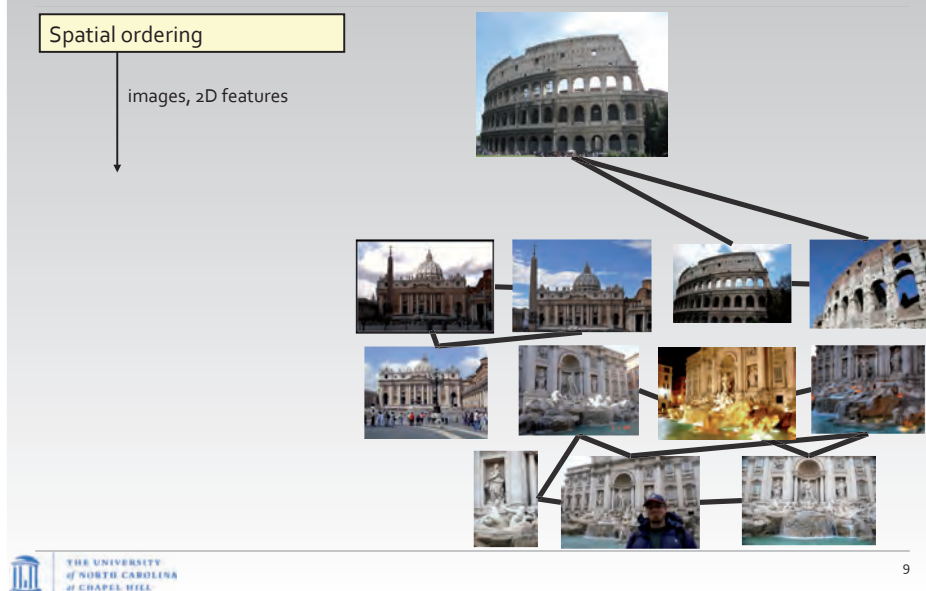
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Challenges for Reconstruction

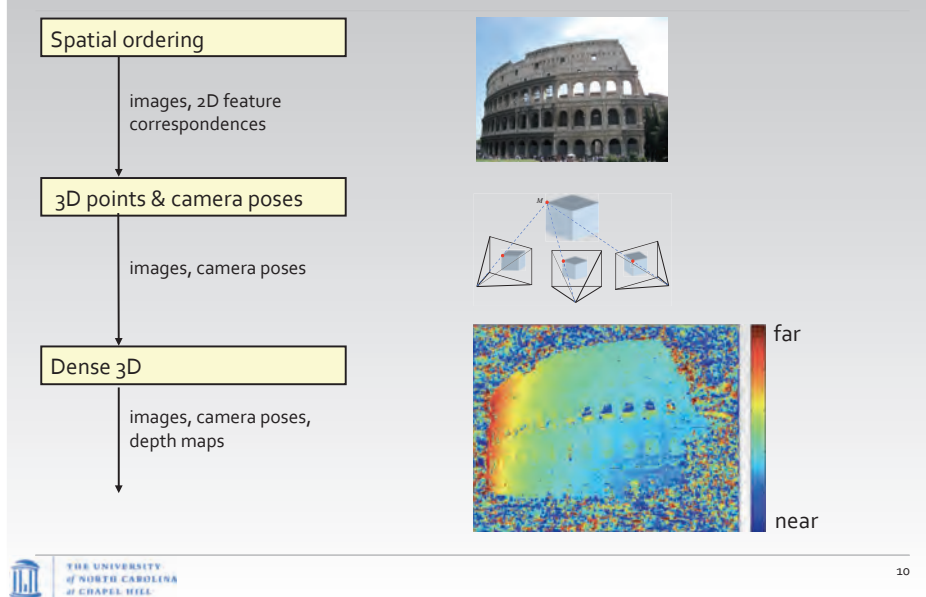
- Scalability/Speed
- Variety of cameras
- Appearance variability
- Resolution variability
- Model completeness
- Location completeness



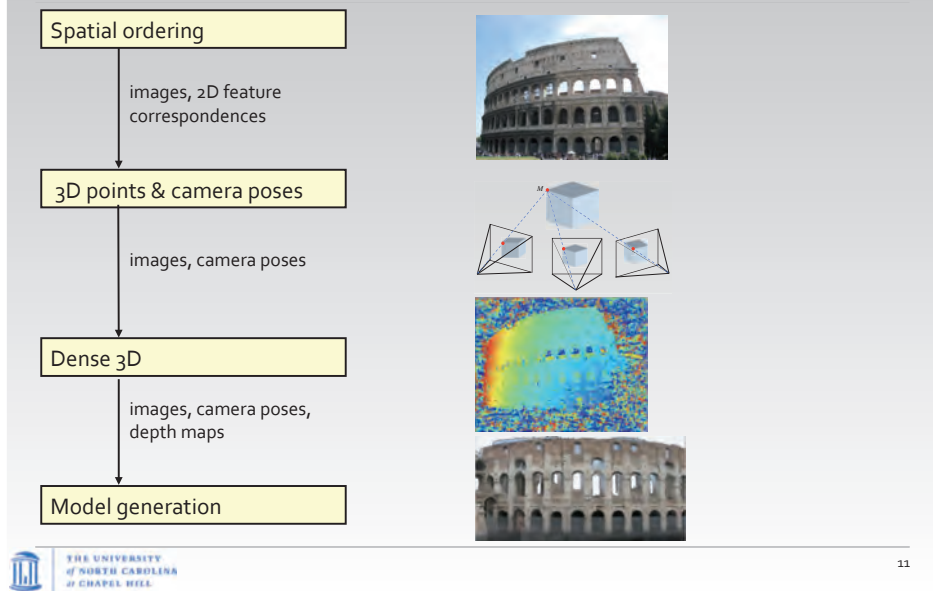
Spatial Correlation



3D model from video

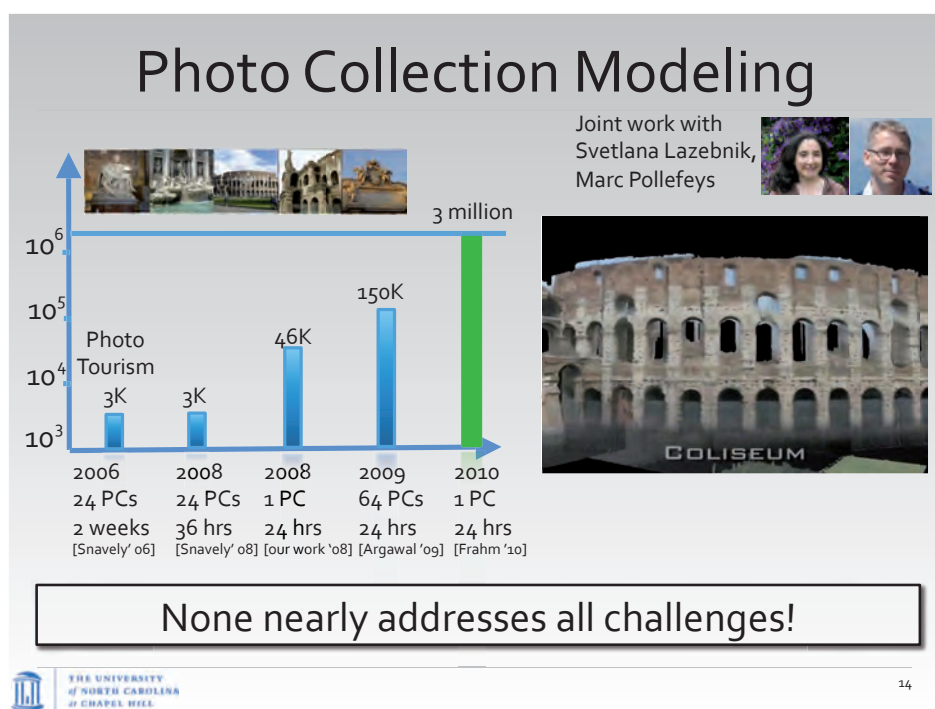
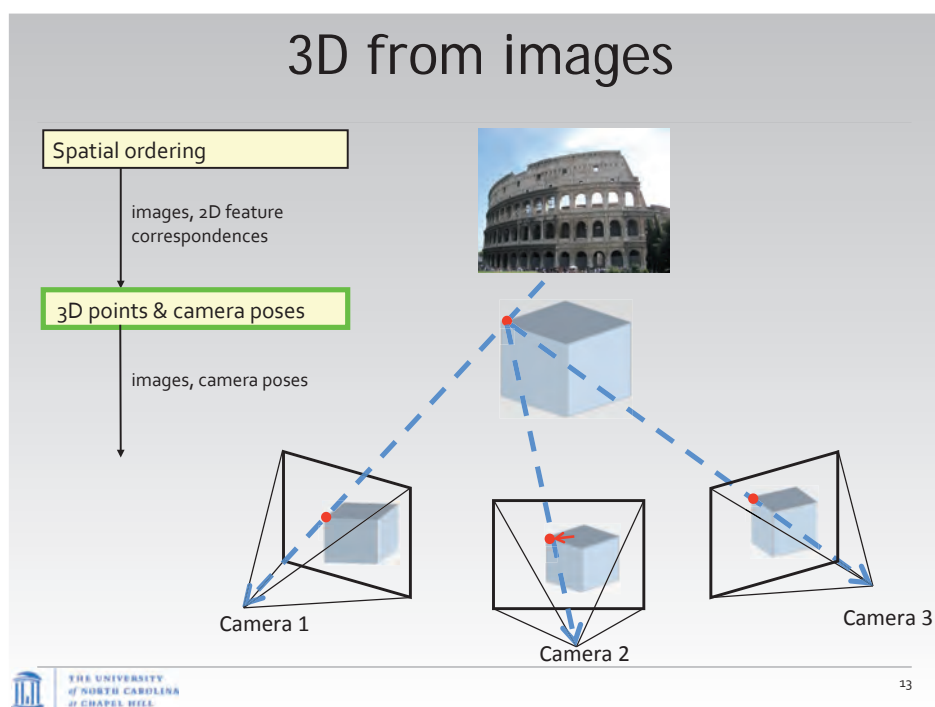


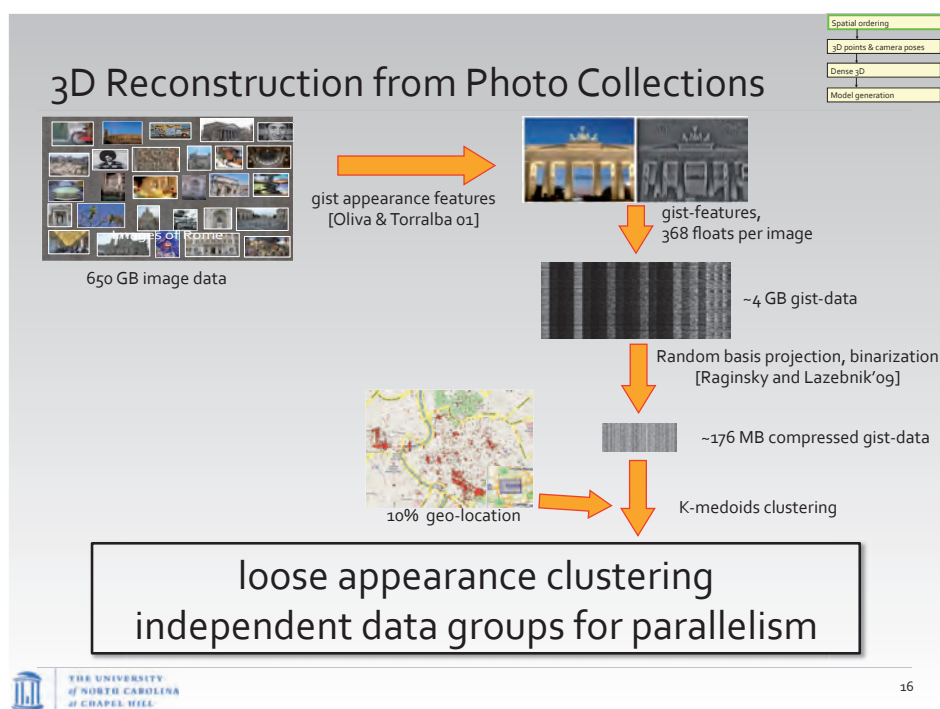
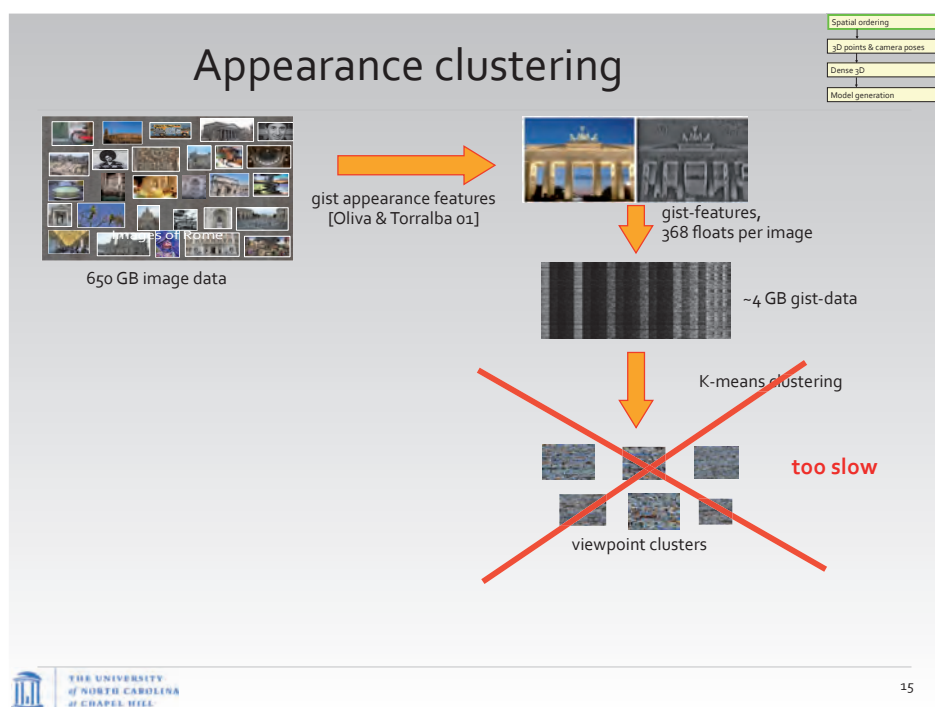
3D model from video



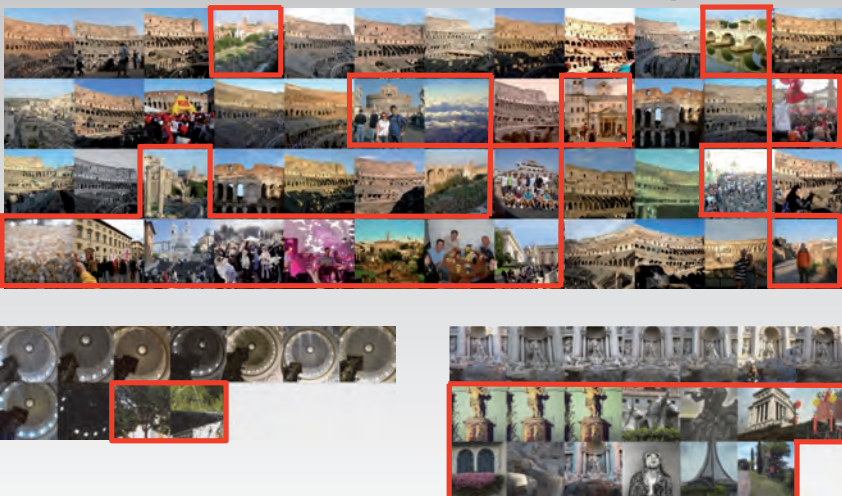
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Appearance clustering




Spatial ordering
3D points & camera poses
Dense 3D
Model generation

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Geometric verification



- RANSAC (computational cost is exponential in outlier fraction)
- typically < 1 Hz computation with traditional methods
- Faster computation ["ARRSAC", ECCV 2008],
- Error propagation for better performance ["Cov-RANSAC", ICCV 2009]
- Threshold free robust estimation ["RECON ...", ICCV 2011]

Rahul Raguram

~500 Hz geometric verification at same quality

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Geometrically verified clusters

Spatial ordering
3D points & camera poses
Dense 3D
Model generation

21,651 geometrically verified cluster with at least 3 images

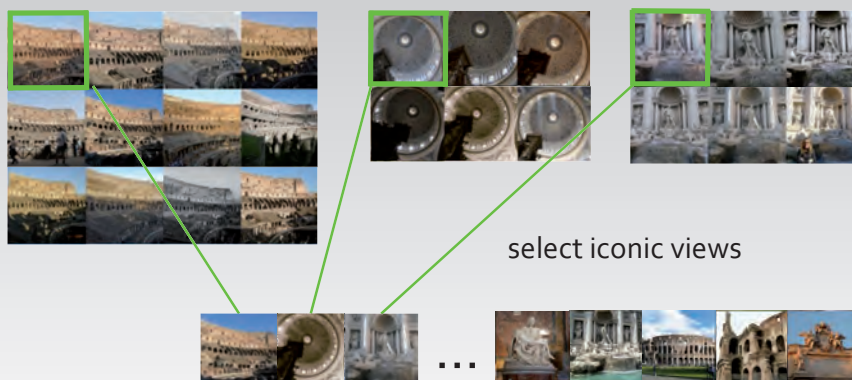
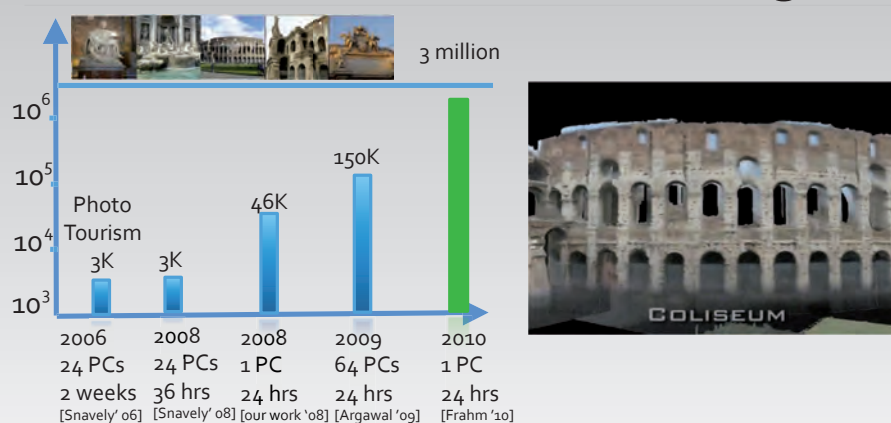
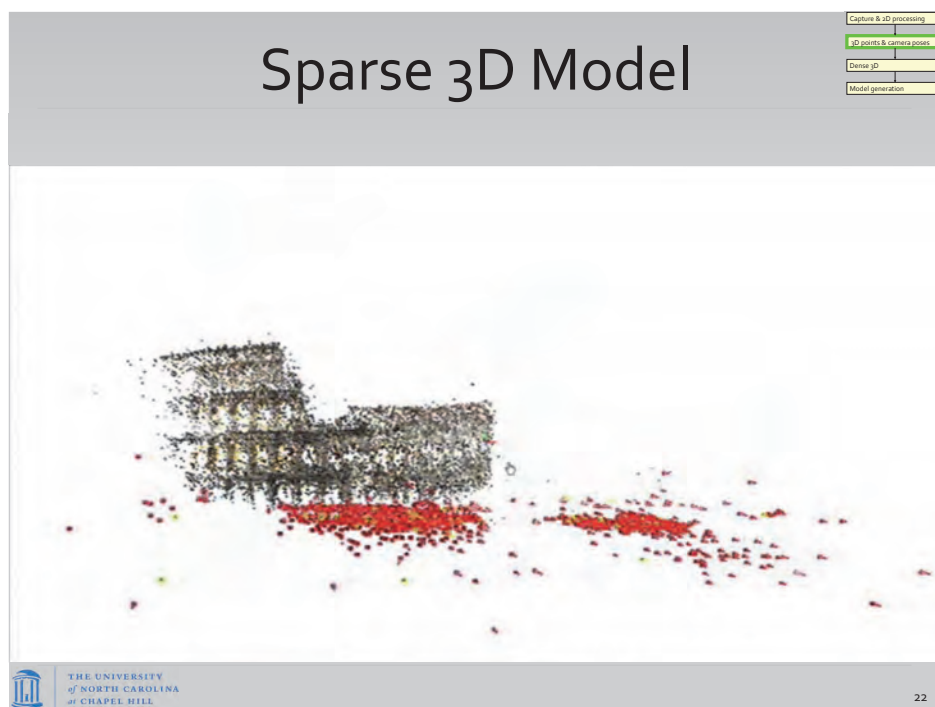
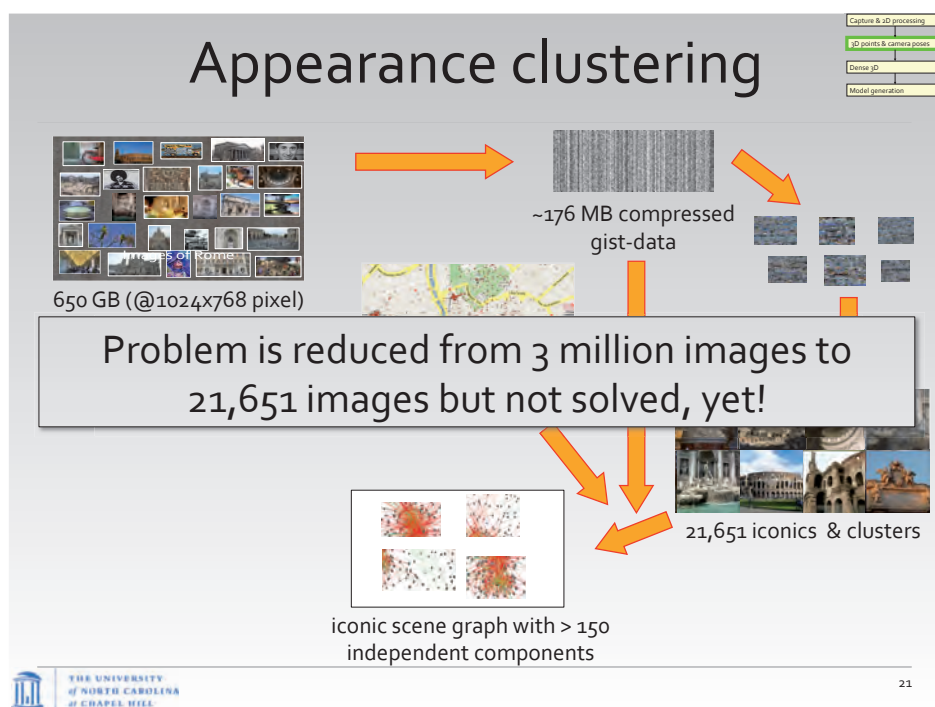


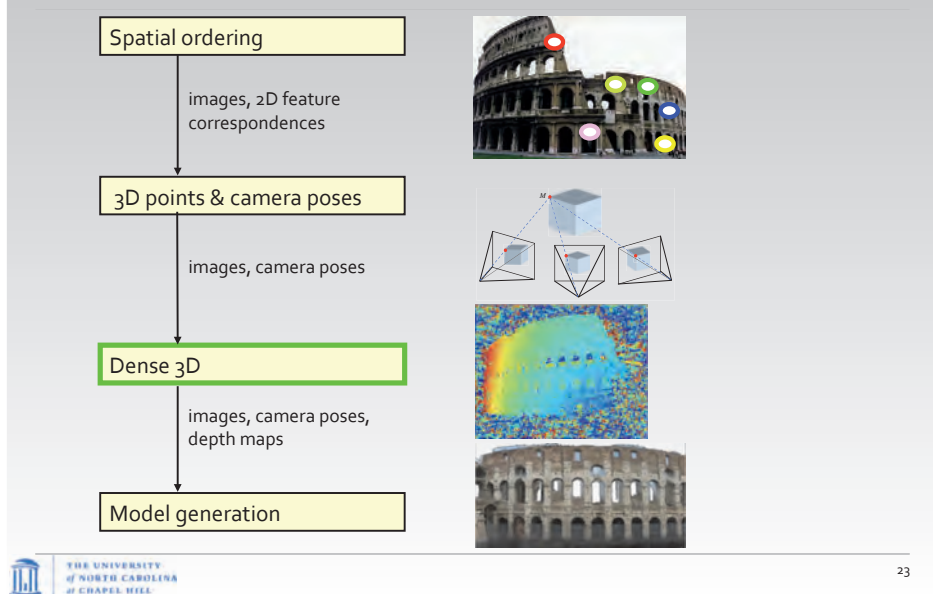
Photo Collection Modeling



- Scalability/Speed ✓
- Appearance variability (✓)



3D Model from Photo Collections



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Depth estimation

[Gallup et al., DAGM'10]

Challenge: appearance variation images

- k-medoids clustering of views deploys color
- => NCC based plane sweeping stereo (>40 Hz GPU)



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Plane sweeping stereo

Spatial ordering
3D points & camera poses
Dense 3D
Model generation

Problem:

- highly noisy depth estimates
- no depth estimates



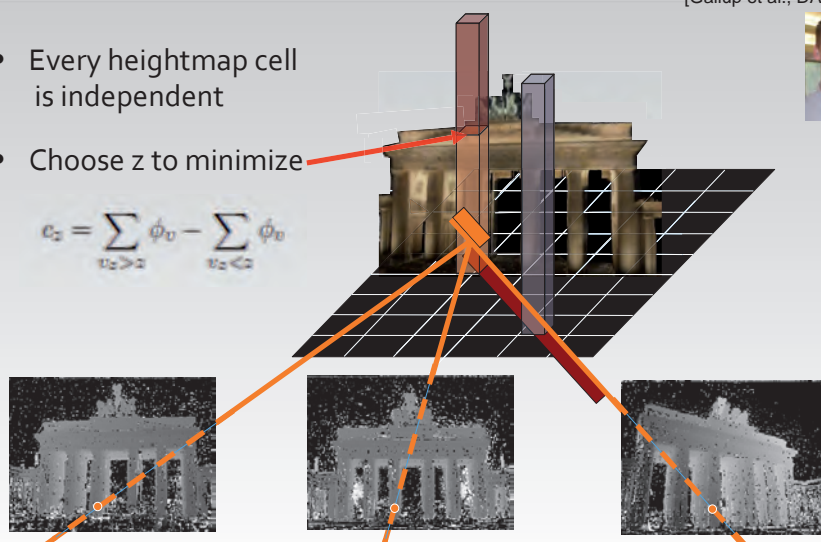
Robust stereo fusion process

[Gallup et al., DAGM'10]

- Every heightmap cell is independent

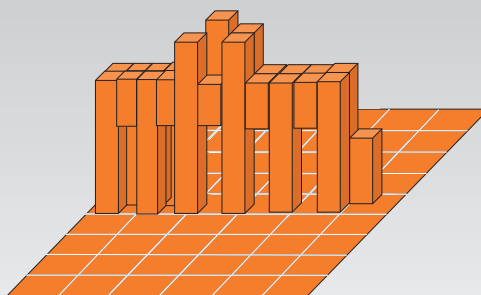
- Choose z to minimize

$$c_z = \sum_{v_z > z} \phi_v - \sum_{v_z < z} \phi_v$$



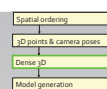
Robust stereo fusion process

[Gallup et al., DAGM'10]

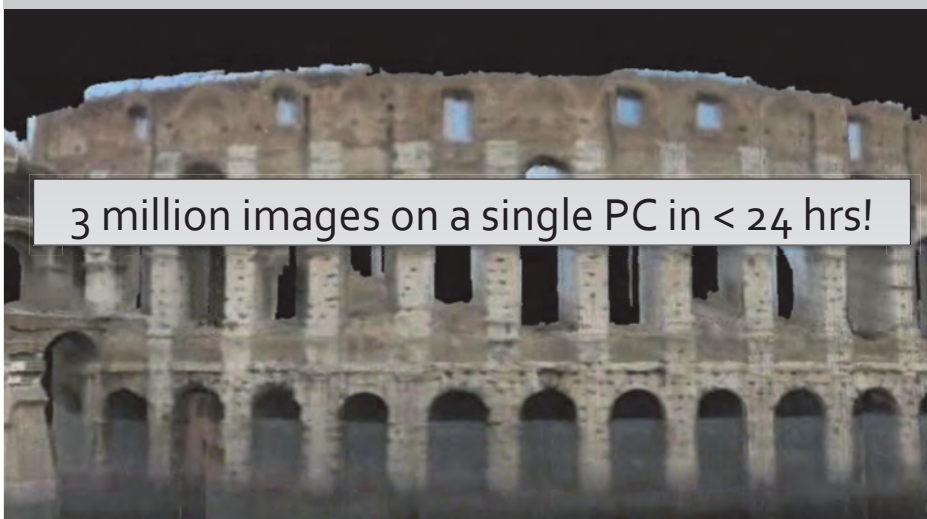


- Enforces vertical facades
- One continuous surface, no holes
- Fast to compute, easy to store

Dense 3D Model



3 million images on a single PC in < 24 hrs!

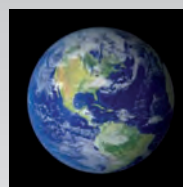


Challenges for Reconstruction

- Scalability/Speed ✓
- Appearance variability (✓)
- Resolution variability (✓)
- Model completeness
- Location completeness

Future Directions

- "Building the world in 6 days"



- Dynamic Scene modeling



- Scene understanding



People & Sponsors

Head: Jan-Michael Frahm

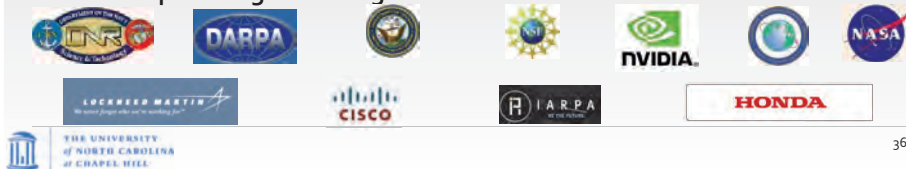
Postdocs: Pierre Georgel, Richard Steffen, Enrique Dunn

Students: Dibyendu Goswami, Yi-Hung Jen, Rahul Raguram, Anson Liang, Jared Heinly, Enliang Zheng,

Former members: Christopher Zach (ETH), Seon-Joo Kim (NUS), Brian Clipp (ARA), David Gallup (Google), Changchang Wu (UW), Paul Merrell (Stanford), Ram Kumar, Xiaowei Li (Google), Megha Pandey, Christina Salmi, Sudipta Sinha (Microsoft Research), Brad Talton, Li Guan (GE Research), Tim Johnson

Collaborators: Svetlana Lazebnik (UNC), Marc Pollefeys (ETH), Friedrich Fraundorfer (ETH), Philippos Mordohai (Stevens Institute of Technology)

Flickr users providing their images



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