Model and Stochastic Search

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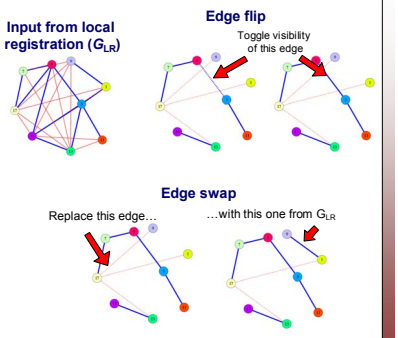
Searching for the optimal model hypothesis

Algorithm overview

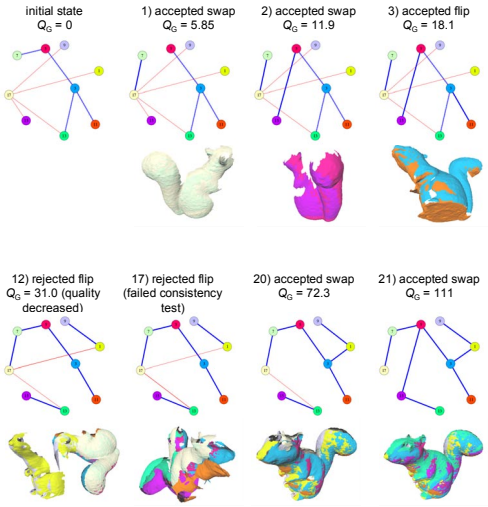
- Initialize with random model hypothesis
- Maximize Q_G through repeated incremental hypothesis update operations – edge swap or edge flip
- Update choice is weighted using quality of underlying pair-wise registration (Q_L)

Hypothesis update operations



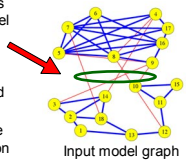
Example trace

(some iterations skipped due to space limitations)

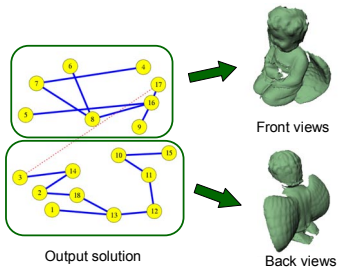


Multi-part hypotheses

- It is possible that a single-part solution does not exist within the model graph
- Our hypothesis representation explicitly represents disconnected parts
- **Result:** the output is the correct multi-part solution



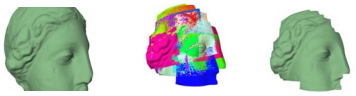
Input model graph



Results

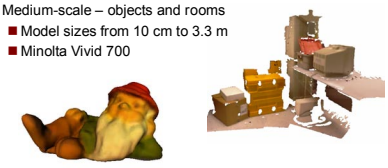
Scale, scene, and sensor invariance

- Extreme close-ups as in Digital Michelangelo project
  - ~ 3x3 cm surface patches
  - Synthetic views with noise

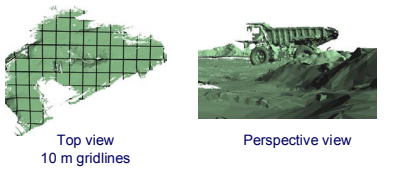


Close-up of input object | Registered views | Reconstructed model

- Medium-scale – objects and rooms
  - Model sizes from 10 cm to 3.3 m
  - Minolta Vivid 700



- Large-scale – interiors and terrain
  - Model sizes up to 224 m
  - Z+F scanner



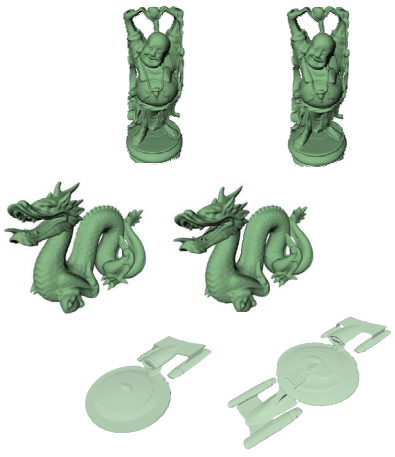
Top view 10 m gridlines | Perspective view

Experiments on a large database

- 36 test objects (18 real, 18 synthetic with added noise)
- 15 – 32 views per object
- Results: 32 correct, 1 partially correct, 3 wrong
- Errors occur on thin, symmetric objects

Example real objects
(input object on left, output model on right)

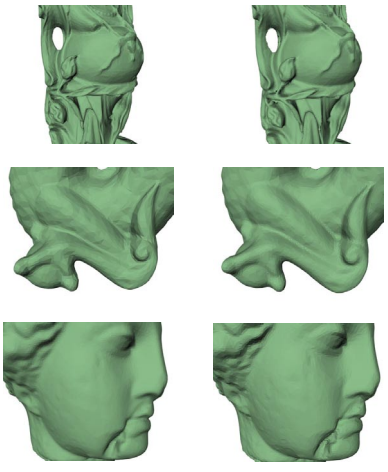
Example synthetic objects
(input object on left, output model on right)



Model accuracy

- Controlled experiments using simulated range sensor on synthetic objects show
  - Accuracy not limited by the registration
  - Reconstruction error ~ 0.02% of model size (0.04mm)
  - Main error sources – sensor resolution, sensor noise, surface reconstruction voxelization

Input objects | Reconstructed models



Representative statistics

object	views	iters (time)	E_{MC}	E_{MR}
gnome	27	69 (106)	n/a	n/a
squirrel	18	48 (87)	n/a	n/a
angel1	17	45 (34)	n/a	n/a
Buddha	32	61 (194)	0.04%	0.30%
teeth	32	61 (215)	0.037%	0.20%
enterprise	32	n/a	109%	10%

E_{MC} = maximum correspondence error
E_{MR} = maximum reconstruction error
Time in seconds, errors normalized by model size

Future work

- View selection – Selectively register views to enable scaling to large numbers of views. Use *a priori* information such as view order or an estimate of likelihood of registration success
- Online algorithms – Adapt current batch processing to an online algorithm for real-time automatic modeling
- Symmetry – incorporate model of symmetry into the process