Lag Camera: Separating Foreground and Background Motion

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Goals
- Reconstruct the background in the presence of moving objects.
- Foreground object cutout from video.

Applications
- Capture and reconstruct busy environment.
- Enable compositing novel image sequences.

Related Work I
- Scene Acquisition
  - Image-based rendering only static scenes
  - Spatial-temporal IBR does not reconstruct background

Related Work II
- Motion segmentation
  - Image segmentation uses static images
  - Video object cut and paste uses video from a static camera
  - Interactive object cutout
Challenges

- Reconstructing background with a moving camera.
- Video object cutout is only known for static cameras.

Our solution

- Lag camera - a moving camera array.

Still Camera

Sparse and disjoint samples

Video Camera

Dense and continuous samples over space

Lag Camera

Dense and continuous samples over space and time

Lag Camera Configurations

- 6 cameras
- 4 cameras
- 2 cameras
Lag Camera Configurations

- 6 cameras
- 4 cameras
- 2 cameras

2-view Lag Camera

- For acquisition along a line, it obtains images from (approximately) the same viewpoint but at sequential instances in time.

Lag Camera

- Background
- Moving object
- Lag camera

Lag Camera Image Pairs

- Estimate camera pose
  - Currently we use a mechanically tracked arm
  - Proxy-warp the lead image to follow image

Lag Camera Image Pairs
Lag Camera Capturing

- capture.avi

Our Methods: Part 1

- Foreground Motion
  - A motion detection algorithm that identifies object motion even when camera is moving.

- Background Scene
  - A capturing method that samples a static scene in presence of moving objects.

Foreground: Motion Mask

- Isolate foreground using a motion mask

  image differencing thresholding close operator

Stop Motion

- However, when motion stops, the difference image goes to zero.

  3 consecutive frames of difference images

Motion Mask Composition

- Masks for different segments are composited together.

  original frame difference image motion mask

Stop Motion

- Re-project the nearby motion masks to the frame where motion stops.
Background Rendering

- Unstructured Lumigraph Rendering (ULR)

Modified Unstructured Lumigraph

Results

- 2 board scenes with 142 and 102 images
  - board.avi
- 1 bookcase scene with 298 images
  - bookcase.avi

Problems So Far…

- Self-similarity of the moving object
  - Causes the mask to be zero when foreground object is similar to itself.
- Conservativeness of the motion mask
  - Sometimes the motion mask is too conservative.

Our Methods: Part 2

- Foreground Motion Segmentation
  - A color-segmentation-based method to include self-similarity regions in the initial motion mask.
  - An iterative segmentation algorithm for progressively refining the segmentation.

Initial Motion Mask

- The self-similarity problem:
Initial Motion Mask
- Use color segmentation to fill the regions.

Iterative Refinement
- Rank all the segments in all images.
- Choose the highest ranked segment and convert it from motion mask to background.
- Re-rank all the remaining regions.

Iterative Refinement
- The definition of the score $S$ of a segment:
  - $D$: re-project a segment to nearby images and compute the dissimilarity.
  - $C$: the percentage of the re-projected region inside the mask.
  - $S = w_1 D + w_2 C$

Interactive Editing Tool
- System iteratively updates the scores, refines the mask; until a threshold is reached.
- User removes some segments from the mask.

Occlusion-compatible Processing Order

Occlusion-compatible Processing Order
Results

boardisr.avi

cisr.avi

Future Work

- Elimination of shadows.
- Vision based camera pose estimation.
- Other lag camera configurations.

Future Work

- Spatial-temporal coherent image segmentation
  - New formulation of the mean-shift clustering
- Generalized energy term
  - Min-cut

Conclusions

- An efficient motion detection algorithm with moving camera.
- A capturing method that samples a static scene in presence of moving objects.
- An editing tool for quickly segmenting moving foreground objects captured by moving cameras.
- An iterative segmentation algorithm for progressively refining the segmentation.