

# Interactive Image-Based Rendering using Feature Globalization

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ACM SIGGRAPH 2003 Symposium on Interactive 3D Graphics

# Image-Based Rendering (IBR)

- Create photorealistic models of real-world environments by resampling images from a (large) set of pictures



Frank Lloyd Wright  
Fallingwater House, PA

Thomas Jefferson  
Monticello, VA

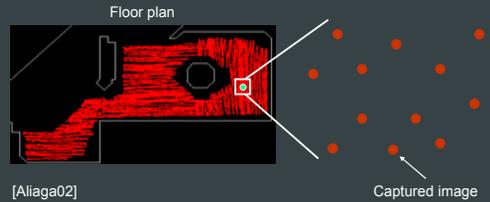
Inside Independence Hall,  
Philadelphia, PA

# IBR Components

- Capture
- Representation
- Resampling

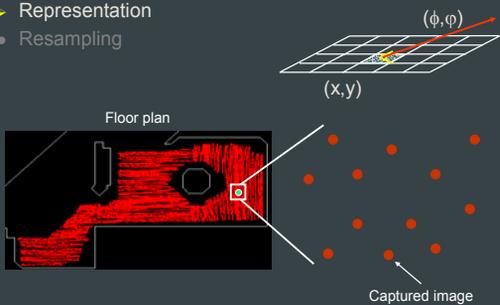
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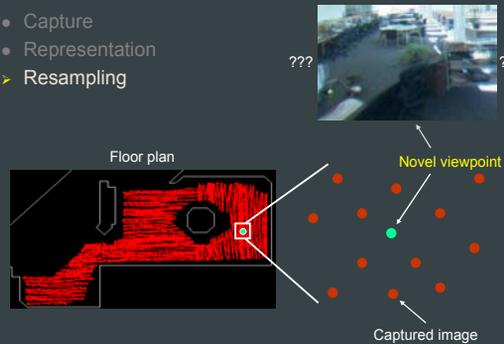
# IBR Components

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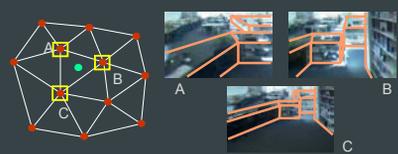
## Possible Approaches

- Ideal image warping
  - Requires dense correspondence or depth for every pixel
- Proxy-based warping
  - Quality depends on accuracy of proxy
- Feature-based warping
  - Image reconstruction depends on having sufficient features



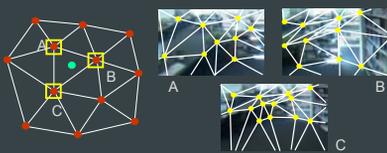
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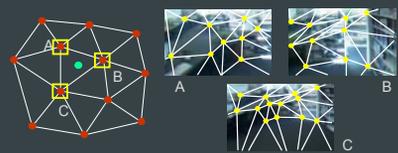
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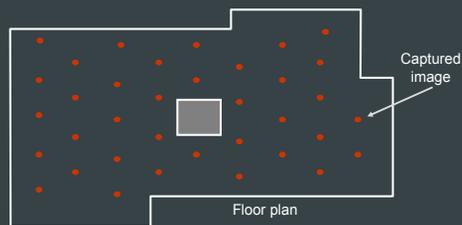
## Possible Approaches

- Ideal image warping
  - Requires dense correspondence or depth for every pixel
- Proxy-based warping
  - Quality depends on accuracy of proxy
- Feature-based warping
  - ADVANTAGE: No a priori model needed, sharp details preserved, hides calibration errors



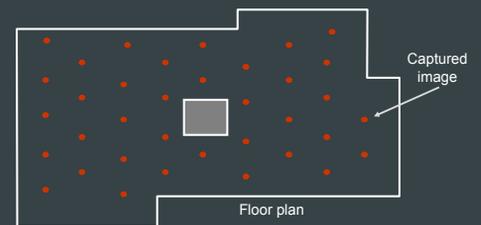
## Feature-based Warping: Goal

- Given a collection of images, compute a large set of consistent features across the images



## Feature-based Warping: Challenge

- Overcome the limitations of feature detection, feature tracking, and correspondence to create a large set of consistent features





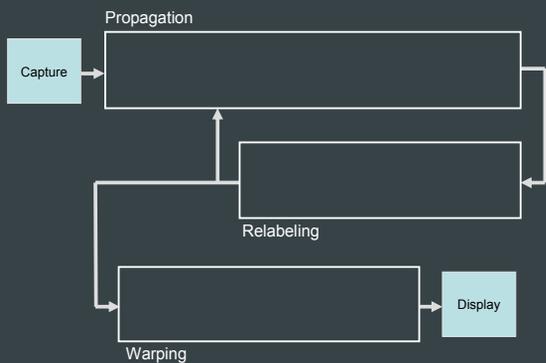
## Feature Globalization Benefits

- Global
  - Far apart images still have large set of common features
  - Supports rendering from images currently loaded from disk
- Consistent
  - No single feature has two global labels
- Automatic
  - Supports large environments
- Efficient
  - Able to control the tradeoff of amount of globalization and work

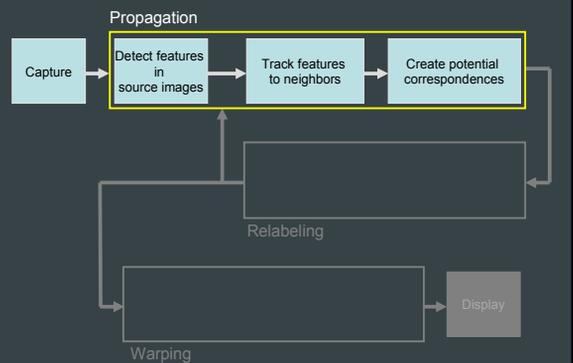
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## Feature Globalization Algorithm

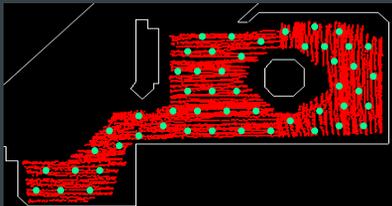


## Feature Globalization Algorithm



## Propagation

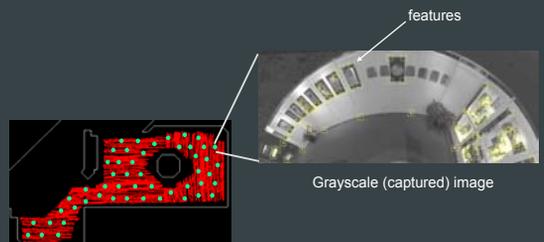
- Choose a set of source images throughout the dataset



Each red-dot is a captured image  
Each green dot is a source image

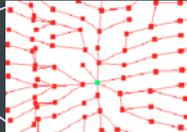
## Propagation

- Detect features in every source image
  - Our "corner" features lie at the intersection of nearly orthogonal edges [Shi94]



## Propagation

- Track features from image to image along disjoint paths originating at each source image

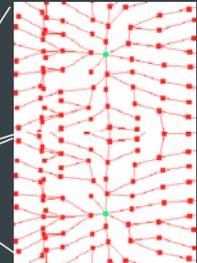


Source image A & feature set F

## Propagation

- Track features from image to image along disjoint paths originating at each source image

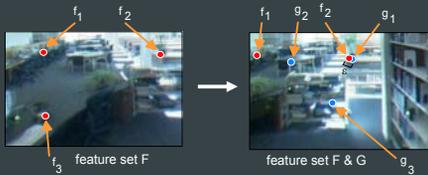
Source image B & feature set G



Source image A & feature set F

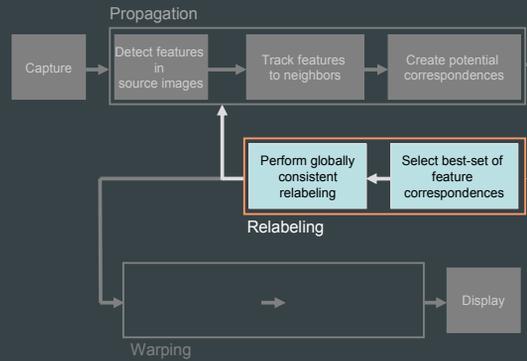
## Propagation

- Create candidate correspondences between features from different source images that track to the same location and satisfy correlation and quality criteria



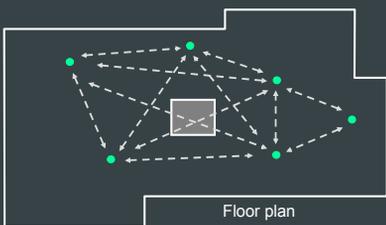
e.g.,  $f_2 = g_1$  is a potential correspondence...

## Feature Globalization Algorithm



## Relabeling

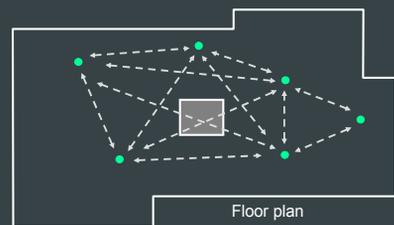
- We have tracked features from each source image outwards and created all potential correspondences...



Floor plan

## Relabeling

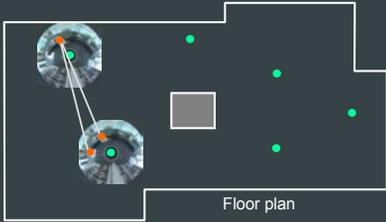
- The task is to choose the "best" subset of consistent correspondences between features of the source images



Floor plan

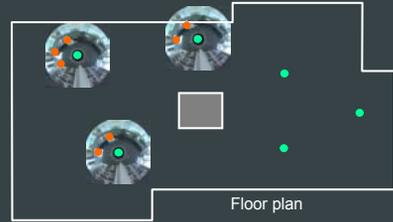
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  - Consistent implies that no single feature has two labels



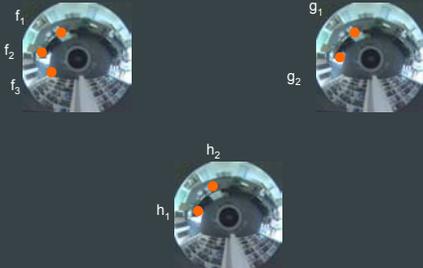
## Relabeling

- The task is to choose the “best” subset of consistent correspondences between features of the source images
  - As an example, let's choose a subset...



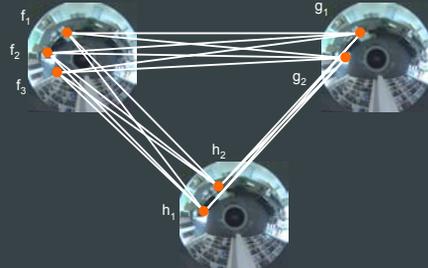
## Relabeling

- Use a greedy graph-labeling algorithm to iteratively accept the next “best” potential correspondence



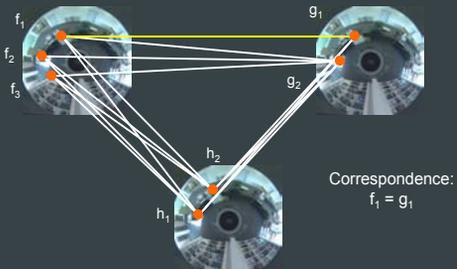
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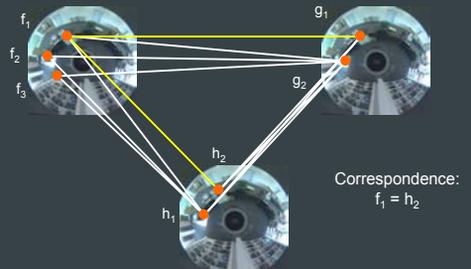
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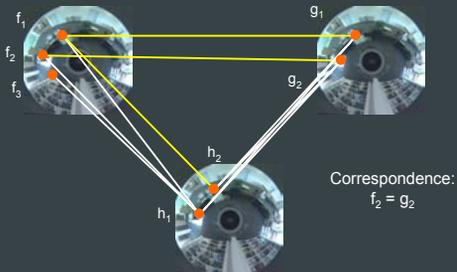
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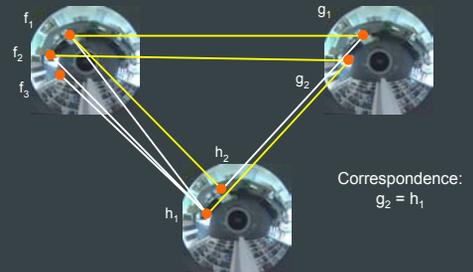
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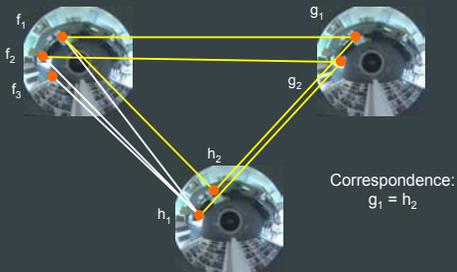
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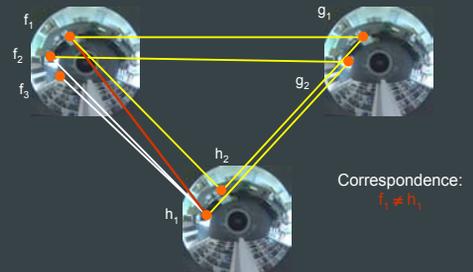
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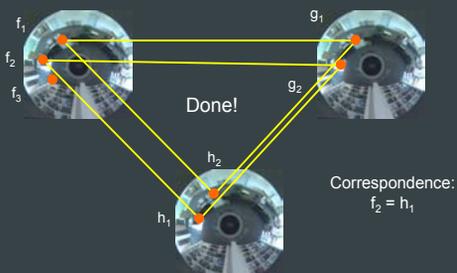
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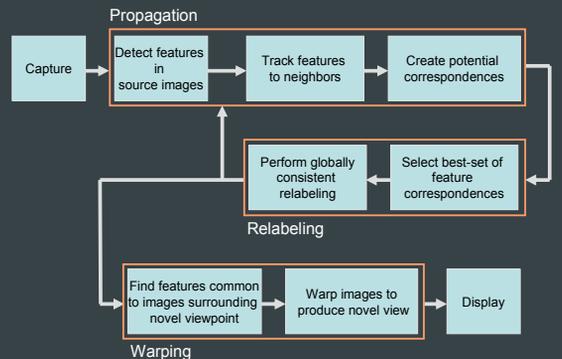


## Relabeling

- Use a greedy graph-labeling algorithm to iteratively accept the next "best" potential correspondence



## Feature Globalization Algorithm



## Experimental Results

## Experimental Results

- Bell Labs Museum
  - 1000 square ft
  - 9832 images
  - 2.2 inches spacing
- Princeton Library
  - 120 square ft
  - 1947 images
  - 1.6 inches spacing
- Personal Office
  - 30 square feet
  - 3475 images
  - 0.7 inches spacing



[Aliaga02]

## Experimental Results

- System
  - C/C++ with OpenGL/GLUT
  - SGI Onyx2 with InfiniteReality2
  - Pentium IV 3 GHz with NVidia board
- Times
  - Reconstructions: 1024x1024 @ ~15-20Hz (SGI), @ ~60Hz (PC)
  - Number of initial features: ~1500 per image
  - Image-to-image tracking: 2-3 seconds
  - Preprocessing time: 4 to 30 hours

## Rendering Results

- Use naïve image blending (no warping)
  - [Levoy96]
- Use a proxy to warp images
  - [Gortler96, Buehler01, Aliaga02]
- Use feature globalization



cylindrical projection

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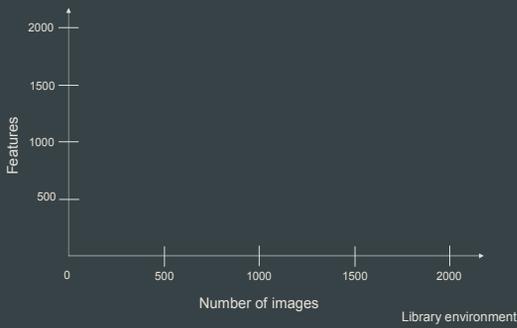
- Video



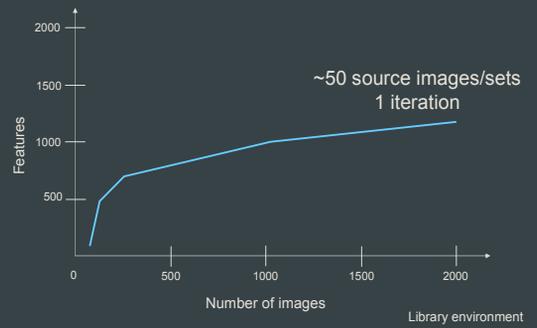
## Globalization Parameters

- Number of source images
  - An initial feature set is created at each source image
- Number of iterations
  - Each iteration does one step of propagation and relabeling
- Thresholds
  - Tracking quality
  - Feature quality

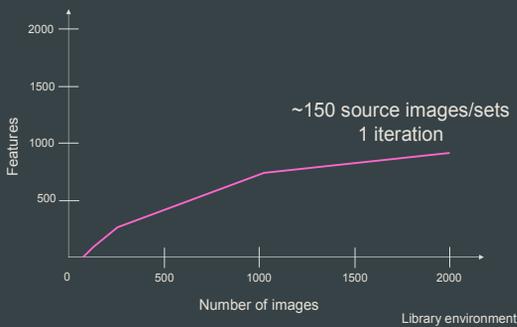
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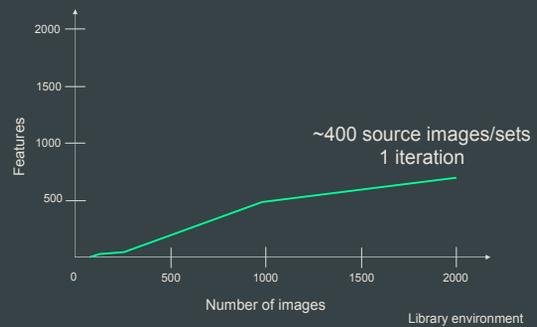
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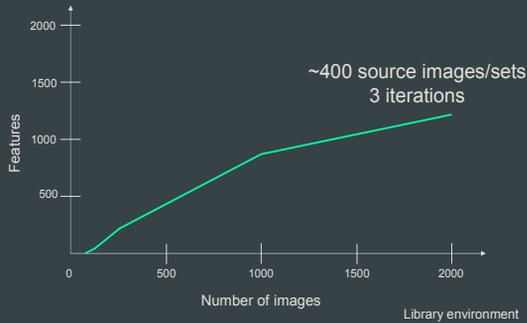
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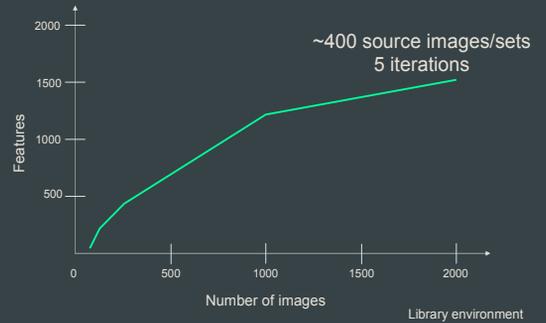
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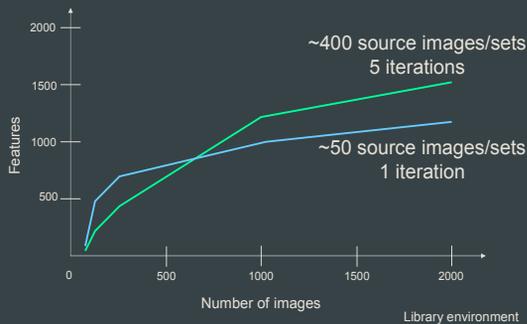
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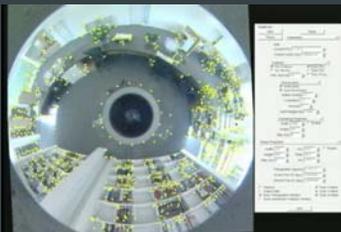


## Globalization Parameters

- Feature globalization using more iterations outperforms using longer tracking sequences
  - 400 srcs/5 iterations is up to 2x better than 400 srcs/1 iteration
  - More iterations makes globalization less sensitive to number of source images (because complete globalization is approached)

## Current Limitation

- Although not very noticeable visually, common features found on the fly can change significantly from one set of reference images to another



## Conclusions

- Improved feature tracking
  - Redundancy of dense sampling exploited to achieve longer/better feature tracking
- Globally consistent feature labeling
  - Able to produce a globally-labeled set of features for a large dense collection of images
- High quality image reconstructions
  - Significantly improved imagery as compared to previous image-based rendering algorithms

## Future Work

- Use feature globalization for compression
- Use (real-time) feedback to guide capture and improve globalization and reconstruction quality
- Use features for 3D reconstruction of the scene

## Acknowledgments

- We are grateful to Sid Ahuja, Multimedia Research Lab VP at Bell Labs, Bob Holt, and Steve Fortune

Thank you!

## Interactive Image-Based Rendering using Feature Globalization

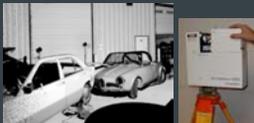
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## Possible Rendering Approaches

- Naive image blending
  - Produces blurry images if not sampled very densely [Levoy96]
- Proxy-based warping
  - Quality depends on accuracy of proxy [Gortler96, Buehler01]
- Depth-based warping
  - Requires dense physical measurements [Nyland01] or dense correspondences to estimate depth [Chen93, McMillan95]
- Or...



## Feature-based Warping

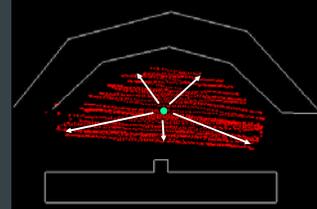
- Combine a feature tracking method and a global labeling algorithm in order to create correspondences over a wide viewpoint range and produce novel views in real-time
- -----needs works-----
- Diff from Pollefeys, where?

## Our Approach: Feature Globalization

- Combine a feature tracking method and a global labeling algorithm in order to create correspondences over a wide viewpoint range and produce novel views in real-time
- needs works-----
- Diff from Pollefeys, where?

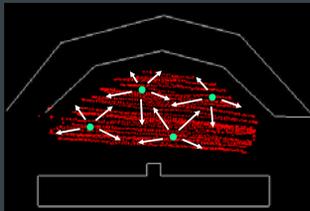
## Feature Globalization

- Simplest algorithm is to detect (corner) features in one source image and track features to all other images
  - Fails because features quickly become lost



## Feature Globalization

- Instead, detect features in many source images and track to nearby images
  - Features are only tracked short distances
  - Matching creates correspondences over large ranges

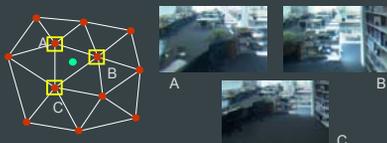


## IBR Resampling Goals

- High-Quality
  - Prevent ghosting and blurring at all times
  - Reliable across whole environment
  - Independent from accurate 3D knowledge of environment
- Automatic
  - To support large environments, method must be automatic
- Real-time
  - Create novel views at high frame rates
- Flexibility (??)
  - To support hierarchies and prefetching of large models, method must generate novel views with whatever samples are in cache

## Possible Approaches

- Naive image blending
  - Produces blurry images if not sampled very densely [Levoy96]
- Proxy-based warping
  - Quality depends on accuracy of proxy [Gortler96, Buehler01]
- Feature-based warping
  - Difficult to obtain a large number of features across a wide range of viewpoints



## Interactive Image-Based Rendering Using Feature Globalization

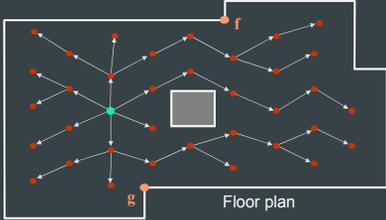
- Acknowledgments:
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  - NSF CAREER ????



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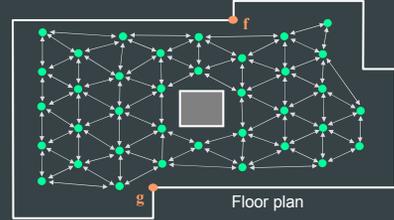
## Feature Globalization

- Create a global set of features using a dense set of captured images (over a plane)
  - If one image is a source image, *feature tracking limitations* causes features to be lost

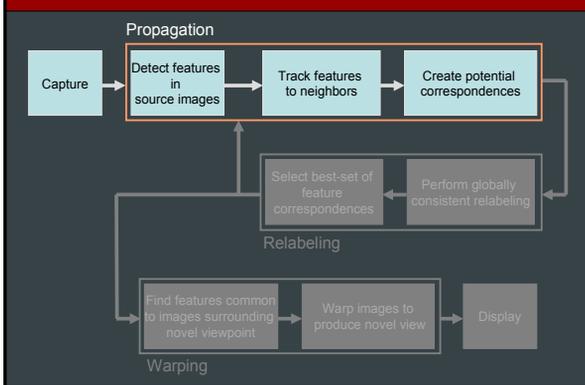


## Feature Globalization

- Create a global set of features using a dense set of captured images (over a plane)
  - If every image is a source image, *feature detection limitations* cause neighboring images to have different features



## Feature Globalization Algorithm



## Feature Globalization Algorithm

