The General Pinhole Camera

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Outline

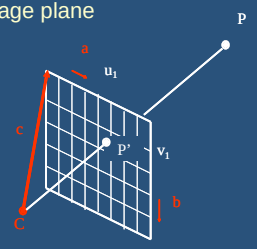
- Background
- Problem
- Solution
- Implementation
- Conclusions
- Future Work
- Acknowledgements

Background

- Computer Graphics
  - Image synthesis from geometry and color models
- Projection
  - Fundamental operation
  - Maps 3-D points to 2-D image locations

Background

- Planar Pinhole Camera (PPC)
  - Rays defined by a center of projection
  - Regular grid on an image plane



Limitations of PPC

- Limited field of view
- Limitation of all rays passing through a common point
  - rendering curved reflectors
- Does not provide sampling rate flexibility
  - shadow rendering, antialiasing, continuous local zooming

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Solution

- The General Pinhole Camera (GPC) model
- Supports any set of sampling locations on the image plane
- Several GPCs sharing a center of projection
  - Combined can overcome field of view limitation
- Samples 3d scene at the desired image plane sampling locations

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Three GPC Variants

- Quasi-regular set of sampling locations
  - Defined using a regular grid
  - Offset GPC
- Two sampling rates
  - Regular sampling rate + “super” pixel rate
- No pattern
  - Samples partitioned recursively using quad-tree image plane subdivision

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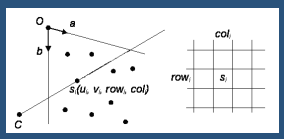
The GPC Model

- Specifies a mapping between image points and rays
- Center of projection: C
- Image plane
  - Origin: O
  - Axes: (a, b)
- Set S of N sampling locations $s_i(u_i, v_i)$
  - u_i and v_i image plane coords.
- GPC ray is defined by the ordered pair $(C, O+au_i+bv_i)$
- Sampling location s_i defined by the 4-tuple: (u_i, v_i, row_i, col_i)



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Offset GPC Model

- Specialization of the generic GPC model
- Obtained from slightly perturbing a regular planar pinhole camera
- Define a uniform grid that maps well to the perturbed sampling location

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Offset GPC Model

- Image plane coordinate system (O, a, b) defines a regular grid such that each cell contains at most one sampling location
- Denote an offset GPC sampling location (o_{ui}, o_{vi}, row_i, col_i), where image plane coordinates (u_i, v_i) are replaced with offsets (o_{ui}, o_{vi})
- The image plane coordinates can be computed by adding the offsets to the implicit grid cell indices

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Superpixel GPC

- Anti-aliasing
  - Requires increasing resolution at some pixels
- Conventional approach
  - Increase resolution at all pixels
  - Inefficient
- GPC allows for super-sampling at only the necessary points

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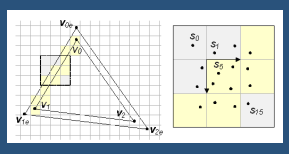
Superpixel Camera Model



- Edges are where anti-aliasing is key
- All pixels intersected by edge are superpixels
- Re-sampling is similar
  - Compute offsets
  - Recolor image for superpixels

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Anti-Aliasing GPC Application

- Designed specifically for high-quality anti-aliasing
  - Render scene with PPC in a framebuffer which, in addition to the usual depth and color channels, also has a triangle ID channel
  - Examine the framebuffer and set superpixels. A pixel has to be rendered as a superpixel if any of its 8 immediate neighbors belongs to a different triangle and has a sufficiently contrasting color
- GPC is only concerned with anti-aliasing triangle edges with severe color changes

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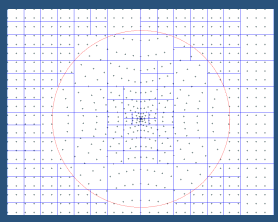
No Pattern in Samples

- Quad-Tree Subdivision algorithm
- Recursively divides plane into 4 pieces
- Divides sampling locations until a minimum number is reached in each cell



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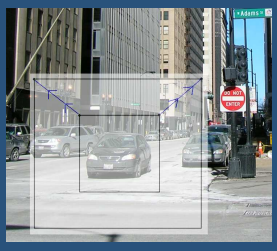
Preliminary Implementation



- User clicks on image
- Resample points from a new location
- User can define parameters for offset of samples

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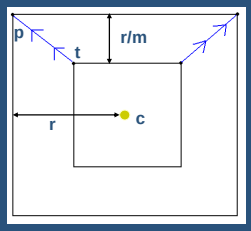
Preliminary Implementation

- Resample points from new locations
  - Based on offsets
- Recolor image using new sample colors
- Interpolate a transition area for blending
- Parameters:
  - m = multiplicity
    - Decrease > more zoom
  - r = radius
  - c = center of click



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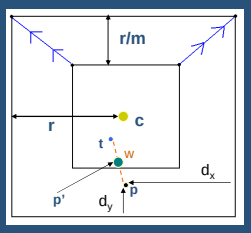
Transition Area Interpolation



- Find minimum distance to outside edge (d)
- Divide distance (d) by the total distance in transition area (r/m)
  - ratio = d / (r/m)
- Multiply ratio by the distance between original dot and remapped dot (w)
  - Gives a dot in between
- Move further out from center > dots more closely packed from original image

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Original Image

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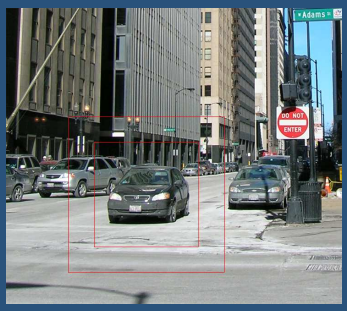
Resample



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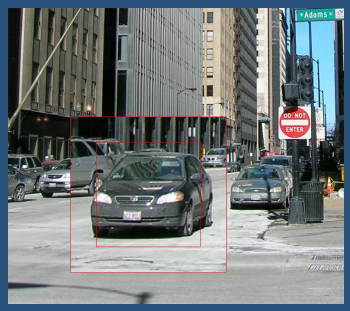
Recolor Image with Samples



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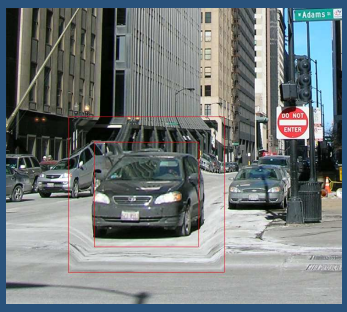
Interpolate Transition Area



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Finished Image

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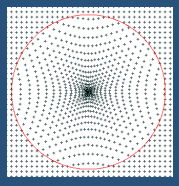
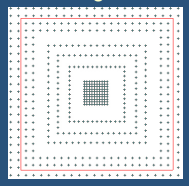
Determining Samples

- Any sampling rate can be used
- Specify different offsets for color location
- Example Visualizations:
  - Circular
  - Rectangular





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Conclusions

- The General Pinhole Camera model can effectively produce images with non-uniform sampling rates
- Can be specialized
  - Several different variants for different solutions
- Applications
  - Continuous local zooming
  - Anti-aliasing
  - Multiple projector calibration

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Future Work

- Implement the GPC model for 3d
- Implement a working GPC model in hardware
- Implement more variants of the GPC
- Look at different types of offsets that may be effective for different applications

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Acknowledgements

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Questions?

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