Disparity Estimation for Lightfields

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Overview

- Image based rendering.
- Disparity Estimation for better rendering:
  - Globally
  - Locally
- Results.
- Conclusions.

Conventional rendering

- Describe scene with polygons.
- Apply projection & lighting model.
- Problems:
  - Complex lighting algorithms.
  - Rendering complexity increases with scene complexity.

Image based rendering

- Use pre-rendered or captured images.
- Interpolate between images to construct new views.
- Advantages:
  - Rendering time independent of scene complexity.
  - Photo-realistic results.
  - No model needed.

Lightfields (1)

- Levoy and Hanrahan’s implementation of image based rendering.
- Assumes free space.
- Can describe light function with four parameters [u,v,s,t].
A problem…

- Variation in depth of scene causes ghosting artifacts.
Disparity estimation: a multiresolution approach

- Use multiresolution representation of images.
- Wavelet decomposition of teddy:

Disparity estimation: a multiresolution approach (2)

- Estimate disparity at lowest resolution first.
- Narrow search region at higher resolutions by propagating disparity values to ‘child’ blocks.
- Obvious problem: which subband of wavelet transform to use…

Photoconsistency for disparity estimation

- Solution: don’t compute photoconsistency on the fly: pre-compute.
- Pre-compute depths at \([u,v]\) sample points (each camera).
- Project into neighbouring cameras for disparity estimate.

Overview so far…

- Light fields for quick rendering.
- We can use disparity estimation to (quickly) choose correct samples.
- Alternative rendering method: photoconsistency:
  - Global.
  - Too slow.
  - We adapt to obtain disparity estimates.

An overhead view (revisited)

Disparity

Photoconsistency

- The ‘photo-consistency’ of a point is how consistent the projections into every camera view are.
- We can render novel views in this manner:
  - For each pixel in desired image, find depth which is most photoconsistent.
  - Choose the colour for this pixel which most cameras see at this depth.
  - Problem: too complex for real time rendering.
**Disparity estimation: a multiresolution approach (3)**

- … only need to search in horizontal or vertical direction (between horizontally and vertically separated images respectively…
- … simply use subband with horizontal or vertical energies depending on expected direction of disparity.
Disparity estimation: a multiresolution approach (4)

- A problem: at lower resolutions an $N \times N$ block will cover a large area of the original image.
- A single disparity value for this block may not accurately describe the changes between two images.

The problem redefined…

- For a block at a given resolution, how much should we trust estimates from parent blocks?
- A statistics problem — what’s the probability of a disparity estimate, given the estimates from lower resolutions…

… the solution: Kalman filter

- Assuming probability densities are Gaussian, an iterative solution exists of comparatively low complexity—the Kalman filter.

Kalman filter

- At resolution $k$, our estimated disparity values have means $x_k$ with variances $P_k$.
- At the next highest resolution we estimate the disparities $z_{k+1}$ with variance $R_{k+1}$. 
Kalman filter (2)

- Two steps to our Kalman filter…
  i. Account for difference in scale between scales $(A = 2I)$ to predict new mean and variance
     
     \[
     x'_{k+1} = A x_k \\
     P'_{k+1} = A P_k A^T
     \]
  ii. We would like to update our predicted disparity map with the new measurement:
     
     \[
     x_{k+1} = x'_{k+1} + K (z_{k+1} - x'_{k+1})
     \]

Kalman filter (3)

- How much should we trust measurements at resolution $k+1$ relative to our previous estimates?
  
  Answer:
  
  \[
  K = P'_{k+1} (P'_{k+1} + R_{k+1})^{-1}
  \]

Results

- An example…

Lower level…

...
... top level

Kalman gain

Error maps (1)
- Synthetic model means we have ground truth.
Error maps (2)

• Allows us to see where algorithm gets it wrong.

Error maps (3)

Future work

• Problems around depth discontinuities.
• Identify these areas and adapt algorithm.
• Flaw in model: assuming pure translation.

Conclusions

• We can use disparity compensation to compensate for under-sampling in [u,v] plane.
• We can improve disparity estimates by using a Kalman filter.
• Algorithm performs poorly at depth discontinuities.
• Need to improve model.

Questions…