Progress on: Variable Viewpoint Reality Image Database

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MIT Artificial Intelligence Lab

Overview of Presentation

- Variable Viewpoint Reality
  - Overview
  - Progress at MIT
- Image Database Retrieval
  - Overview
  - Progress
- http://www.ai.mit.edu/projects/NTTCollaboration

VVR: Motivating Scenario



- *Construct a system that will allow each/every user to observe any viewpoint of a sporting event.*
- *Provide high level commentary/statistics*
  - *Analyze plays*

For example …

Computed using a single view…
some steps by hand

VVR Spectator Environment

- Build an exciting, fun, high-profile system
  - Sports: Soccer, Hockey, Tennis, Basketball
  - Drama, Dance, Ballet
- Leverage MIT technology in:
  - Vision/Video Analysis
    - Tracking, Calibration, Action Recognition
    - Image/Video Databases
  - Graphics
- Build a system that provides data available nowhere else…
  - Record/Study Human movements and actions
  - Motion Capture / Motion Generation

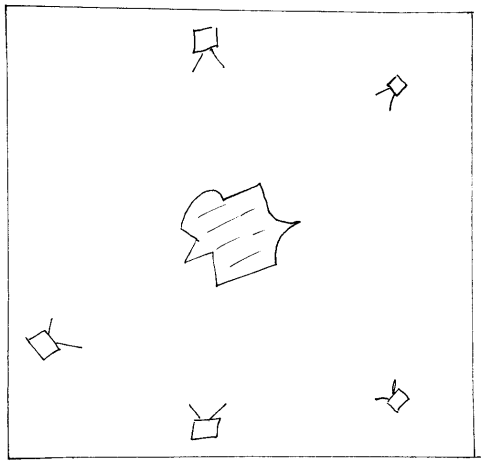
Window of Opportunity

- 20-50 cameras in a stadium
  - Soon there will be many more
- US HDTV is digital
  - Flexible, very high bandwidth digital transmissions
- Future Televisions will be Computers
  - Plenty of extra computation available
  - 3D Graphics hardware will be integrated
- Economics of sports
  - Dollar investments by broadcasters is huge (Billions)
- Computation is getting cheaper

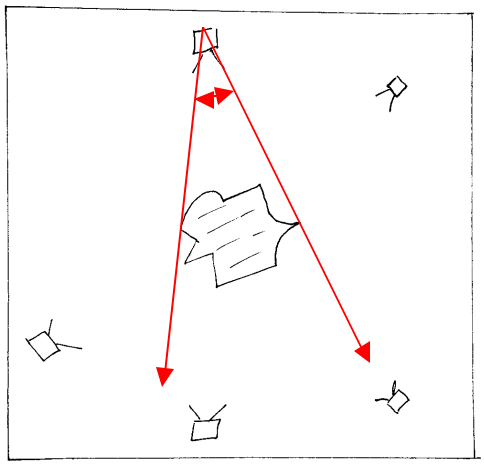
Progress at MIT

- Simple intersection of silhouettes (Visual Hull)
  - Efficient but limited
- Tomographic reconstruction
  - Based on medical reconstruction
- Probabilistic Voxel Analysis (Poxels)
  - Handles occlusion & transparency
- Parametric Human Forms

Visual Hull in 2D



Visual Hull: Segment



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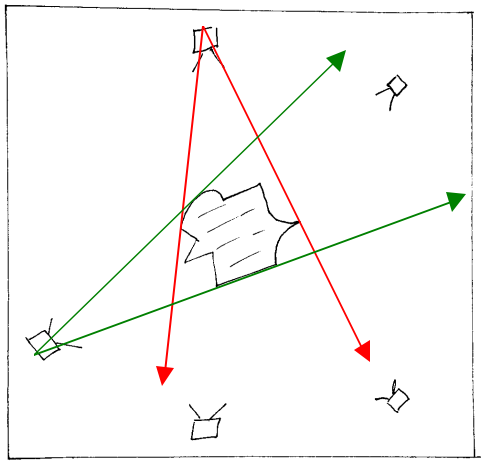

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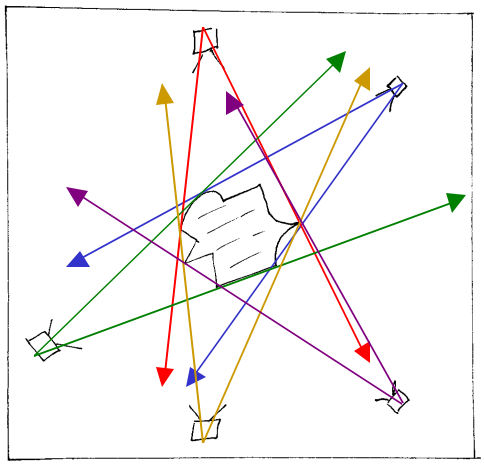
Visual Hull: Segment



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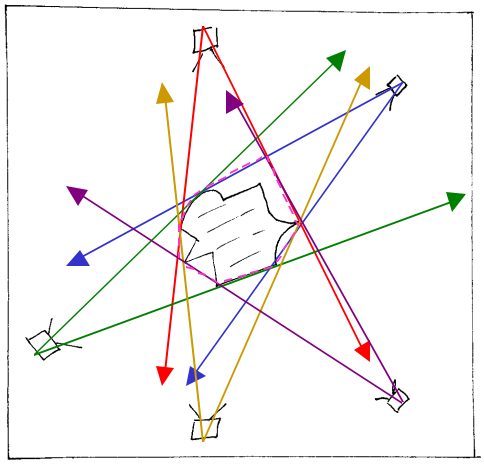
Visual Hull: Intersection



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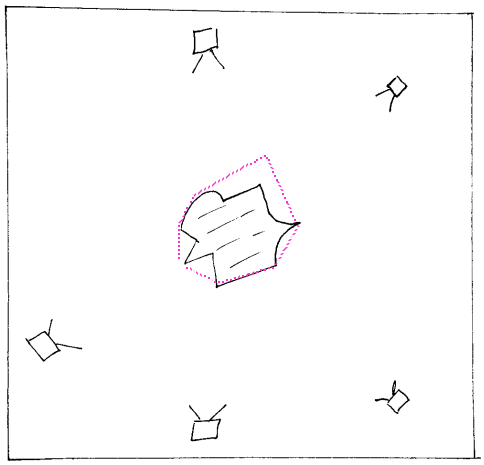
Idea in 2D: Visual Hull

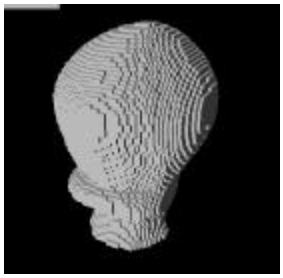


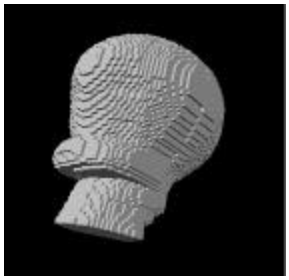
Real Data: Tweety



- Data acquired on a turntable
  - 180 views are available… not all are used.

Intersection of Frusta





- Intersection of 18 frusta
  - Computations are very fast
    - perhaps real-time

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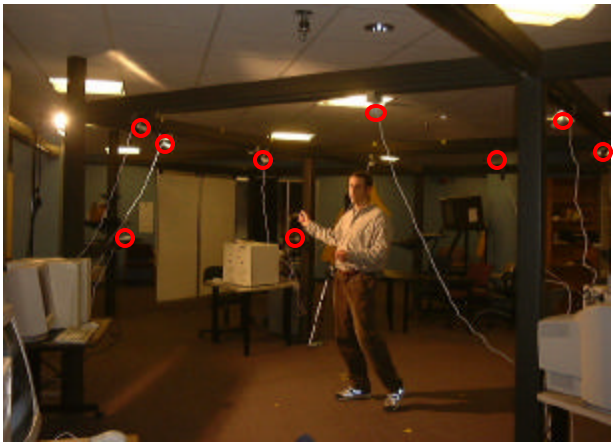
New Apparatus



Twelve cameras, computers, digitizers

Parallel software for acquisition/processing

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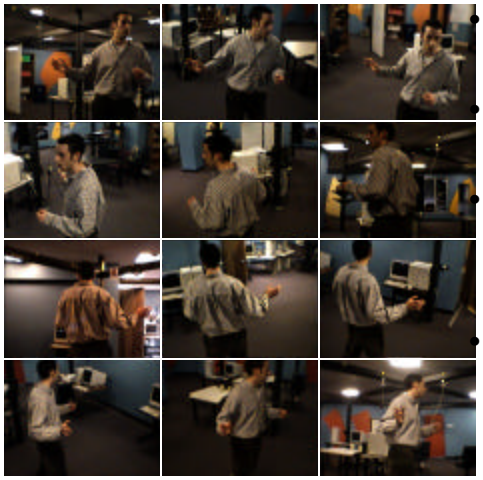
Current System



- Real-time image acquisition
- Silhouettes computed in parallel
- Silhouettes sent to a central machine
  - 15 per second
- Real-time Intersection and Visual Hull
  - In progress

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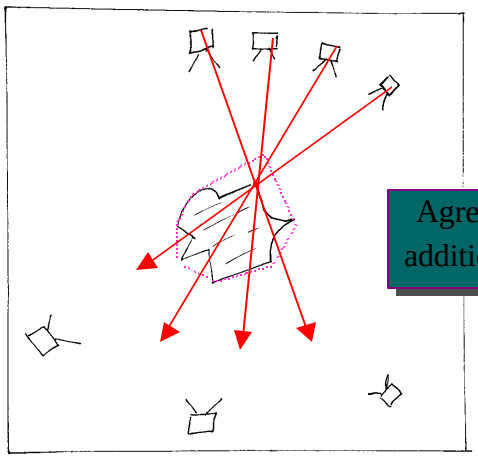
Visual Hull is very coarse …



Agreement provides additional information

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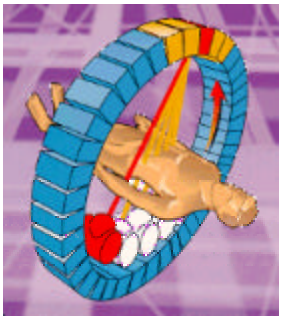
Tomographic Reconstruction

- Motivated by medical imaging
  - CT - Computed Tomography
  - Measurements are line integrals in a volume
  - Reconstruction is by back-projection & *deconvolution*



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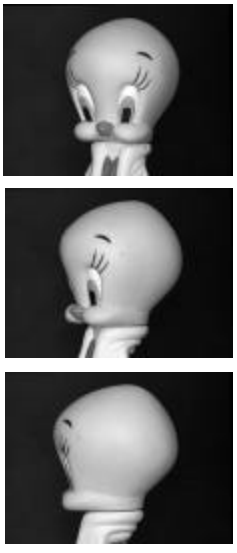
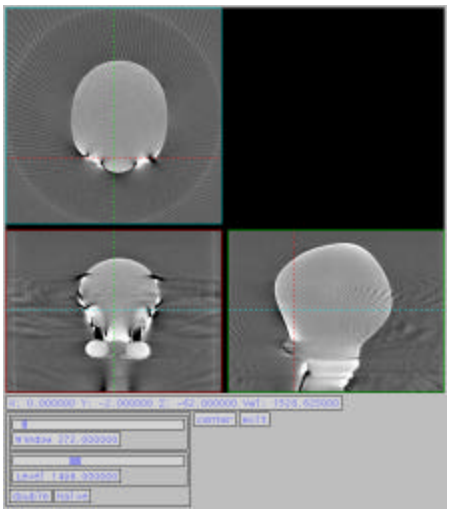
Back-projection of image intensities





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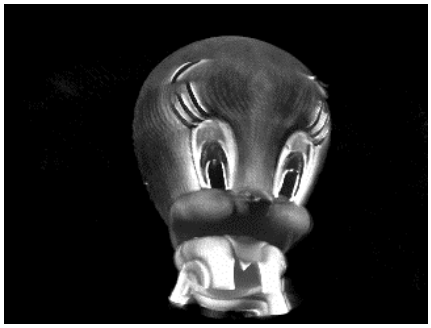
Volume Render...

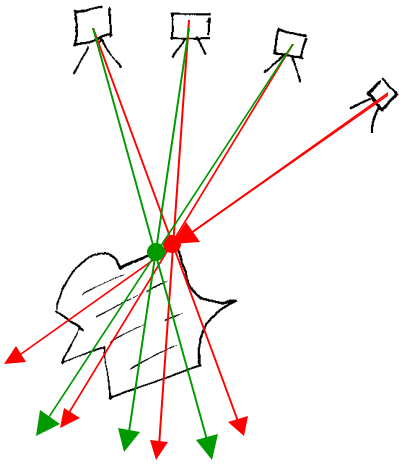


- Captures shape very well
- Intensities are not perfect

Poxels: An improvement to tomography

- Tomography confuses color with transparency
  - Does not model occlusion...
- The Probabilistic Voxel Approach: Poxel
  - Estimates both color and transparency
  - Models occlusion
  - Much better results
    - Though slower
  - Work submitted to ICCV 99

Occlusion causes disagreement



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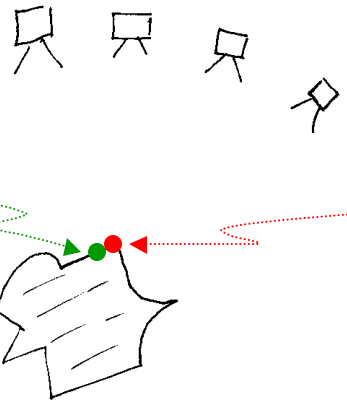
Initial agreement is not enough…



Agreement is poor

Agreement is high *"Opaque"*

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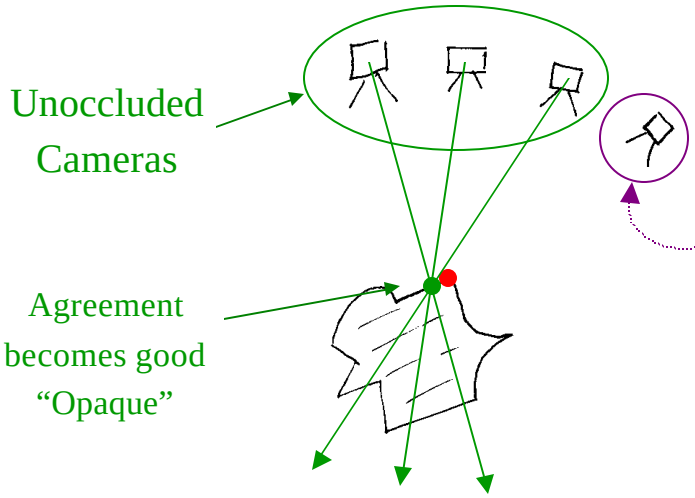
Second pass uses information about occlusion



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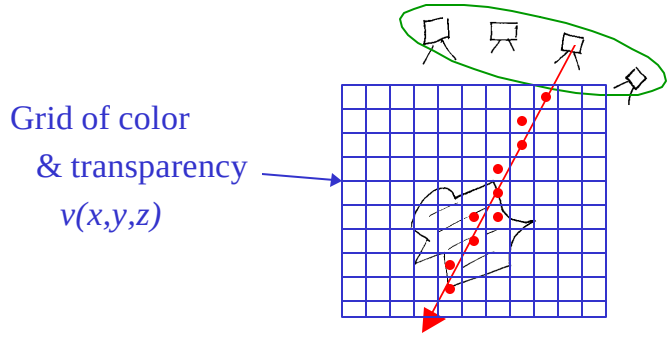
Poxels Algorithm: Definitions



$c(x,y,z)$	*colors*
$a(x,y,z)$	*transparancy*
$v(x,y,z)$	*voxels (color+trans)*
$I_k(u,v)$	*images*
$l_k(u,v,d)=(x,y,z)$	*ray castingimagek*

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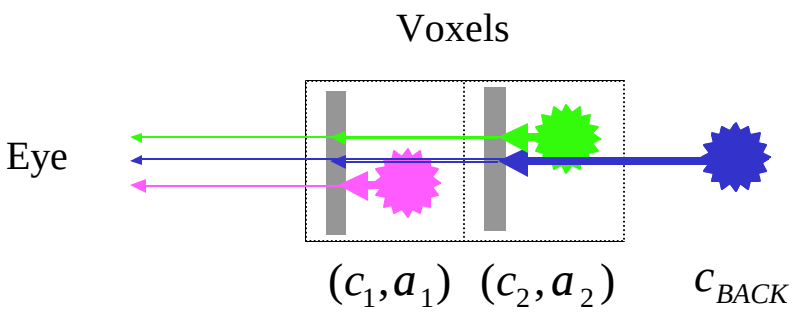
Poxels: Model of Transparency



$$\text{color} = a_1\left(c_1 + a_2\left(c_2 + c_{BACK}\right)\right)$$

$$\hat{I}_k(u,v) = v(l_k(u,v,1)) \wedge v(l_k(u,v,2)) \wedge \Lambda \wedge v(l_k(u,v,d))$$

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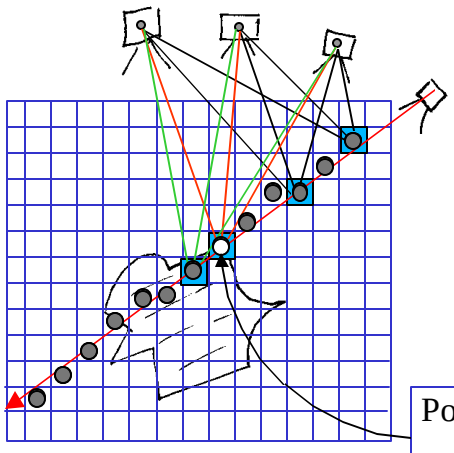
Poxels Algorithm: Agreement (Step 1)



Point of highest agreement

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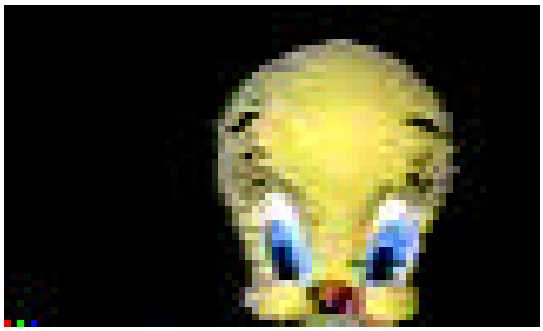
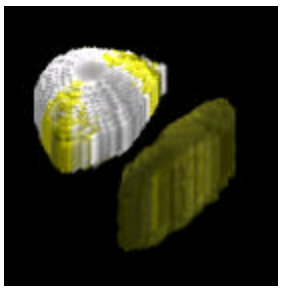
Results…



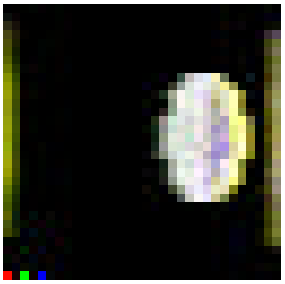
Rendering of reconstructed shape.

From ICCV paper...

Input Image



Reconstructed Volume



… additional results

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Image Databases: Motivating Scenario

- Image Databases are proliferating
  - The Web
  - Commercial Image Databases
  - Video Databases
  - Catalog Databases
    - "Find me a bag that looks like a Gucci."
  - Virtual Museums
    - "Find me impressionist portraits."
  - Travel Information
    - "Find me towns with Gothic architecture."
  - Real-estate
    - "Find me a home that is sunny and open."

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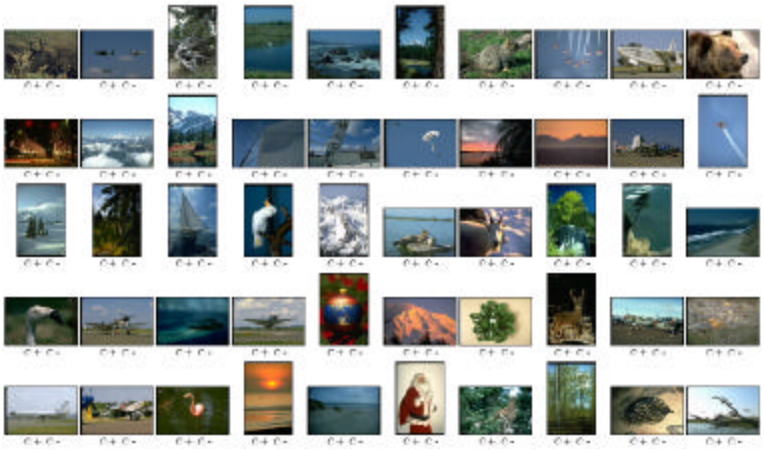
But, the problem is very hard…



There are a very wide variety of images...

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We have made good progress...

Query: “Waterfall Images”

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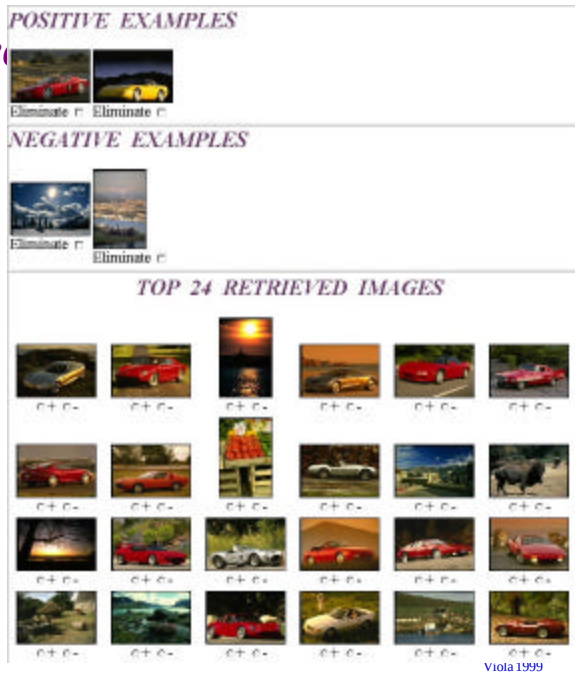
Se

Trained by example



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Complex Feature Representation

- Motivated by the Human brain…
  - Infero-temporal cortex computes many thousand selective features
  - Features are selective yet insensitive to unimportant variations
  - Every object/image has some but not all of these features
- Retrieval involves matching the most salient features

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Image Database Retrieval
NTT: Visit
1/7/99

Overview of IDB Meeting

- Motivation from MIT ...
- Discuss current and related work
  - Flexible Templates
  - Complex Features
  - Demonstrations
- Related NTT Efforts
- Discussion of collaboration
- Future work
- Dinner

Motivating Scenario

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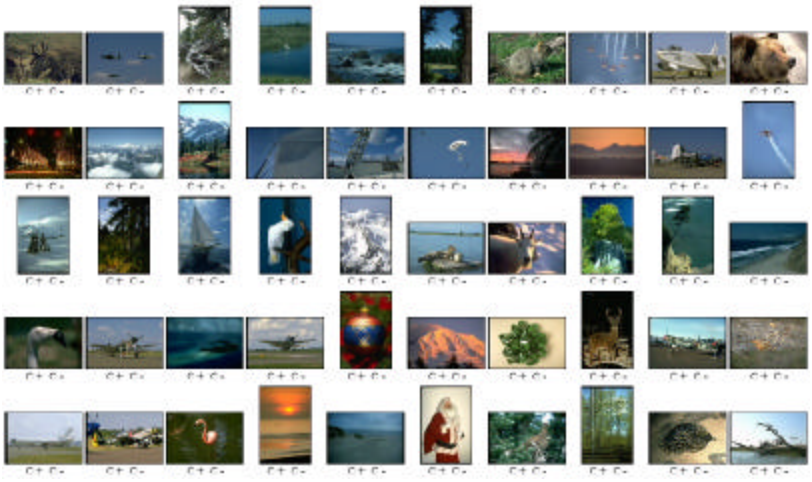

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Search for images containing waterfalls?

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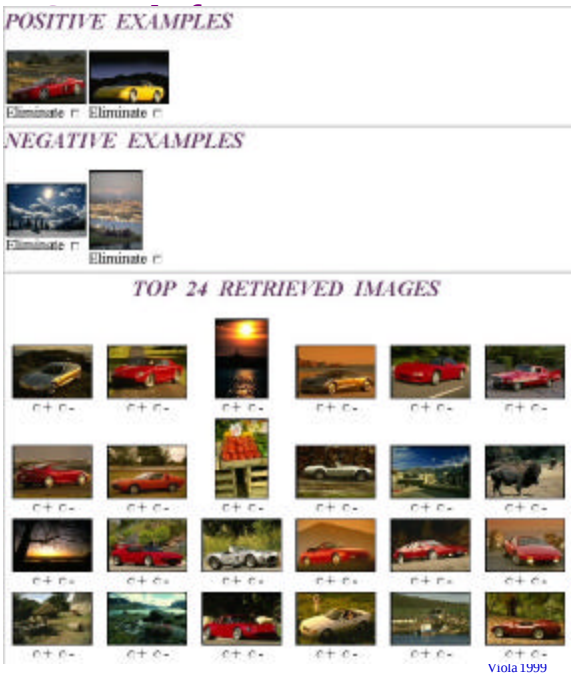

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What makes IDB hard?

- Finding the right features
  - Insensitive to movement of components
  - Sensitive to critical properties
- Focussing attention
  - Not everything matters
- Generalization based on class
  - Given two images
    - Small black dog & Large white dog
    - (Don't have much in common…)
  - Return other dogs

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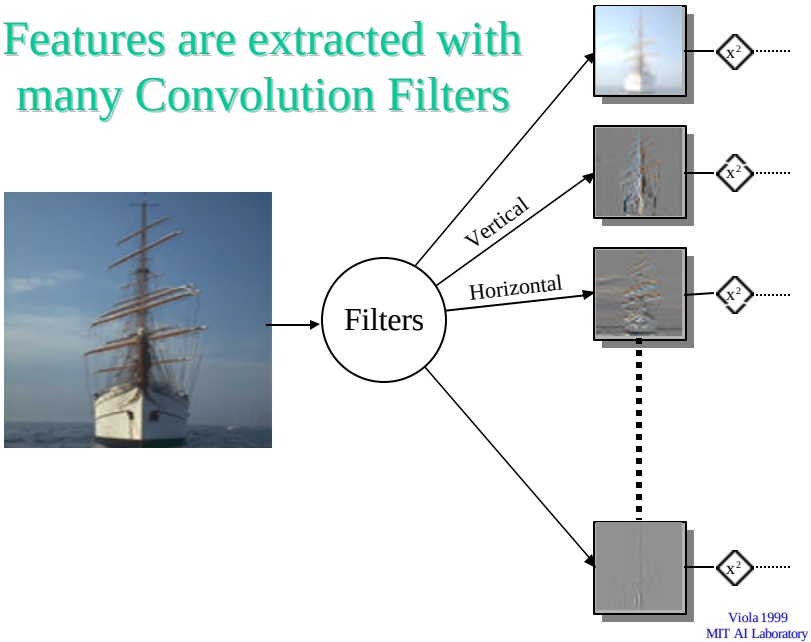
Features are extracted with many Convolution Filters



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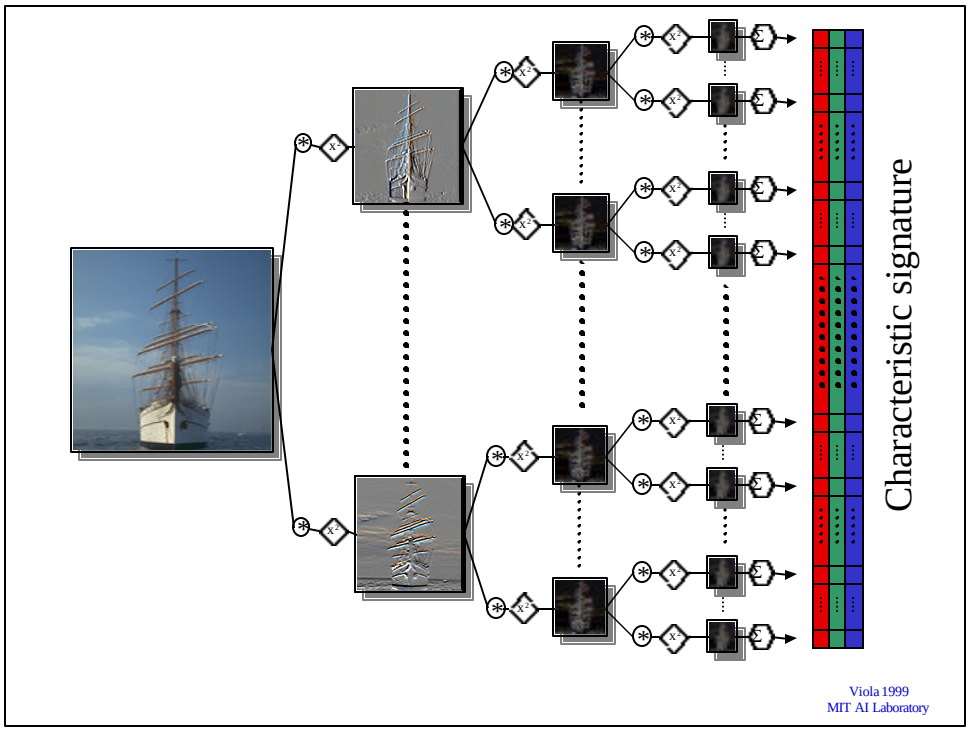
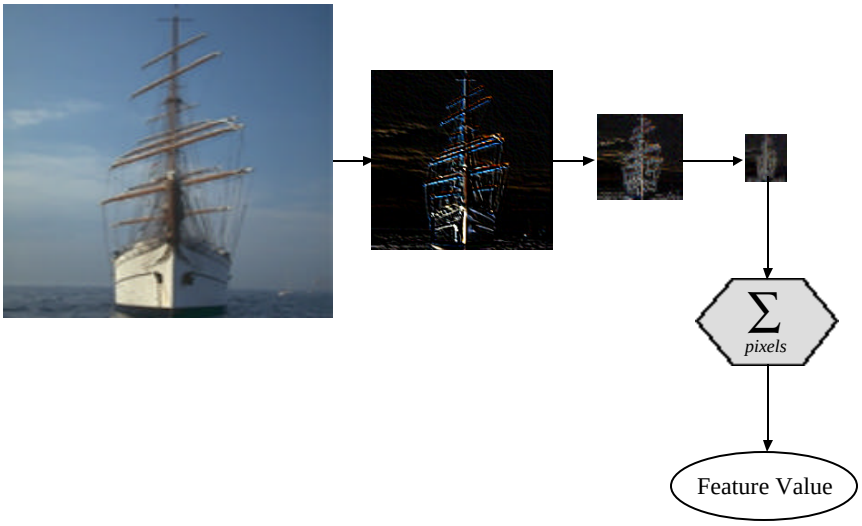
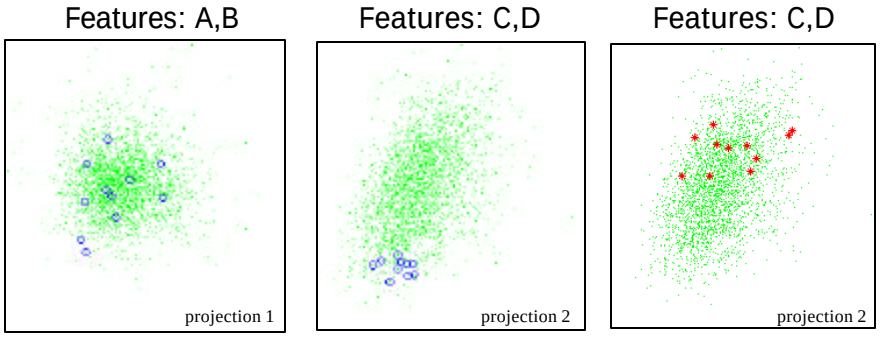


Resolution is reduced at each step…



Not every feature is useful for a query



Poor Features for query 1

Good Features for query 1

Poor Features for query 2

Query 1 (variation of object location)

Query 2 (variation of lighting)

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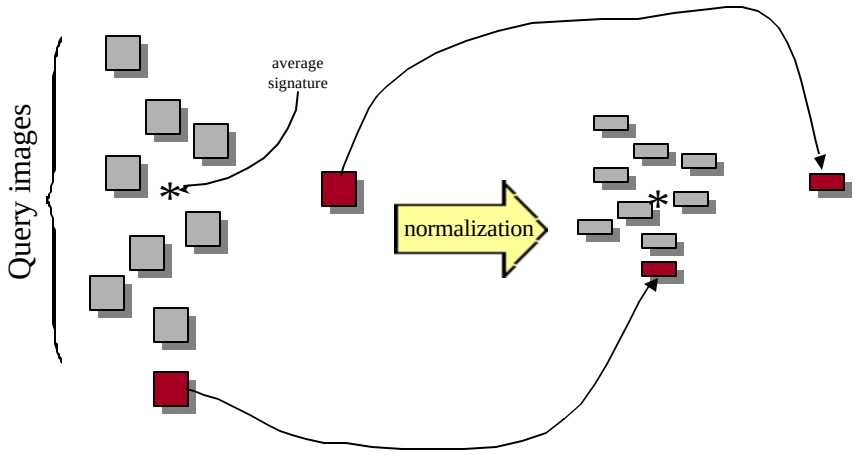
Normalization of Signature Space



•Normalization brings some image closer to the mean

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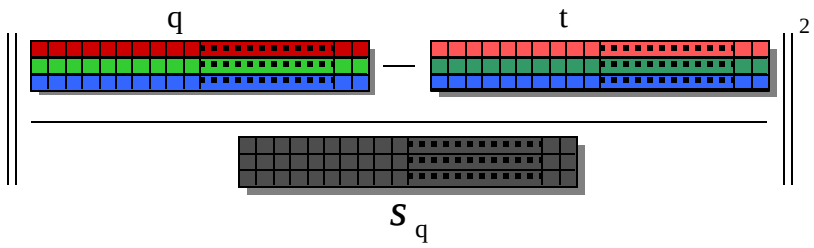
Distance/Similarity Measure



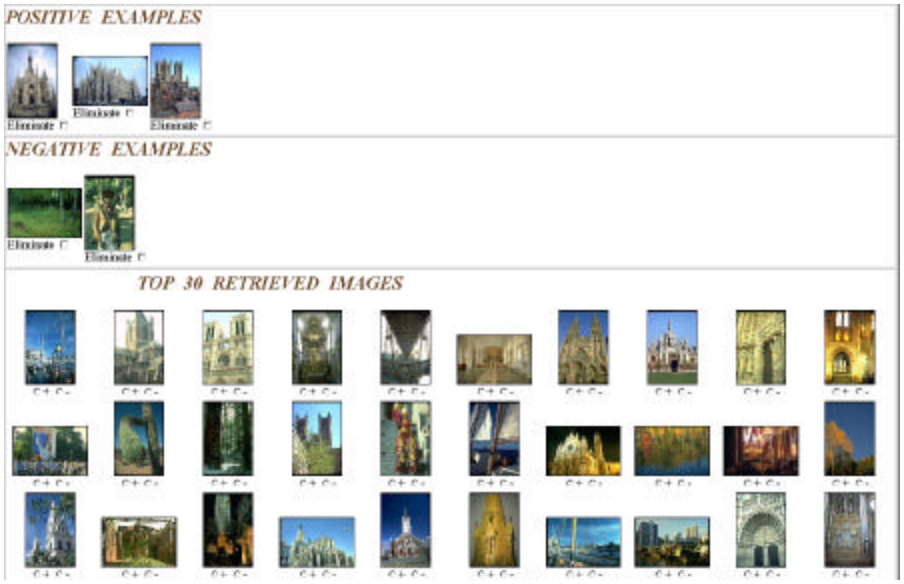
$$\sum_{e=0}^{25^3} \sum_{c=\{r,g,b\}} \left(\frac{\overline{q_{e,c}} - t_{e,c}}{s_{q_{e,c}}} \right)^2$$

Diagonal Mahalanobis Distance

Image Database Progress at MIT

- Better learning algorithms to select features
- Developed a very compact feature representation
  - Fewer features required
  - 2-3 bits per feature

  } factor of 72
- Pre-segmentation of images
  - Better learning
  - More selective queries
- Construction of object models:
  - Faces, people, cars, etc. (ICCV 99)



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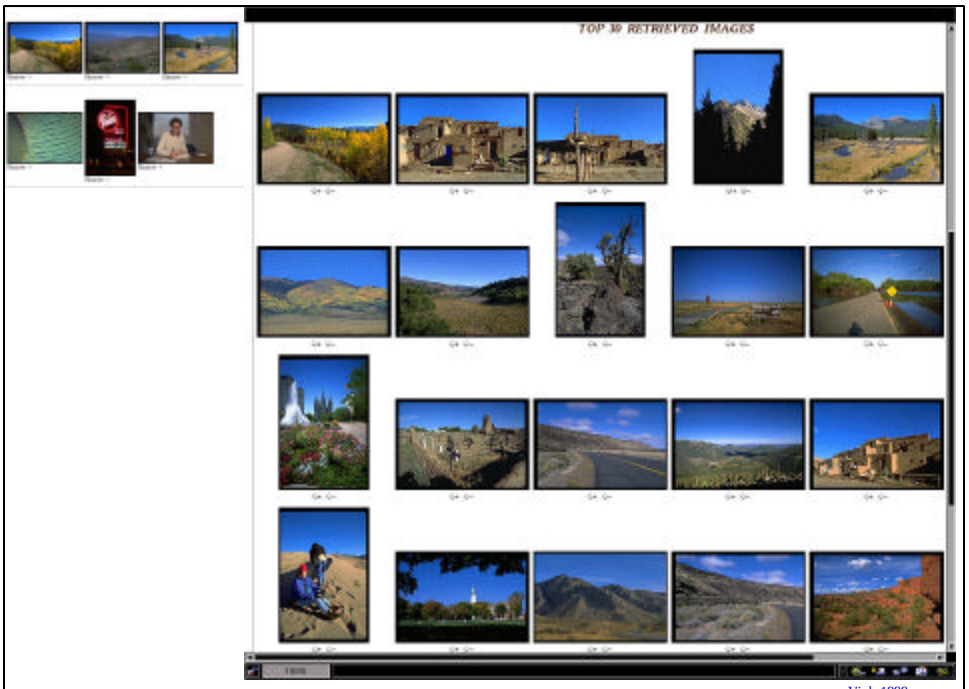

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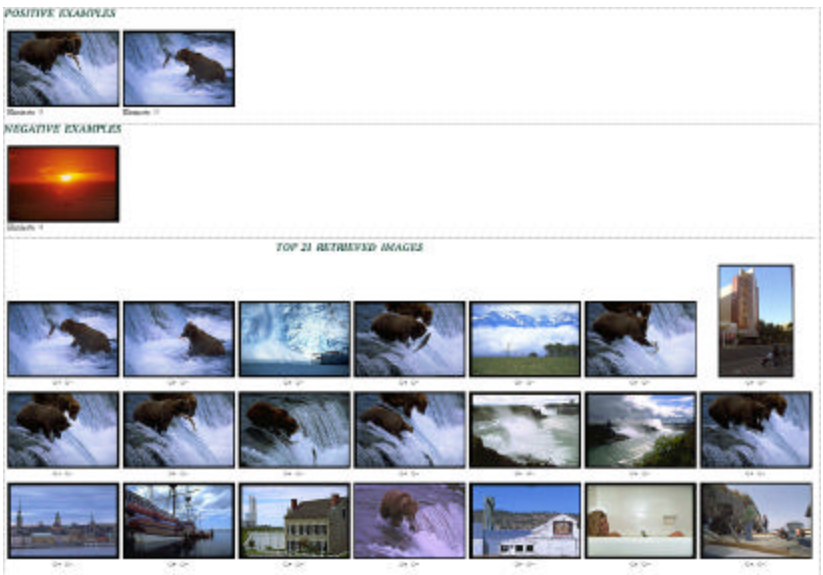

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Conclusions

- Variable Viewpoint Reality
  - Prototypes constructed
  - New approaches
- Image Database Retrieval
  - New more efficient representations
  - Improved performance