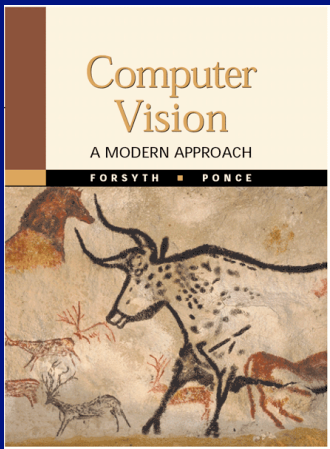


# Computer Vision

D.A. Forsyth



10 years old

6 months old

# COMPUTER VISION

A MODERN APPROACH

SECOND EDITION



FORSYTH | PONCE

# Conclusions

- Two major intertwining themes
  - Reconstruction
    - Build me a model of it
  - Recognition
    - What is this like
- Wildly successful field
  - 20 years ago:
    - eccentric preoccupation of few
  - Now:
    - massive impact, including numerous applications

# Conclusions (2)

- Core technologies
  - Describing local image patches
  - Classification
    - stick in a patch, get yes/no
  - Regression
    - stick in a patch, get out some value
  - Clustering
    - group together data items that are similar

# Example problems

- **Obstacle avoidance**
  - A cricketer avoids being hit in the head (->) (<-)
  - the gannet pulls its wings in in time, by measuring time to contact
- **Reconstructing representations of the 3D world**
  - from multiple views
  - from shading
  - from structural models, etc
- **Recognition**
  - draw distinctions between what is seen
    - is it soggy?
    - will it eat me?
    - can I eat it?
    - is it a cat?
    - is it my cat?

# Reconstruction

- Build me a model
  - from pictures
  - from video
  - containing
    - geometric information
    - surface texture information
    - where was the camera
- Core ideas
  - describing and matching points
  - camera geometry

# Matching

- Problem:
  - what matches what
- Solution
  - detailed local descriptions of points (SIFT)

Matching points is important





# Matching points

- A description of tiny gradients near point is distinctive
  - Lowe's SIFT feature

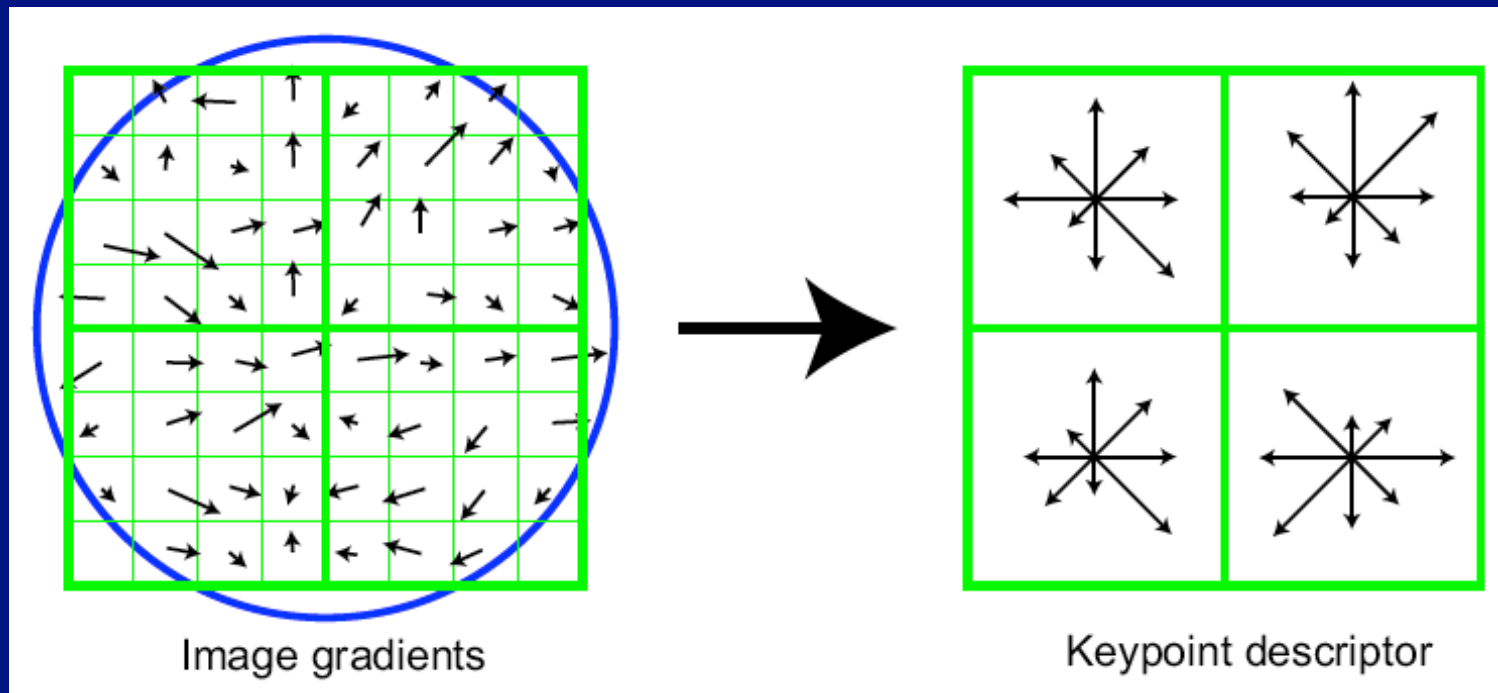
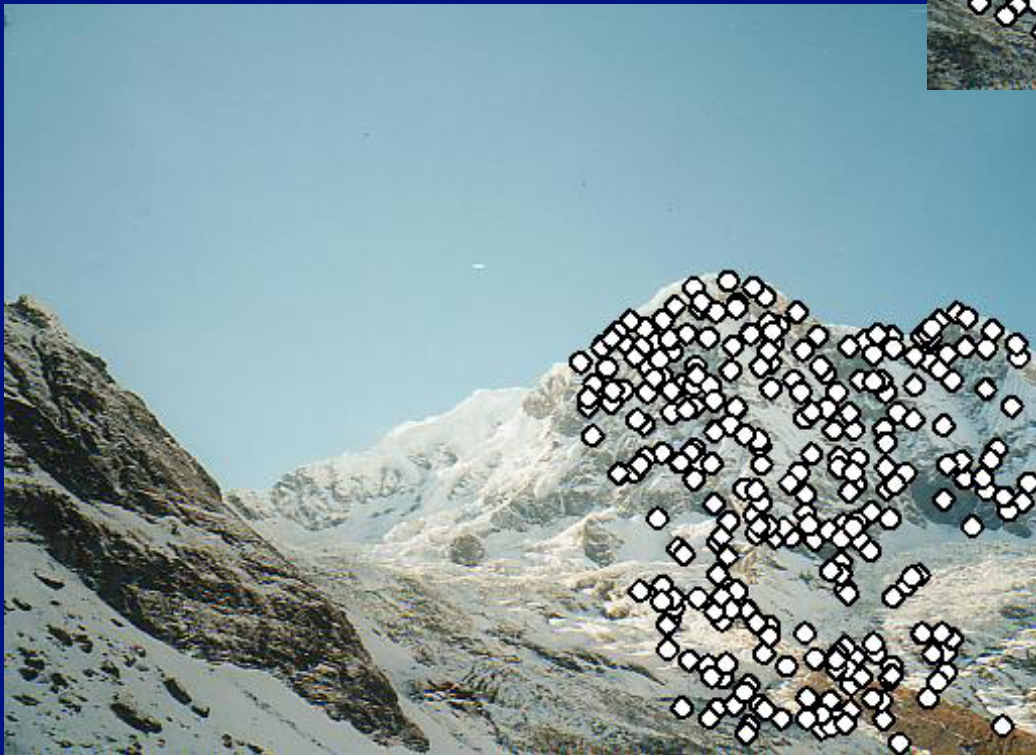
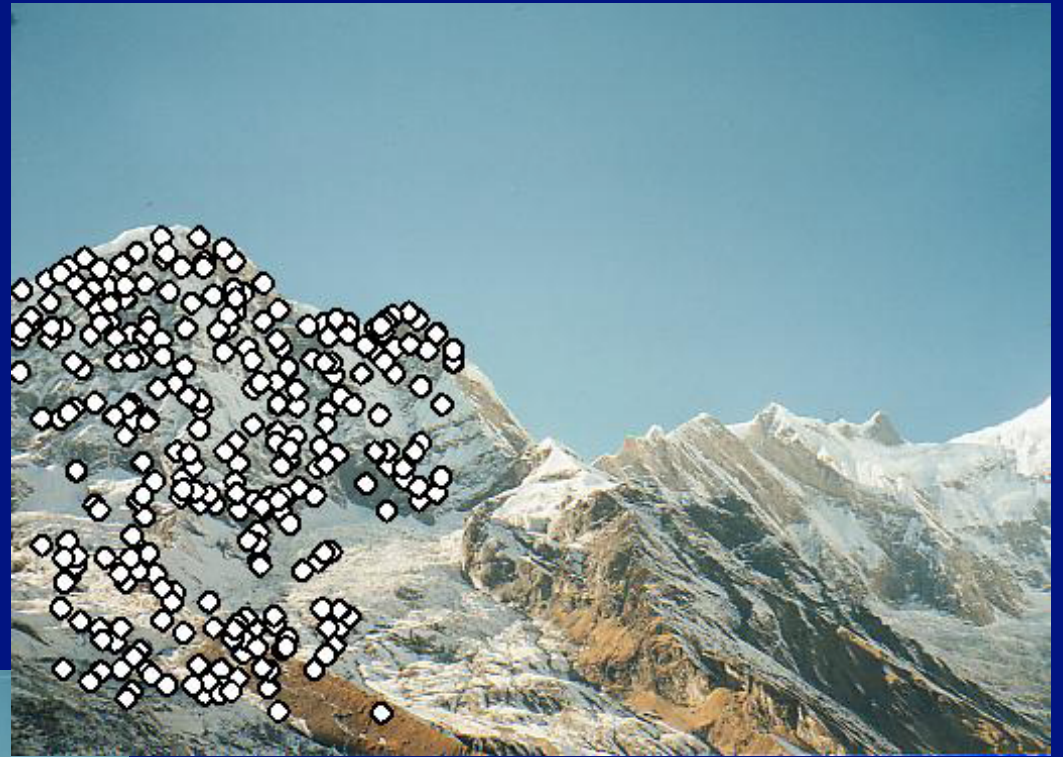


Fig 7 from:  
**Distinctive image features from scale-invariant keypoints**  
David G. Lowe, *International Journal of Computer Vision*, 60, 2 (2004), pp. 91-110.



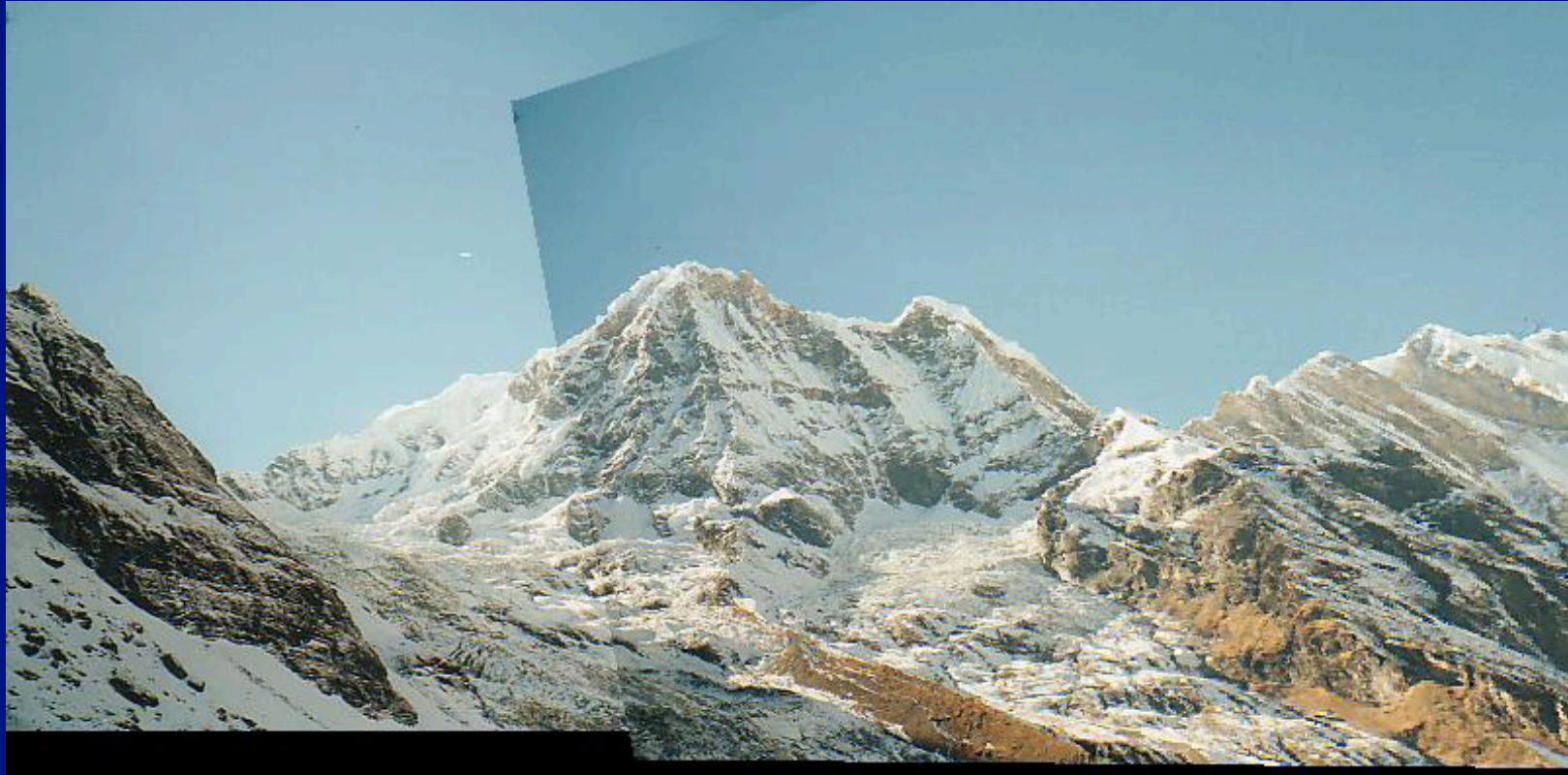
M. Brown and D. Lowe, "Recognising Panoramas", ICCV 2003



Translation isn't enough to align the images - we need to use a homography



M. Brown and D. Lowe, "Recognising Panoramas", ICCV 2003



M. Brown and D. Lowe, "Recognising Panoramas", ICCV 2003



M. Brown and D. Lowe, "Recognising Panoramas", ICCV 2003



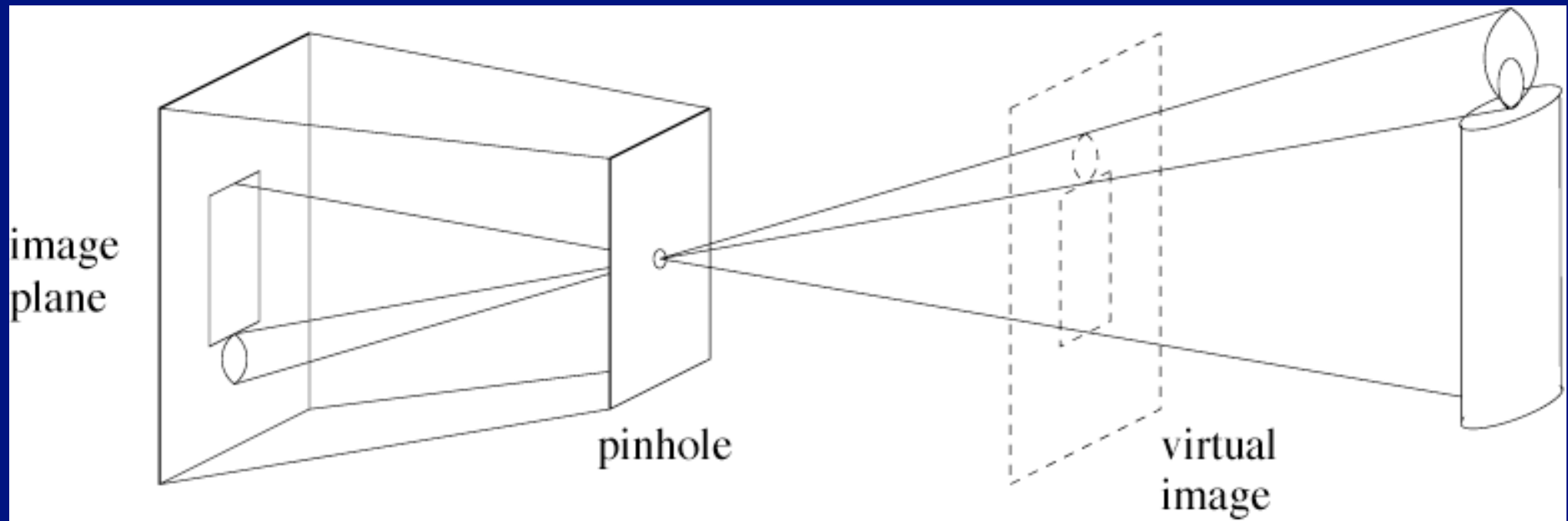
M. Brown and D. Lowe, "Recognising Panoramas", ICCV 2003



M. Brown and D. Lowe, "Recognising Panoramas", ICCV 2003

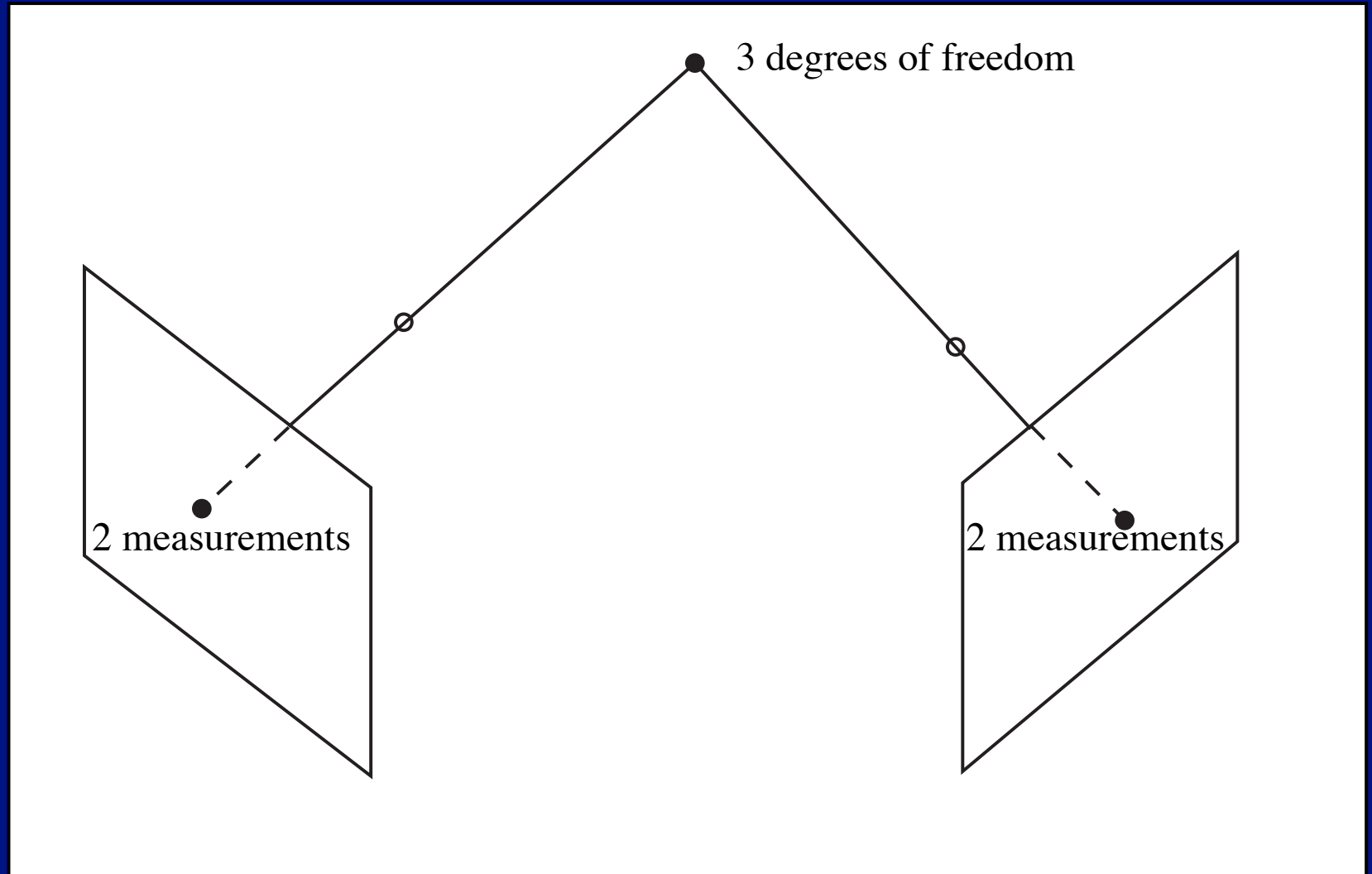
# How cameras work

Pinhole camera - an effective abstraction

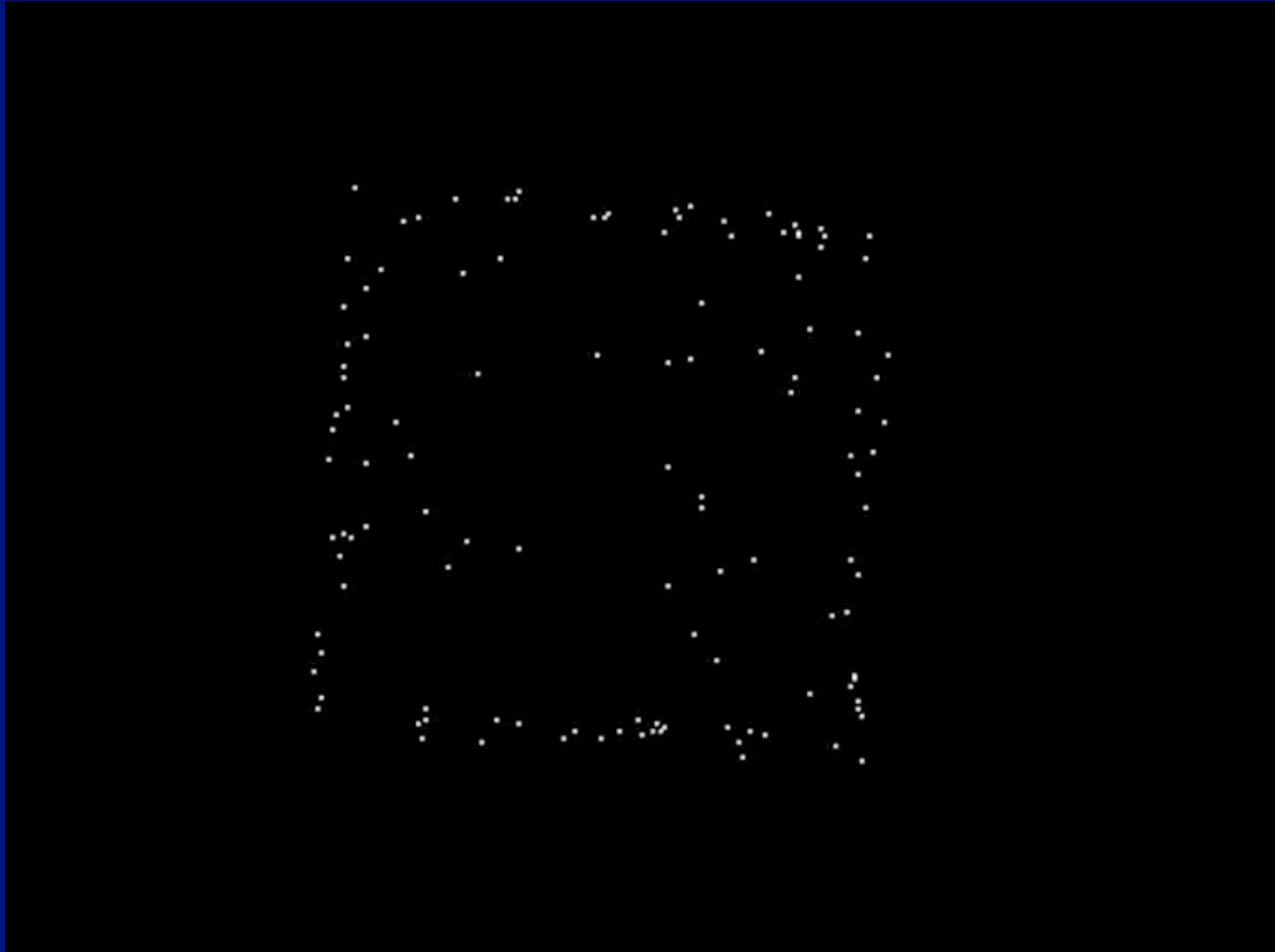




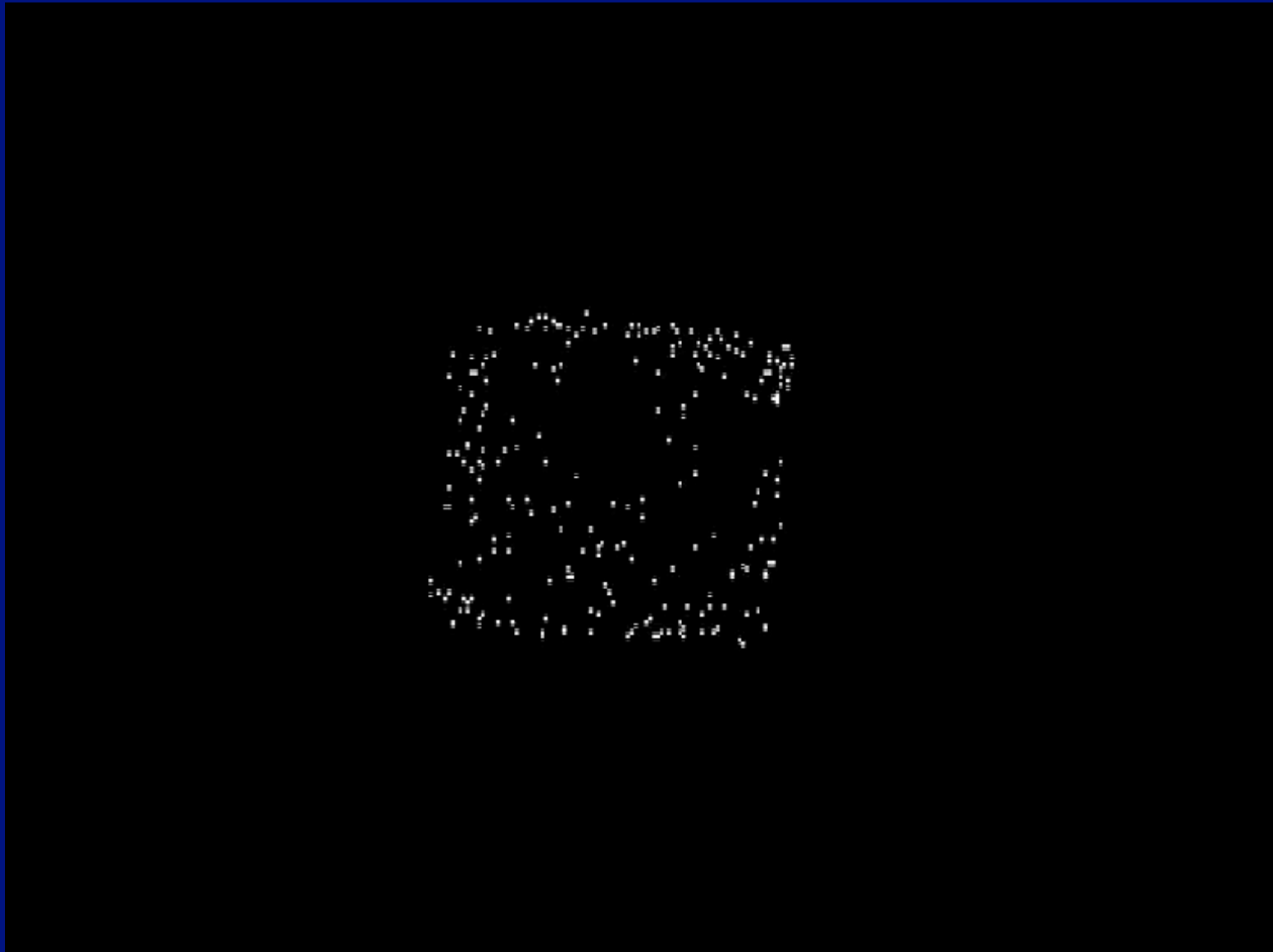
# What happens in two views



# Structure from motion



# Structure from motion

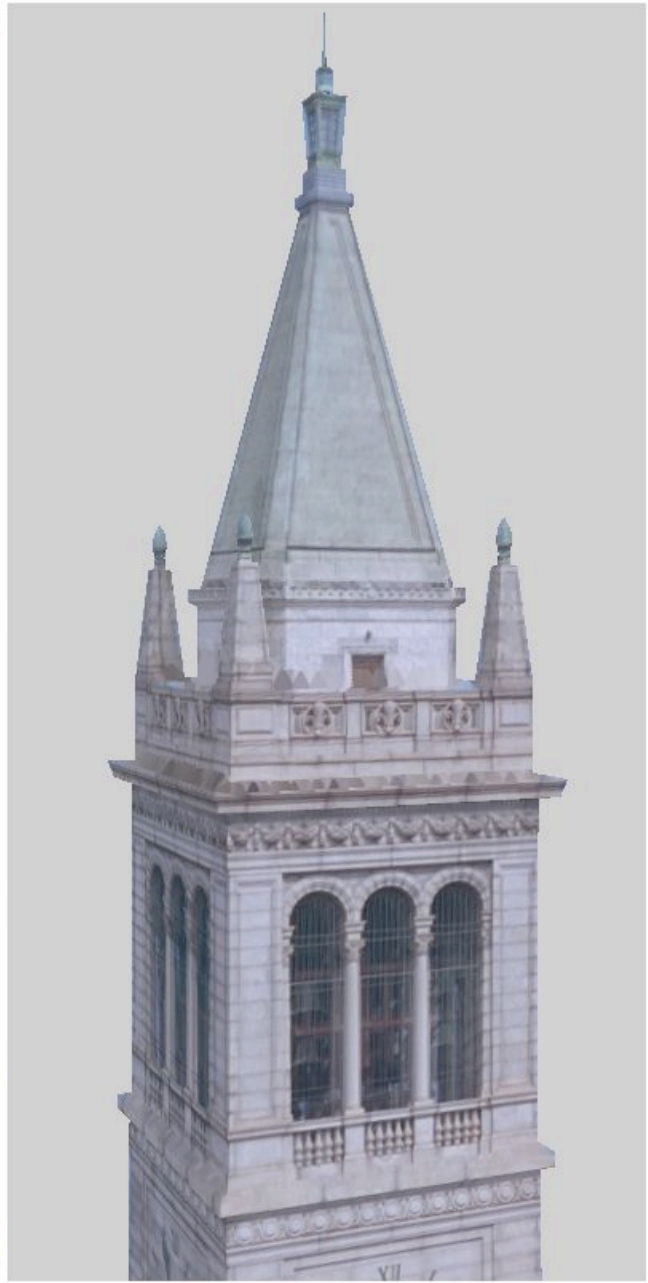


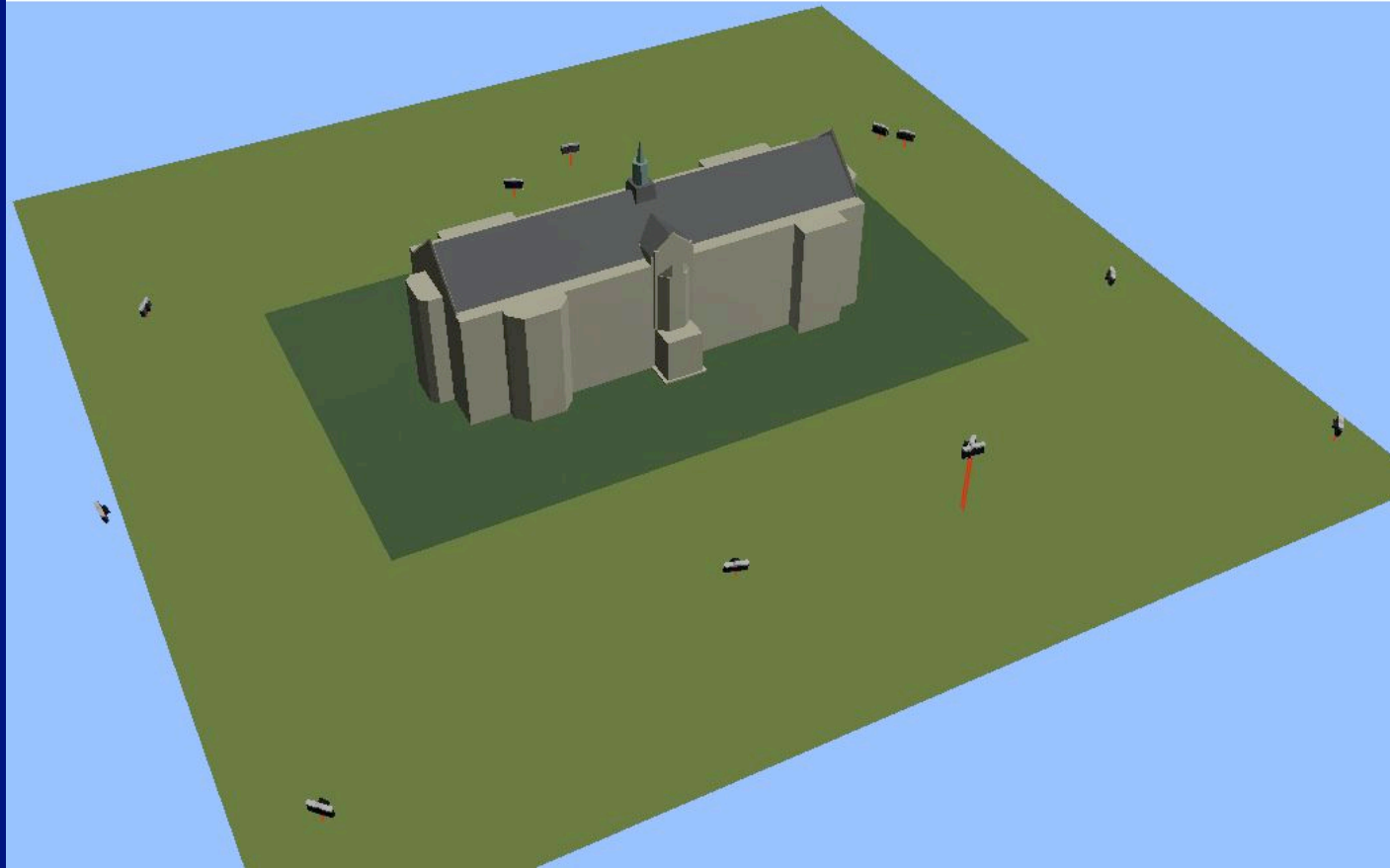
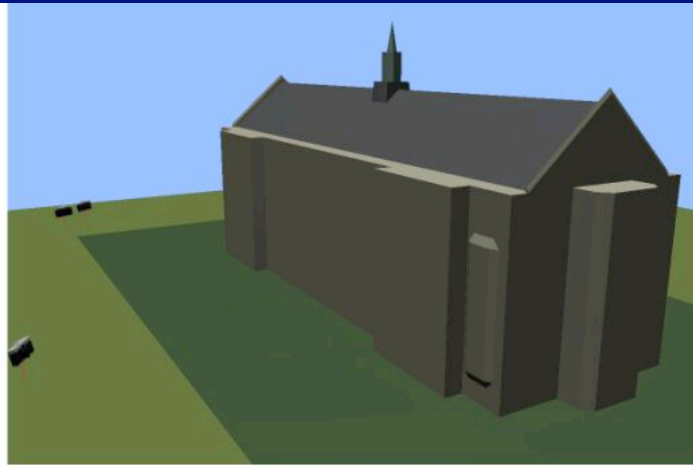
# All of Camera Geometry

- From the picture
  - two views of a point give four measurements of three DOF
  - this means
    - correspondence is constrained
    - if we have enough points and enough pix we can recover
      - points
      - cameras



Work by Paul Debevec and Jitendra Malik





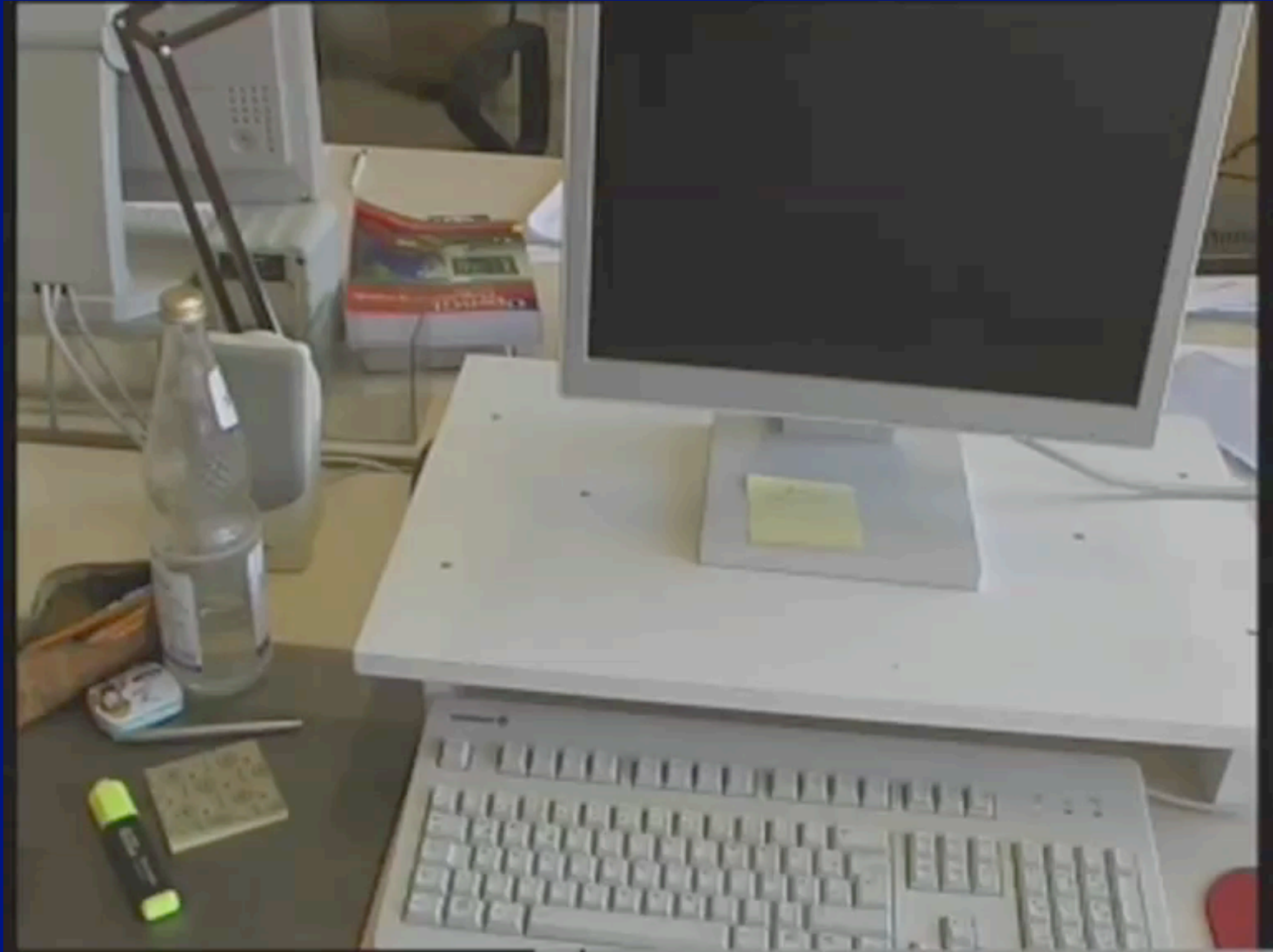


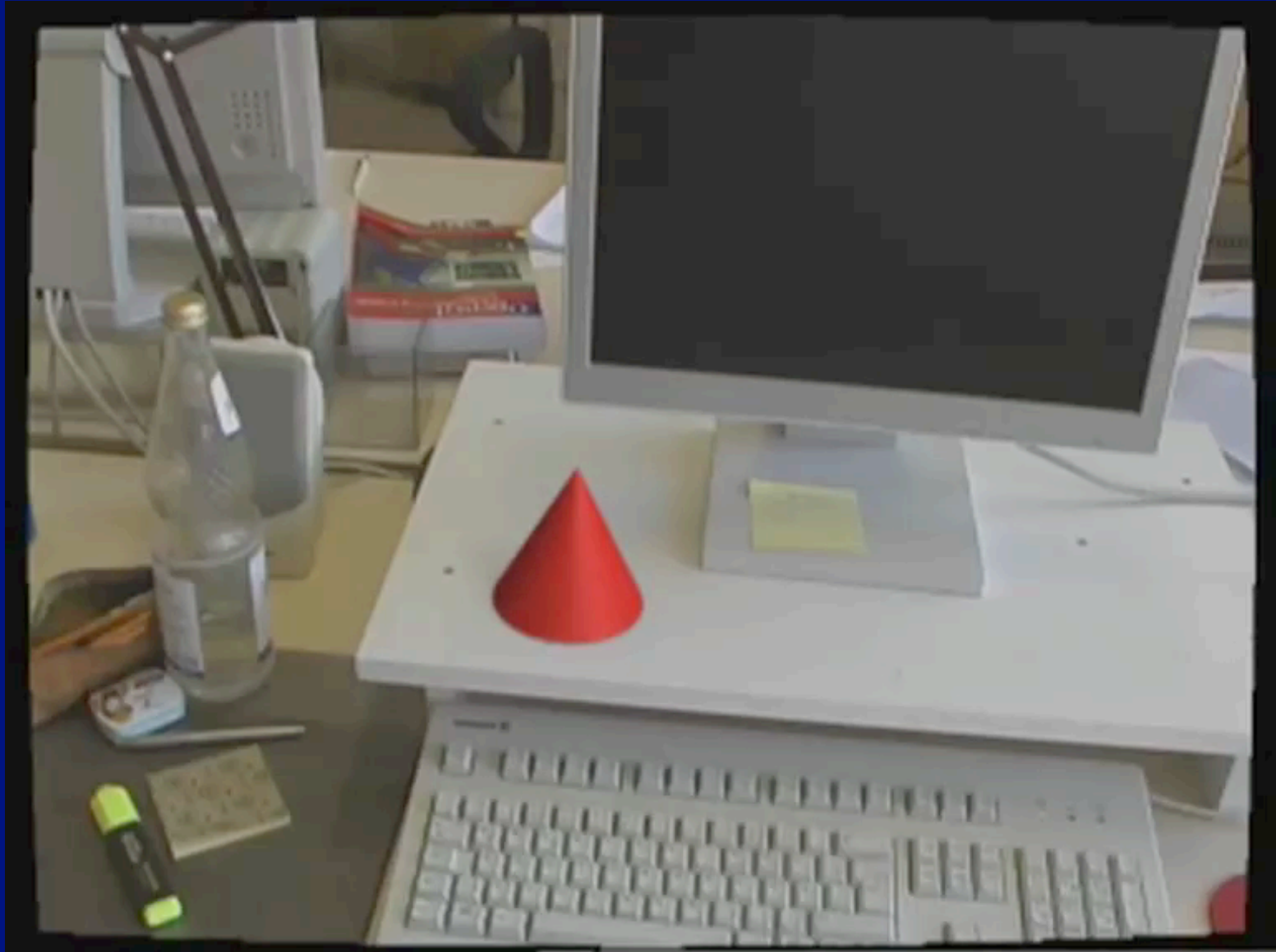
M. Pollefeys, L. Van Gool, M. Vergauwen, F. Verbiest, K. Cornelis, J. Tops, R. Koch, Visual modeling with a hand-held camera, *International Journal of Computer Vision* 59(3), 207-232, 2004



# Match moves

- If you know where the camera is for a sequence you can
  - attach a virtual sequence to the end smoothly
  - insert virtual objects realistically
- Commercial products
  - boujou, MatchMover, 3DEqualizer
- Free research software
  - voodoo





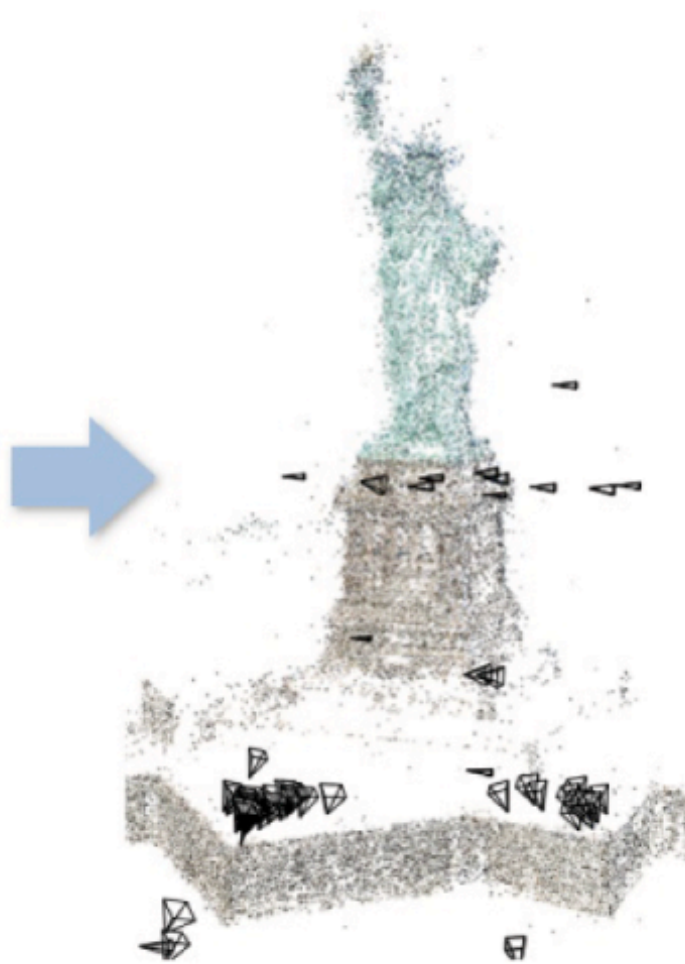


Capturing and animating occluded cloth - R White, K Crane, DA Forsyth SIGGRAPH 2007

a



b



c



M Goesele, N Snavely, B Curless, H Hoppe, "Multi-view stereo for community photo collections",  
ICCV 2007

# Photo Tourism

## Exploring photo collections in 3D

Noah Snavely   Steven M. Seitz   Richard Szeliski

*University of Washington*   *Microsoft Research*

[www.Flip4Mac.com](http://www.Flip4Mac.com)

SIGGRAPH 2006

Noah Snavely, Steven M. Seitz, Richard Szeliski, "Photo tourism: Exploring photo collections in 3D," ACM Transactions on Graphics (SIGGRAPH Proceedings), 25(3), 2006, 835-846.

# Reconstructions from one view

- Symmetry
- Horizontal / vertical planes and contours
- Special geometries
- Texture
- Shading

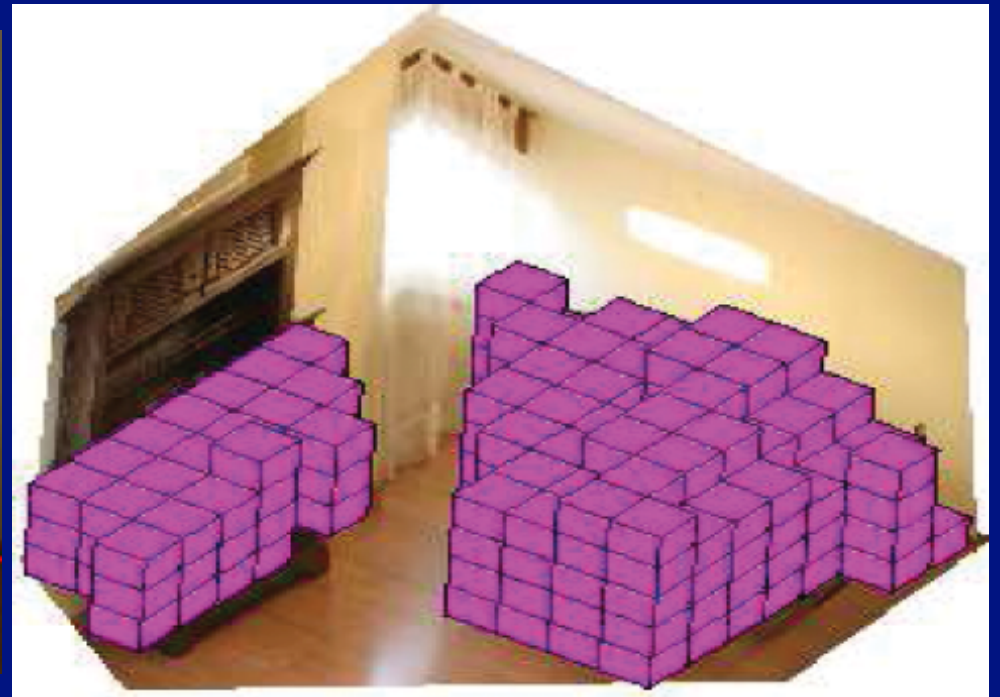
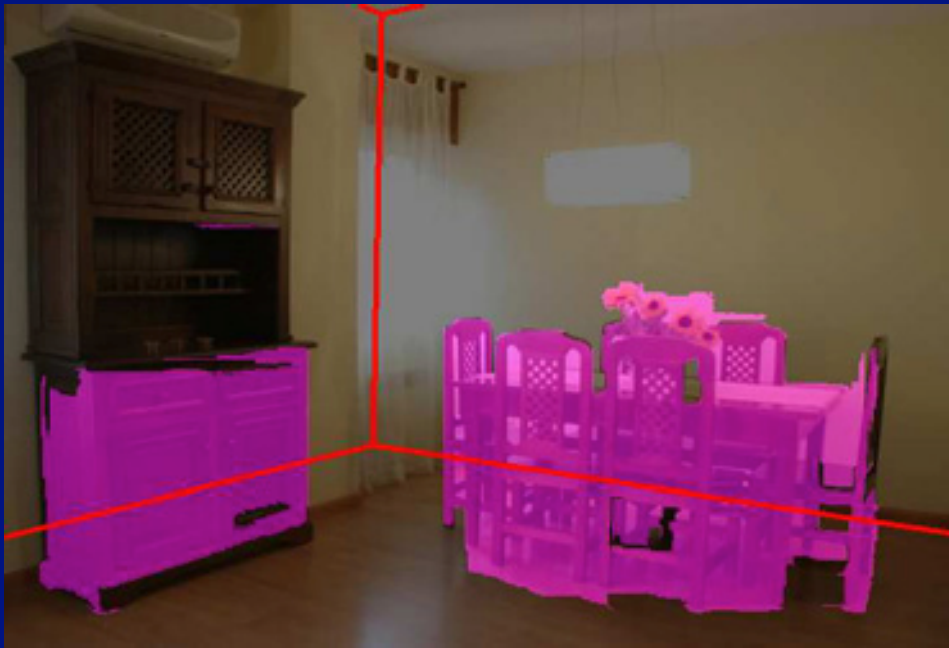
# **Automatic Photo Pop-up**

**D. Hoiem A.A. Efros M. Hebert  
Carnegie Mellon University**





V. Hedau, D. Hoiem, D.A. Forsyth, "Recovering the layout of cluttered rooms", ICCV 2009



V. Hedau, D. Hoiem, D.A. Forsyth, "Recovering the layout of cluttered rooms", ICCV 2009

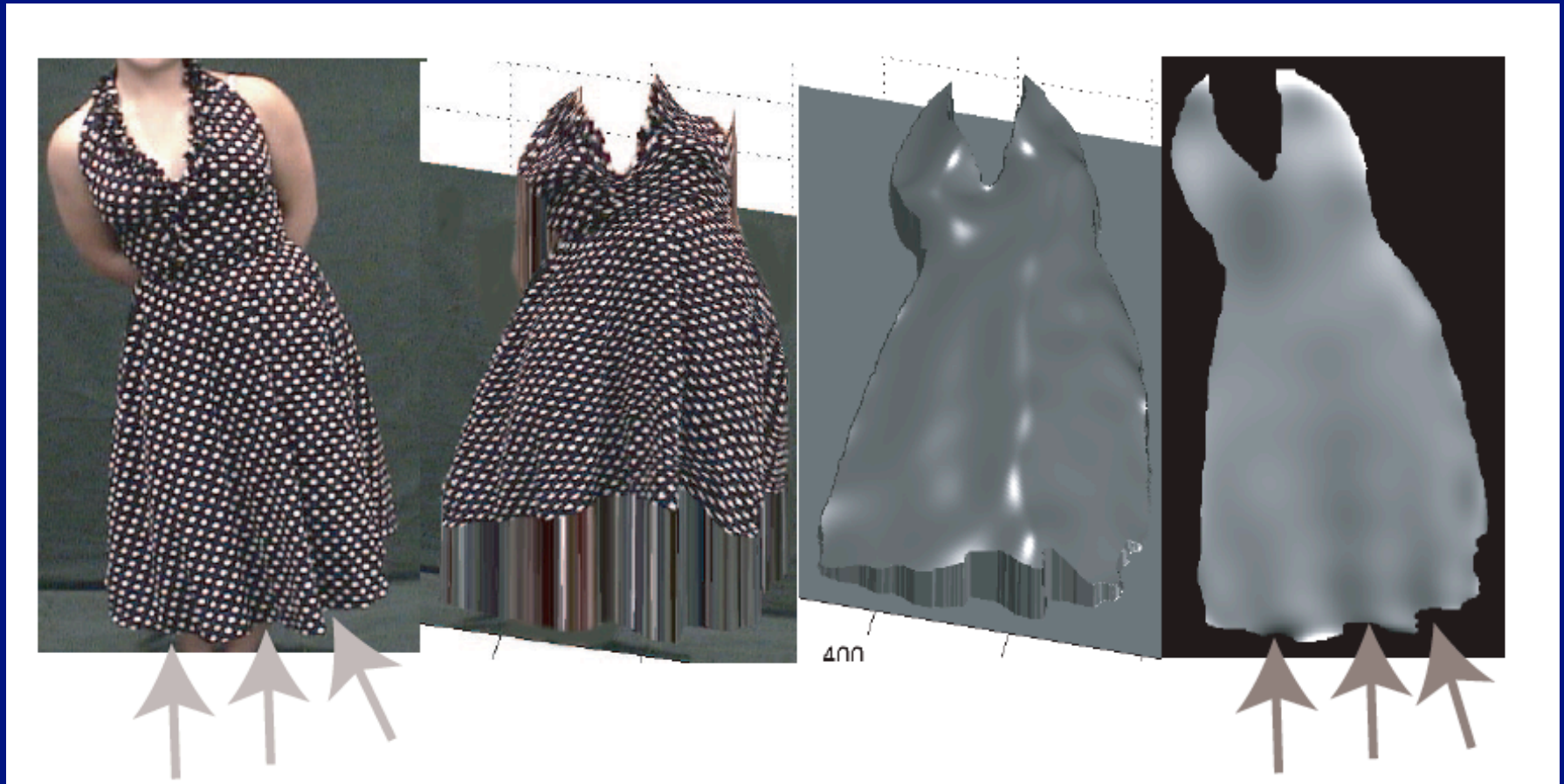




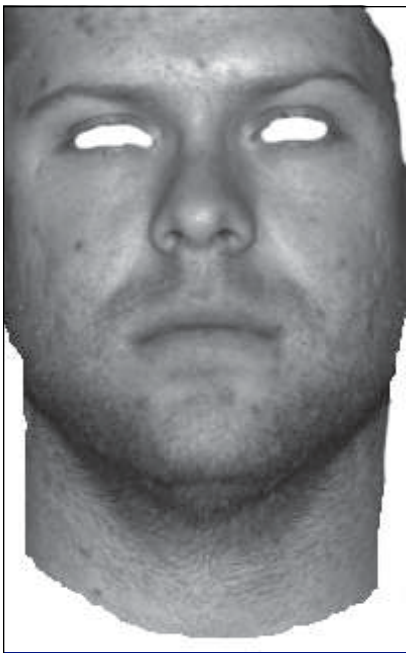
Shown at 2x speed



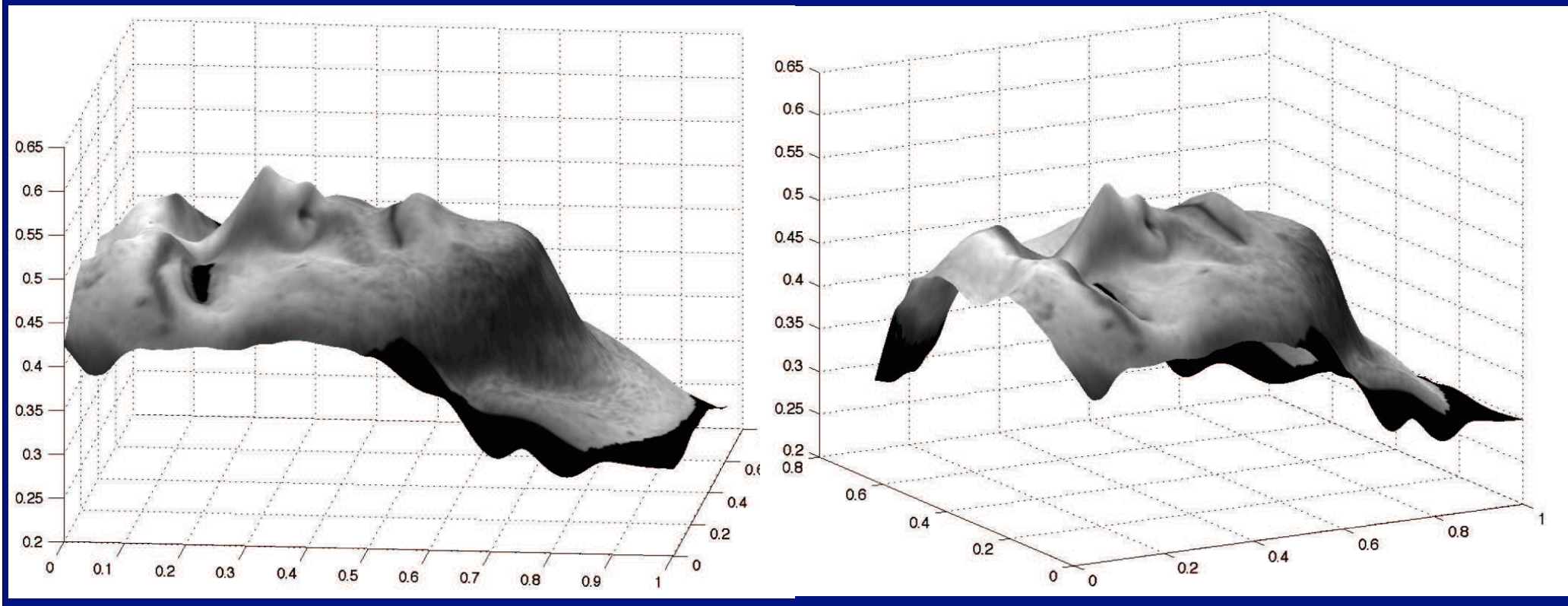
Karsch ea 11



A. Lobay and D.A. Forsyth, "Recovering shape and irradiance maps from rich dense texture fields",  
CVPR 2004



D.A. Forsyth, "Variable source shading analysis," In review



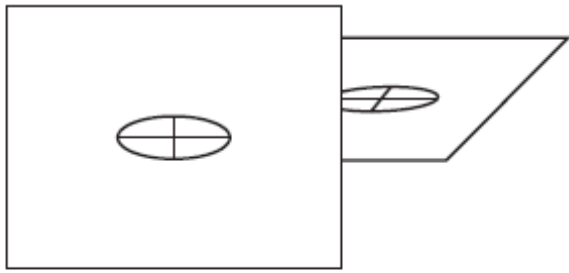


M.K. Johnson and E.H. Adelson “Retrographic sensing for the measurement of surface texture and shape”  
CVPR, 2009

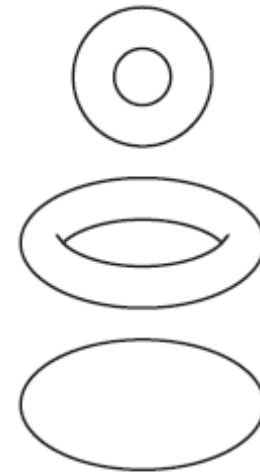


# Recognition

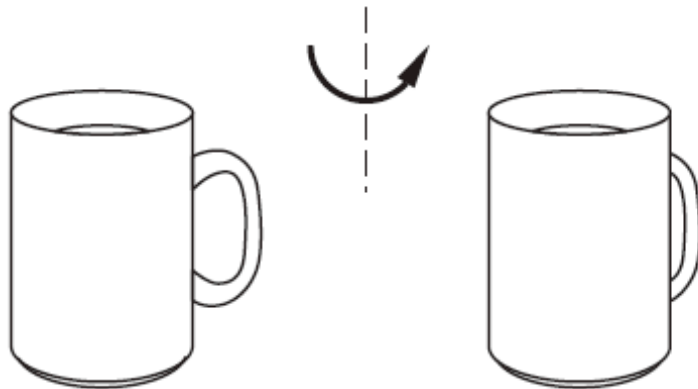
- Problem is somewhat vague
  - what is this
  - what is this like
- Major technologies
  - Classifier
    - stick in a feature, and it says yes/no
  - Rich local feature descriptors (like SIFT)



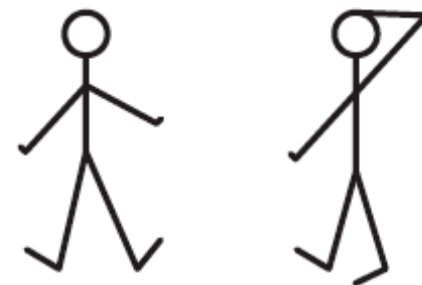
Foreshortening



Aspect



Occlusion



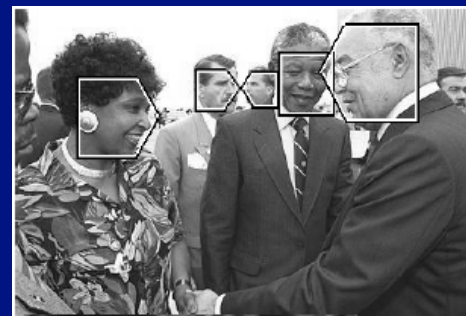
Deformation

# Finding faces

- Faces “look like” templates (at least when they’re frontal).
- General strategy:
  - search image windows at a range of scales
  - Correct for illumination
  - Present corrected window to classifier
- Issues
  - How corrected?
  - What features?
  - What classifier?
  - what about lateral views?

# Sliding window detection

- Detect instances of objects in images



# Sliding window detection



Windows



What the detector sees

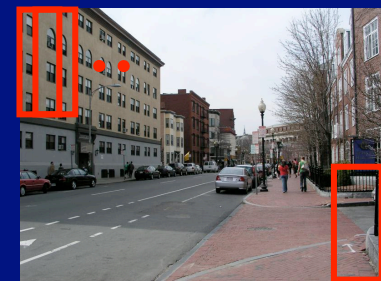
Detector: take a description of a window, say yes or no based on examples, statistical test

# Sliding window detection

- We use fixed size windows
  - find small objects
    - run windows over big version of picture

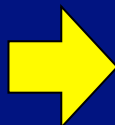


- find big objects
  - run windows over smaller version of picture



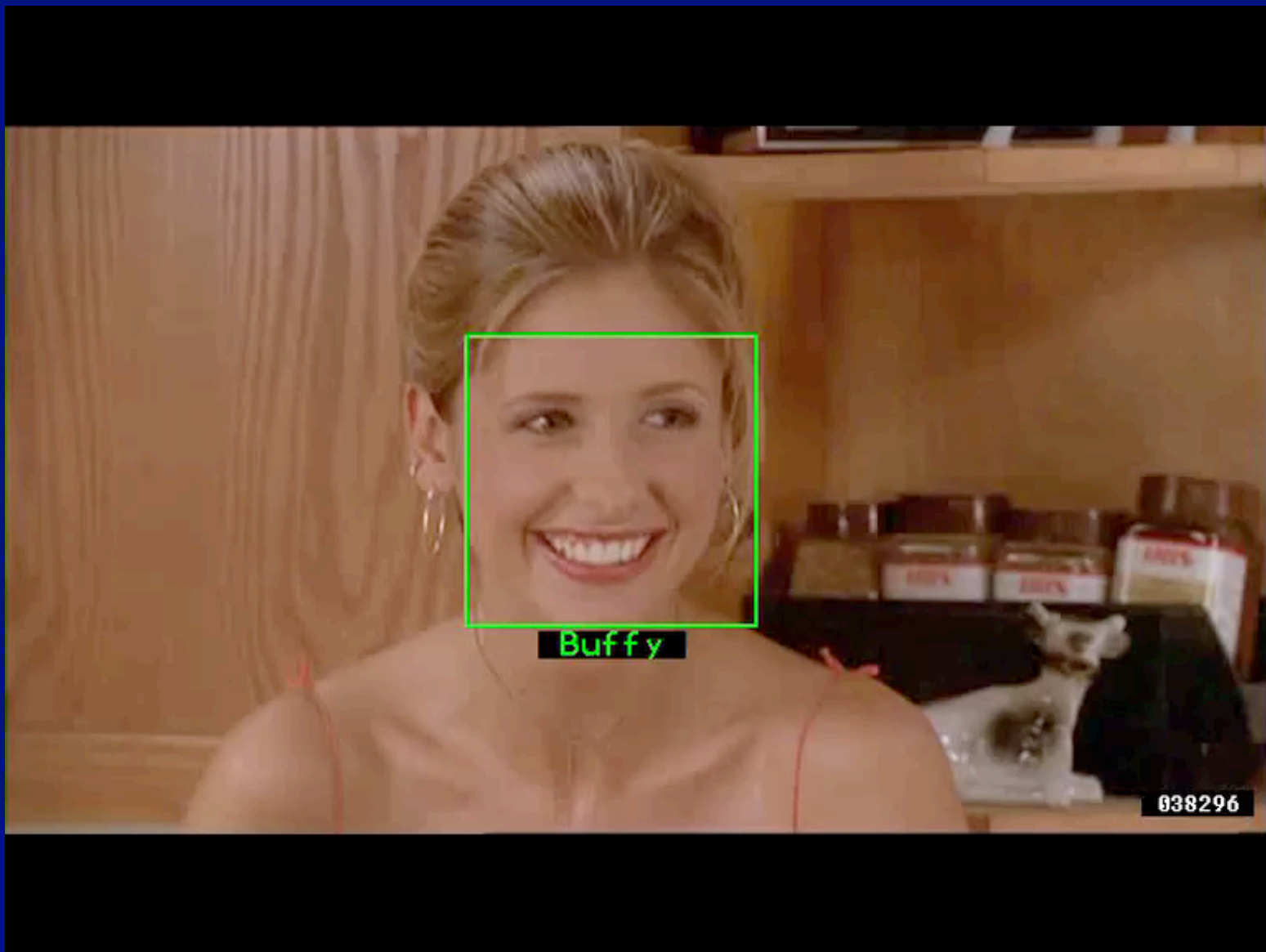


“Rotation invariant neural-network based face detection,”  
H.A. Rowley, S. Baluja and T. Kanade, CVPR 1998



President George W. Bush makes a statement in the Rose Garden while Secretary of Defense Donald Rumsfeld looks on, July 23, 2003. Rumsfeld said the United States would release graphic photographs of the dead sons of Saddam Hussein to prove they were killed by American troops. Photo by Larry Downing/Reuters





Everingham, M., Sivic, J. and Zisserman, A.  
“Hello! My name is... Buffy” - Automatic naming of characters in TV video  
BMVC 2006

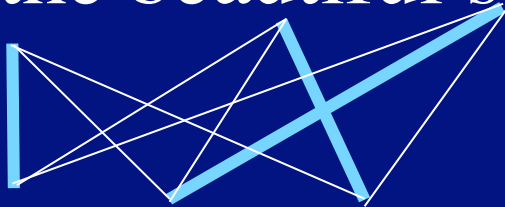


P. Felzenszwalb, D. McAllester, D. Ramanan. "A Discriminatively Trained, Multiscale, Deformable Part Model" CVPR 2008.

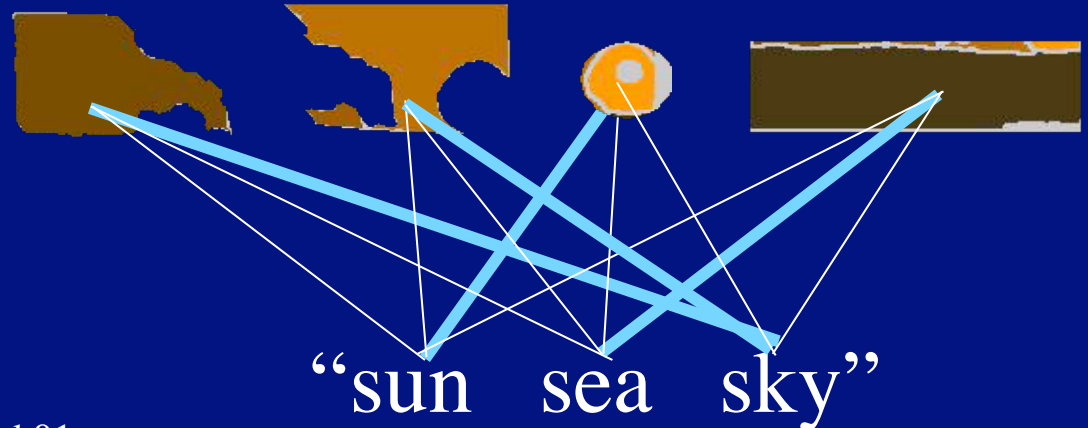
# Linking words and pictures

- In its simplest form, missing variable problem
- Caveats
  - might take a lot of data; symmetries, biases in data create issues

“the beautiful sun”



“le soleil beau”

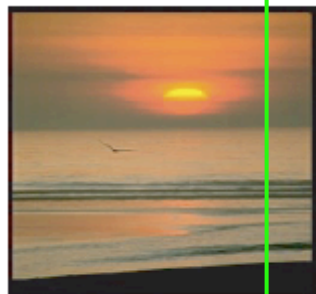


“sun sea sky”

Brown, Della Pietra, Della Pietra & Mercer 93; Melamed 01

Object recognition as machine translation: Learning a lexicon for a fixed image vocabulary -  
P Duygulu, K Barnard, JFG de Freitas, DA Forsyth ECCV 2002

It was there and we didn't



*sky, sun, clouds, sea, waves, birds, water*



*tree, people, sand, road, stone, statue, temple, sculpture, pillar*



*tree, birds, snow, fly*



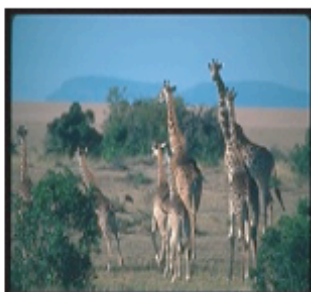
*sky, water, tree, plane, elephant, herd*



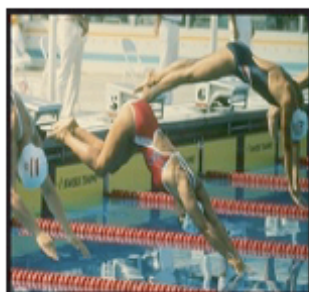
*mountain, sky, water, clouds, tree*



*sky, sun, jet, plane*



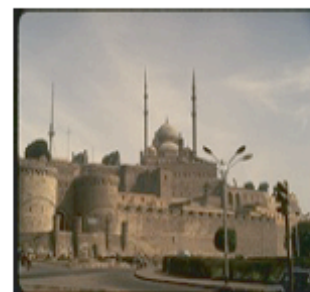
*mountain, sky, water, tree, grass, plane, ground, giraffe*



*water, people, pool, swimmers*



*tree, people, shadows, road, stone, statue, sculpture, pillar*



*people, buildings, stone, temple, sculpture, pillar, mosque*

It was there and we predicted it

It wasn't and we did

Scene Discovery by Matrix Factorization, N Loeff, A Farhadi, ECCV 2008

# Predicting stylized narrations

**Pitching**  
**Hit**  
**Run** **Run**  
**Catch**  
**Throw**  
**Catch**

Pitcher pitches the ball before Batter hits. Batter hits and then simultaneously Batter runs to base and Fielder runs towards the ball. Fielder catches the ball after Fielder runs towards the ball. Fielder catches the ball before Fielder throws to the base. Fielder throws to the base and then Fielder at Base catches the ball at base .

**Pitching**  
**Hit**  
**Catch**

Pitcher pitches the ball and then Batter hits. Fielder catches the ball after Batter hits.

**Pitching**  
**Hit**  
**Run** **Run**  
**Catch**  
**Throw**  
**Catch**

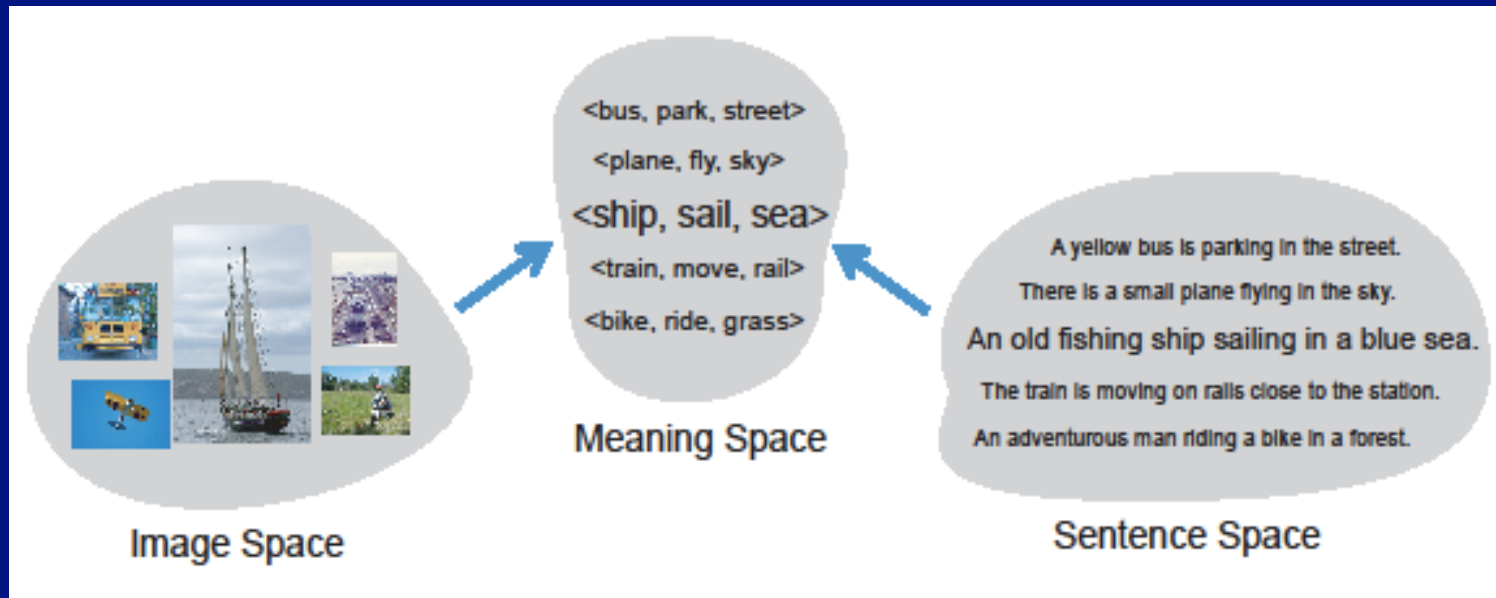
Pitcher pitches the ball before Batter hits. Batter hits and then simultaneously Batter runs to base and Fielder runs towards the ball. Fielder runs towards the ball and then Fielder catches the ball. Fielder throws to the base after Fielder catches the ball. Fielder throws to the base and then Fielder at Base catches the ball at base .

**Pitching**  
**Miss**

Pitcher pitches the ball and then Batter does not swing.





# Rich(ish) sentences from simple intermediates

Object, action, scene

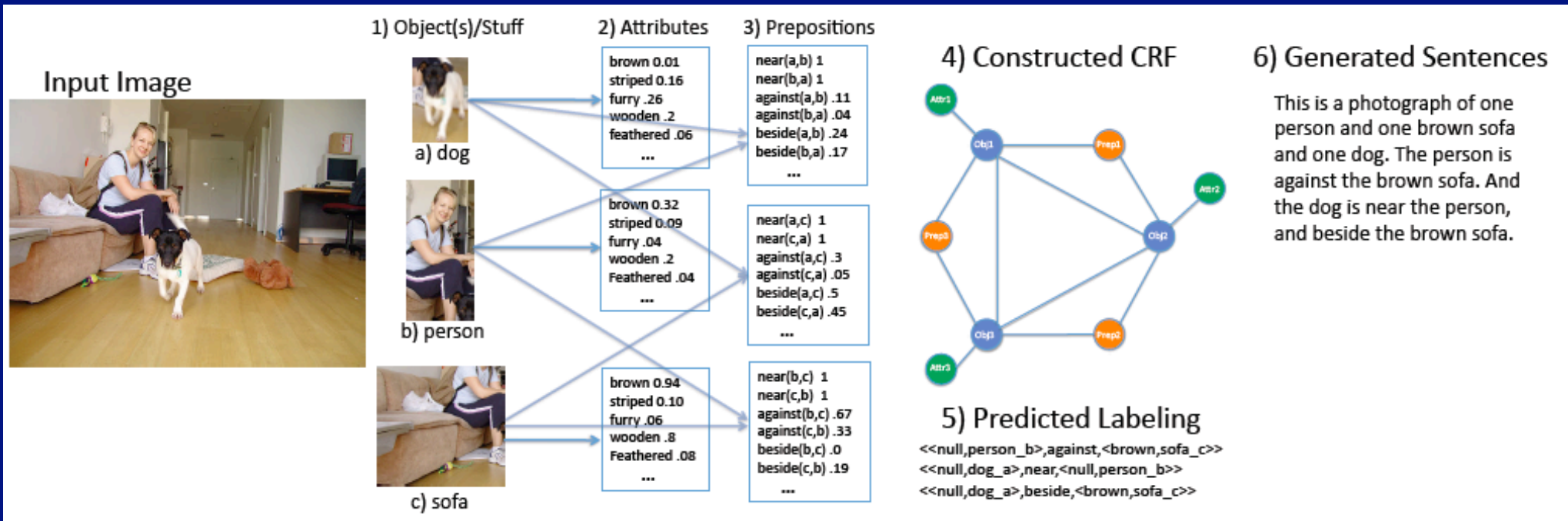


Farhadi ea 10

# Examples

	<p>(pet, sleep, ground)          (dog, sleep, ground)          (animal, sleep, ground)          (animal, stand, ground)          (goat, stand, ground)</p>	<p>see something unexpected.          Cow in the grassfield.          Beautiful scenery surrounds a fluffly sheep.          Dog hearing sheep in open terrain.          Cattle feeding at a trough.</p>
	<p>(furniture, place, furniture)          (furniture, place, room)          (furniture, place, home)          (bottle, place, table)          (display, place, table)</p>	<p>Refrigerator almost empty.          Foods and utensils.          Eatables in the refrigerator.          The inside of a refrigerator apples, cottage cheese, tupperwares and lunch bags.          Squash apenny white store with a hand statue, picnic tables in front of the building.</p>
	<p>(transportation, move, track)          (bike, ride, track)          (transportation, move, road)          (pet, sleep, ground)          (bike, ride, road)</p>	<p>A man stands next to a train on a cloudy day          A backpacker stands beside a green train          This is a picture of a man standing next to a green train          There are two men standing on a rocky beach, smiling at the camera.          This is a person laying down in the grass next to their bike in front of a strange white building.</p>
	<p>(display, place, table)          (furniture, place, furniture)          (furniture, place, furniture)          (bottle, place, table)          (furniture, place, home)</p>	<p>This is a lot of technology.          Somebody's screensaver of a pumpkin          A black laptop is connected to a black Dell monitor          This is a dual monitor setup          Old school Computer monitor with way to many stickers on it</p>

# Adding Attributes and Prepositions





# Adding Attributes and Prepositions



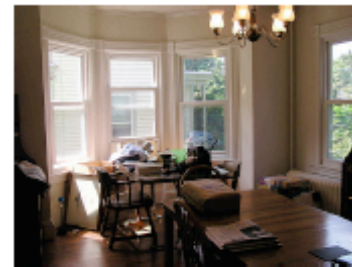
This is a photograph of one sky, one road and one bus. The blue sky is above the gray road. The gray road is near the shiny bus. The shiny bus is near the blue sky.



There are two aeroplanes. The first shiny aeroplane is near the second shiny aeroplane.



There are one cow and one sky. The golden cow is by the blue sky.



There are one dining table, one chair and two windows. The wooden dining table is by the wooden chair, and against the first window, and against the second white window. The wooden chair is by the first window, and by the second white window. The first window is by the second white window.



Here we see one person and one train. The black person is by the train.



This is a picture of one sky, one road and one sheep. The gray sky is over the gray road. The gray sheep is by the gray road.



Here we see one road, one sky and one bicycle. The road is near the blue sky, and near the colorful bicycle. The colorful bicycle is within the blue sky.



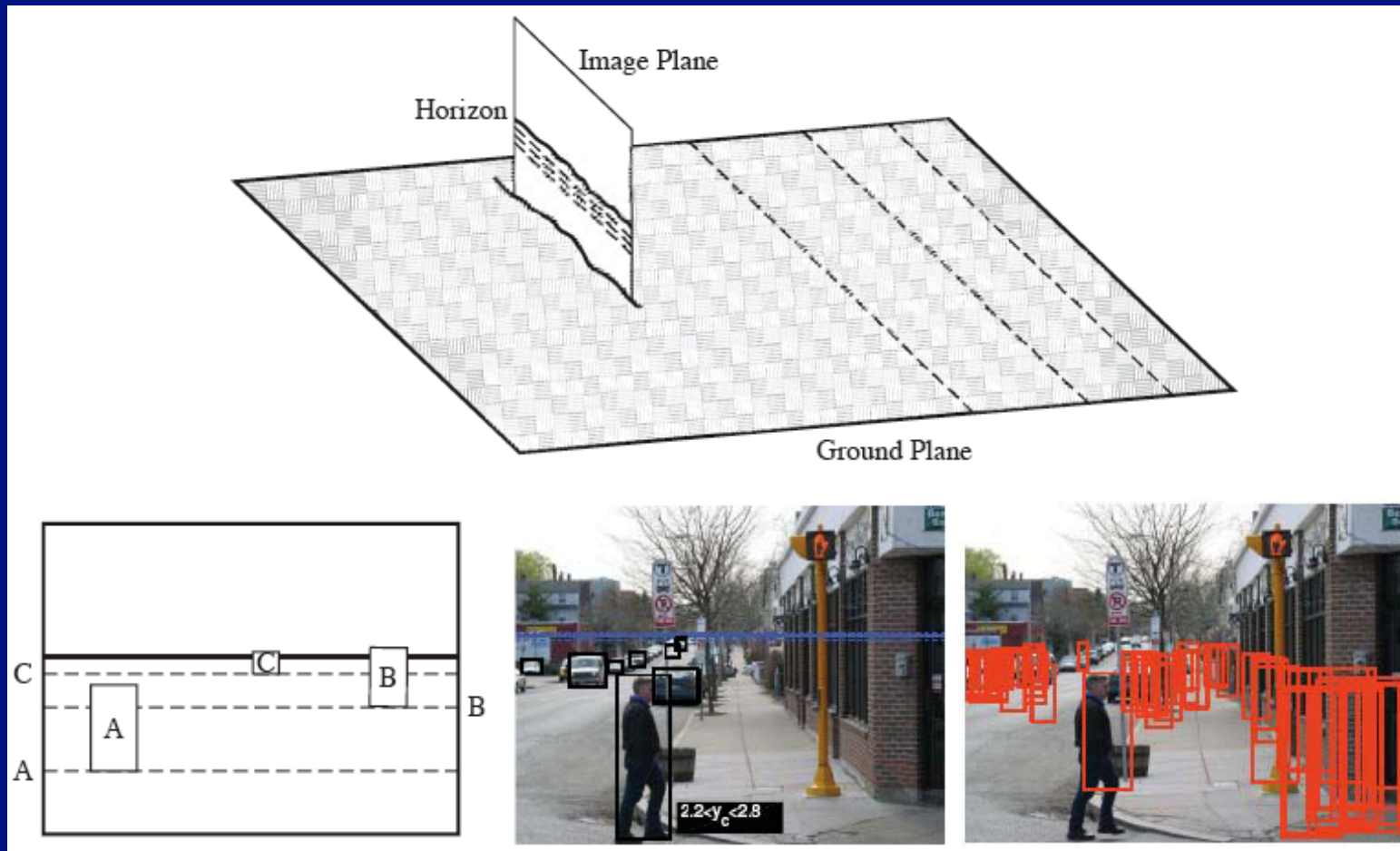
Here we see two persons, one sky and one aeroplane. The first black person is by the blue sky. The blue sky is near the shiny aeroplane. The second black person is by the blue sky. The shiny aeroplane is by the first black person, and by the second black person.



This is a picture of two dogs. The first dog is near the second furry dog.



This is a photograph of two buses. The first rectangular bus is near the second rectangular bus.



Putting Objects in Perspective, D. Hoiem, A.A. Efros, and M. Hebert, in Proc IEEE Conf. Computer Vision and Pattern Recognition, 2006

# Subtleties: What about the unfamiliar?

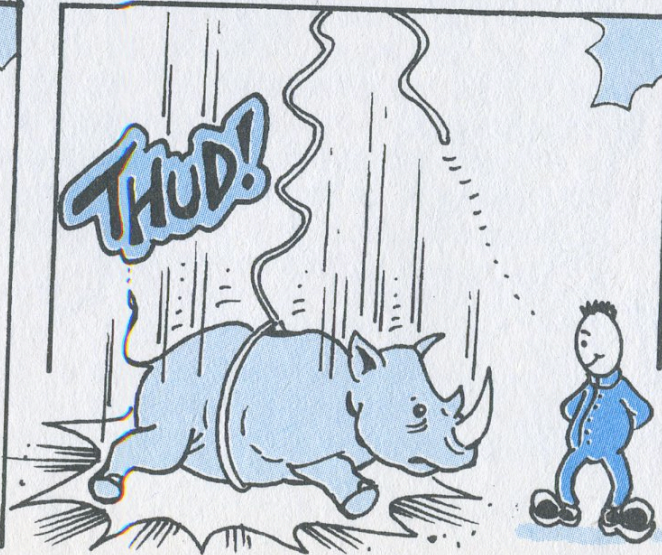
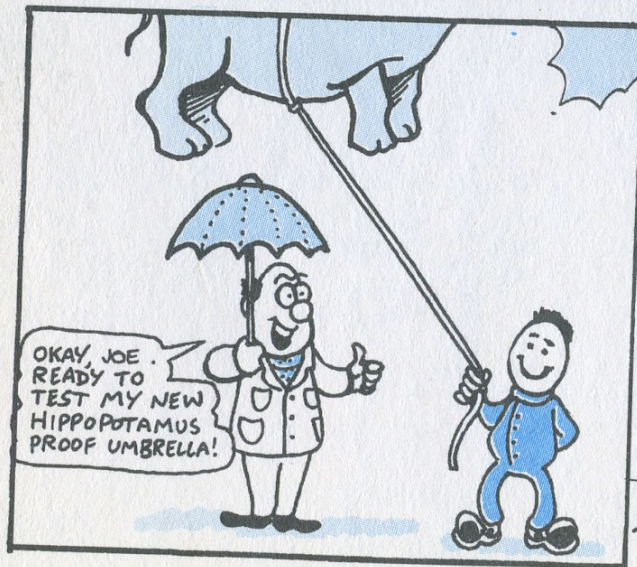




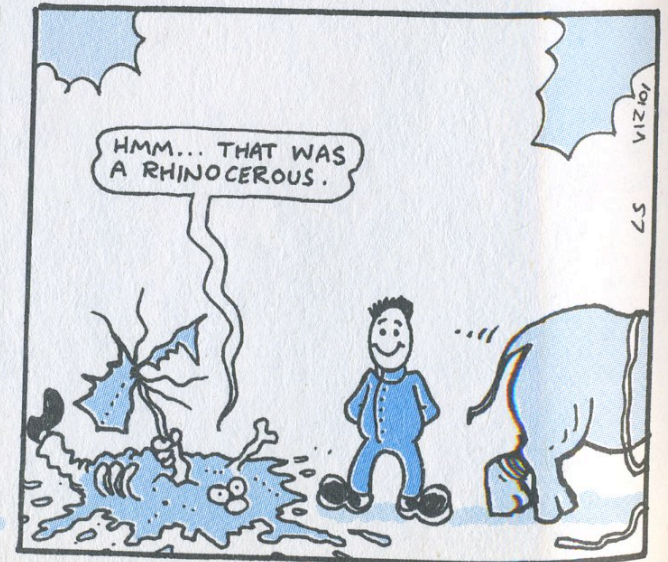
# What is an object like?

## Professor Piehead

and his assistant, TIM

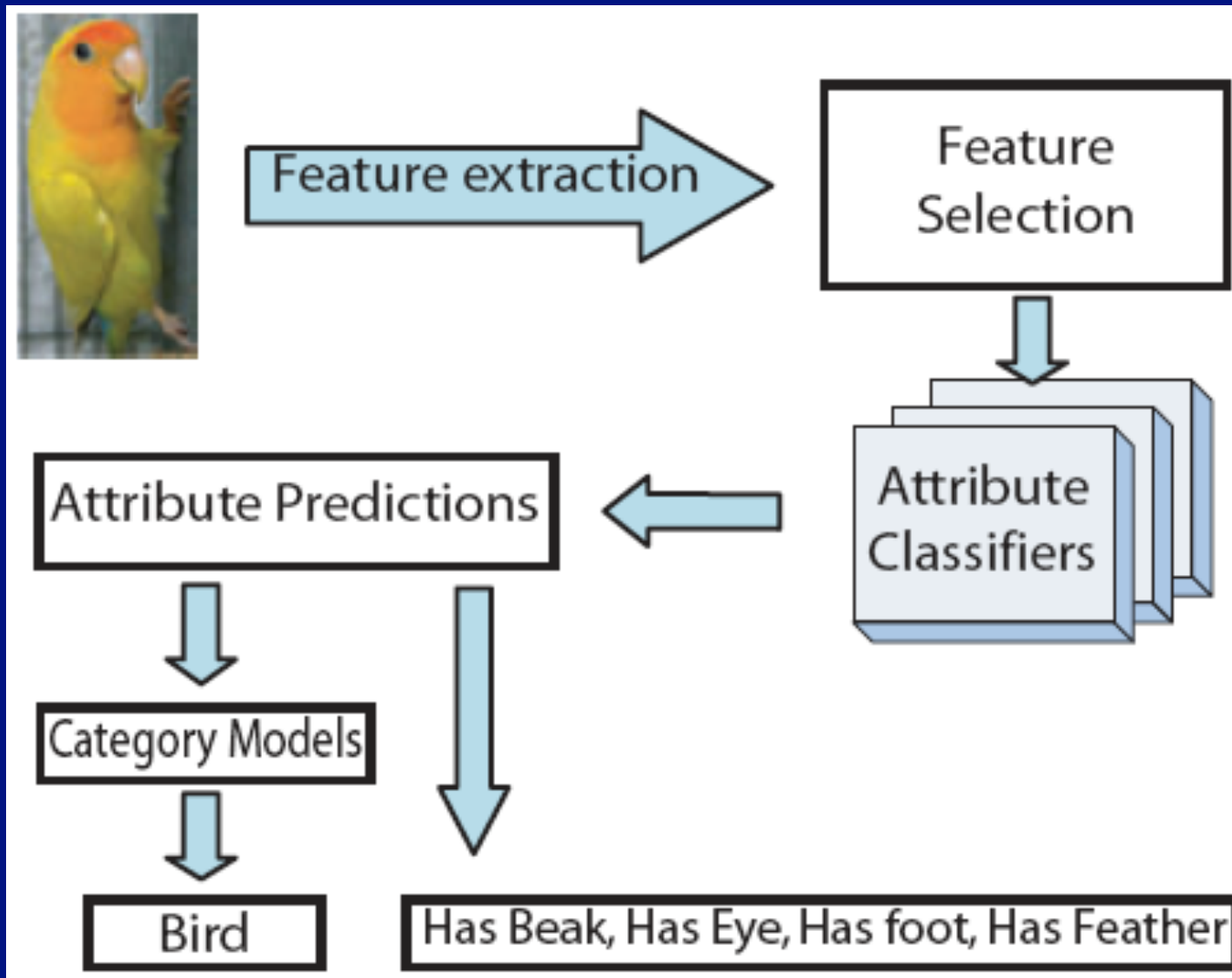


52



Viz comic, issue 101

# General architecture





'is 3D Boxy'

'is Vert Cylinder'

'has Window' ~~'has Screen'~~

'has Row Wind' ~~'has Headlight'~~



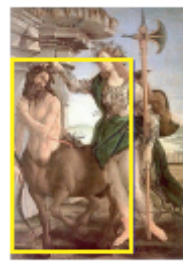
'has Hand'

'has Arm'

~~'has Screen'~~

'has Plastic'

'is Shiny'



'has Head'

'has Hair'

'has Face'

~~'has Saddle'~~

'has Skin'



'has Head'

'has Torso'

'has Arm'

'has Leg'

~~'has Wood'~~



'has Head'

'has Ear'

'has Snout'

'has Nose'

'has Mouth'



'has Head'

'has Ear'

'has Snout'

'has Mouth'

'has Leg'



~~'has Furniture Back'~~

~~'has Horn'~~

~~'s Screen'~~

'has Plastic'

'is Shiny'



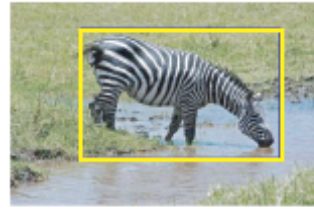
'is 3D Boxy'

'has Wheel'

'has Window'

'is Round'

'has Torso'



'has Tail'

'has Snout'

'has Leg'

~~'has Text'~~

~~'has Plastic'~~



'has Head'

'has Ear'

'has Snout'

'has Leg'

'has Cloth'



'is Horizontal Cylinder'

~~'has Beak'~~

~~'has Wing'~~

~~'has Side mirror'~~

'has Metal'



'has Head'

'has Snout'

'has Horn'

'has Torso'

~~'has Arm'~~

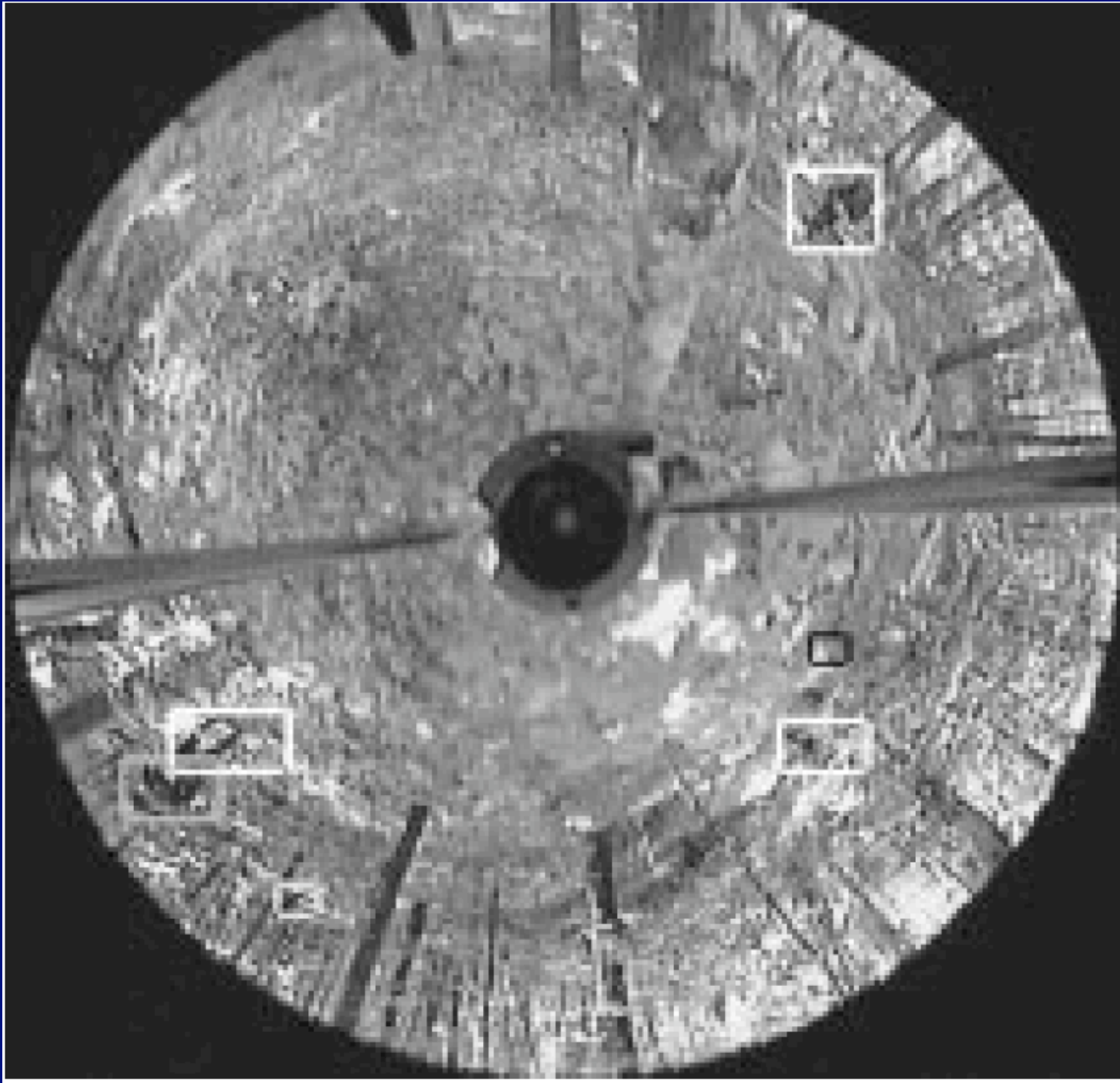
# Looking at People

- What are people doing?
- Hard because
  - hard to extract people from video
    - but quite good trackers are now becoming available
  - hard to know what form the answer takes
    - “walking” vs “running”?
    - “not much of interest” vs “might be a problem”?
    - goals/intentions?



# Why are humans important?

- **Surveillance**
  - prosecution; intelligence gathering; crime prevention
  - HCI; architecture;
- **Synthesis**
  - games; movies;
- **Safety applications**
  - pedestrian detection
- **People are interesting**
  - movies; news



Where you are can suggest  
you are doing something  
you shouldn't be  
Boult 2001



Bill Freeman flies a magic carpet.

Orientation histograms detect body configuration to control bank, raised arm to fire magic spell.

Freeman et al, 98.



9 An example of a user playing a Decathlon event, the javelin throw. The computer's timing of the set and release for the javelin is based on when the integrated downward and upward motion exceeds predetermined thresholds.

Motion fields set javelin timing  
Freeman et al 98

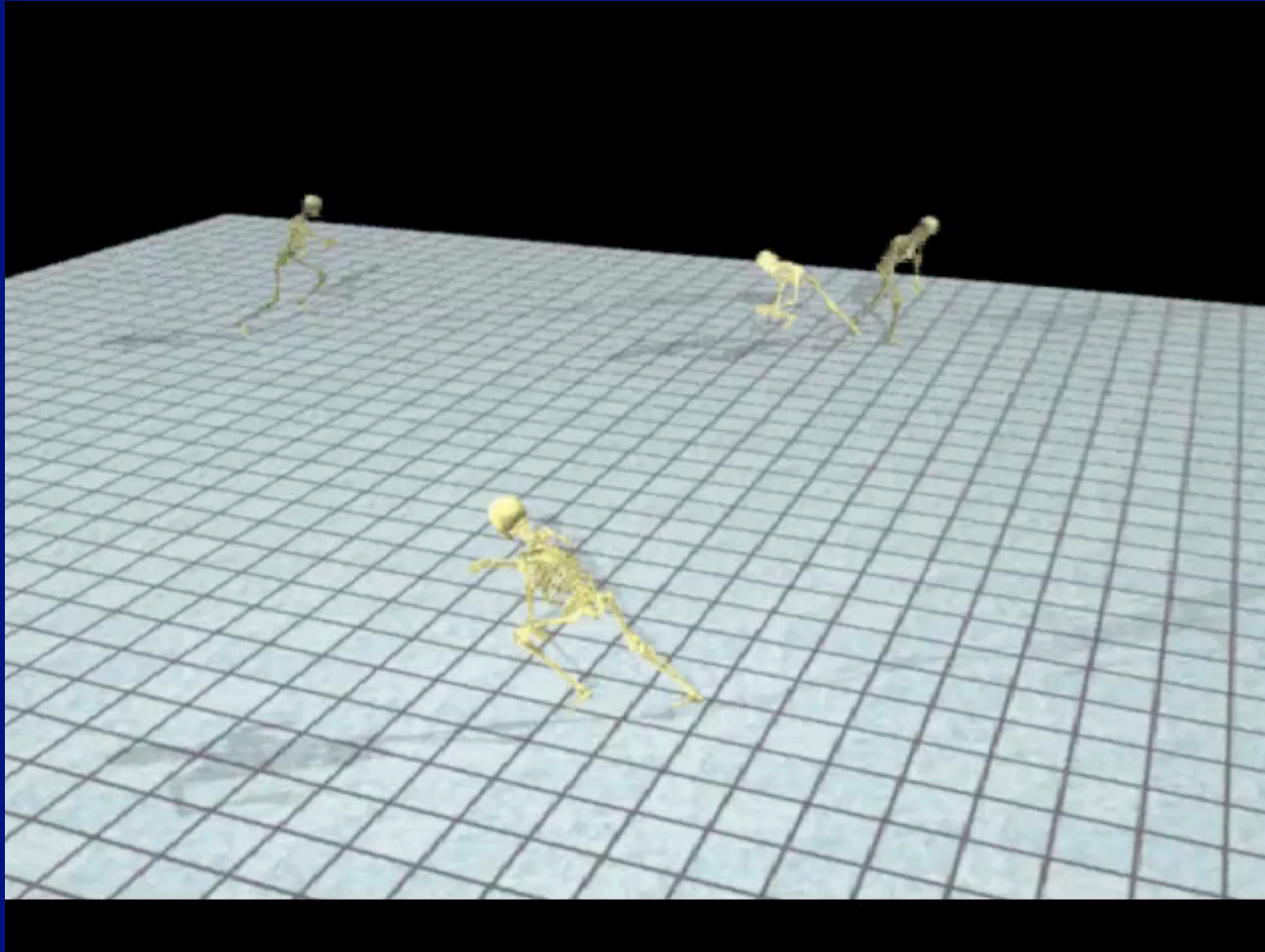


Sony's eyetoy estimates motion fields,  
links these to game inputs.  
Huge hit in EU, well received in US



# Why are humans important?

- Surveillance
  - prosecution; intelligence gathering; crime prevention
  - HCI; architecture;
- **Synthesis**
  - games; movies;
- Safety applications
  - pedestrian detection
- People are interesting
  - movies; news



# Why are humans important?

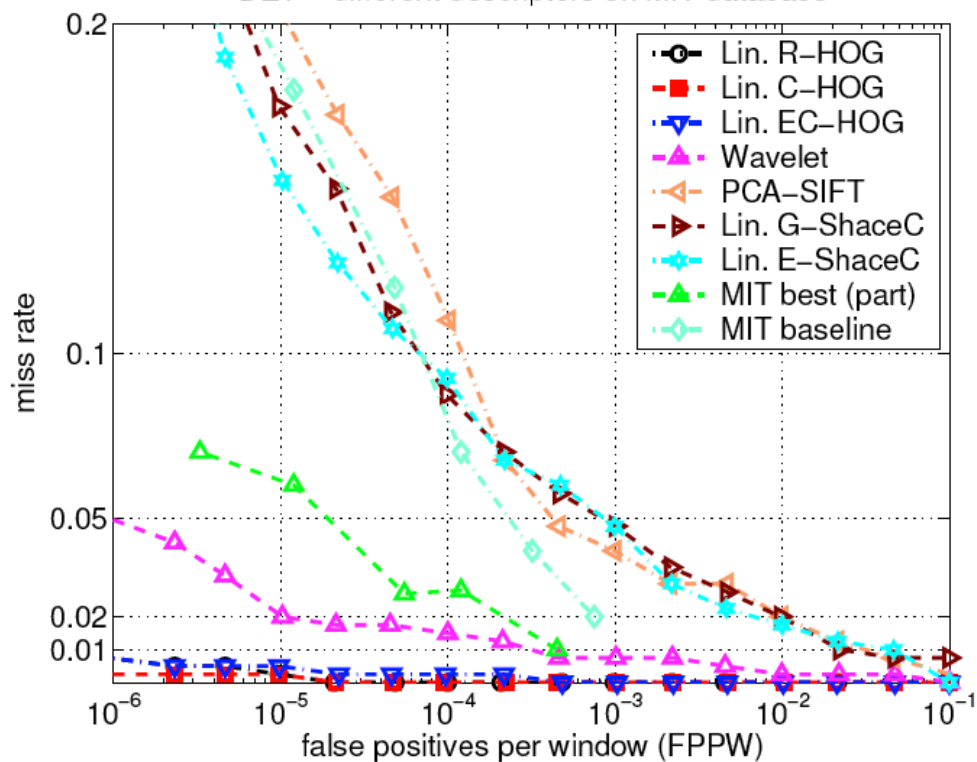
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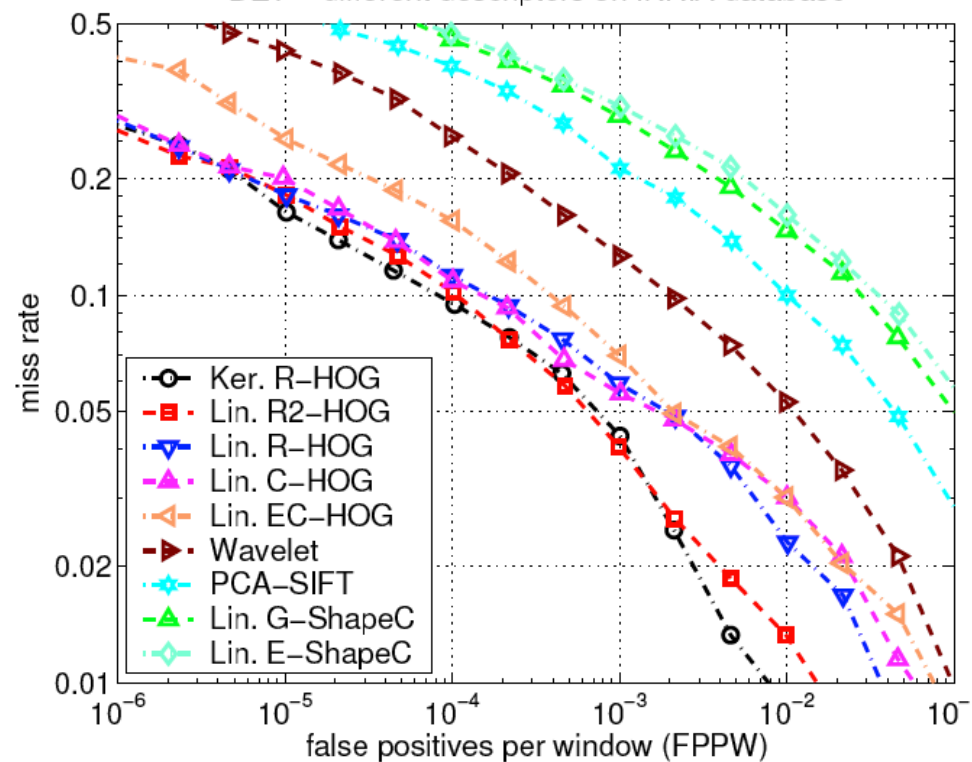


From Dalal+Triggs, 05

DET – different descriptors on MIT database



DET – different descriptors on INRIA database



# Why are humans important?

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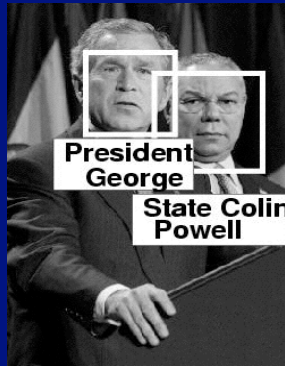
# News Faces

- 5e5 captioned news images
- Mainly people “in the wild”
- Correspondence problem
  - some images have many (resp. few) faces, few (resp. many) names (cf. Srihari 95)
- Process
  - Extract proper names
  - Detect faces (Vogelhuber Schmid 00) 44773 big face responses
  - Rectify faces 34623 properly rectified
  - Kernel PCA rectified faces
  - Estimate linear discriminants
  - Now have (face vector; name\_1, ..., name\_k)  
27742 for  $k \leq 4$
- Apply a form of modified k-means



President George W. Bush makes a statement in the Rose Garden while Secretary of Defense Donald Rumsfeld looks on, July 23, 2003. Rumsfeld said the United States would release graphic photographs of the dead sons of Saddam Hussein to prove they were killed by American troops. Photo by Larry Downing/Reuters





US President George W. Bush (L) makes remarks while Secretary of State Colin Powell (R) listens before signing the US Leadership Against HIV /AIDS , Tuberculosis and Malaria Act of 2003 at the Department of State in Washington, DC. The five-year plan is designed to help prevent and treat AIDS, especially in more than a dozen African and Caribbean nations(AFP/ Luke Frazza)

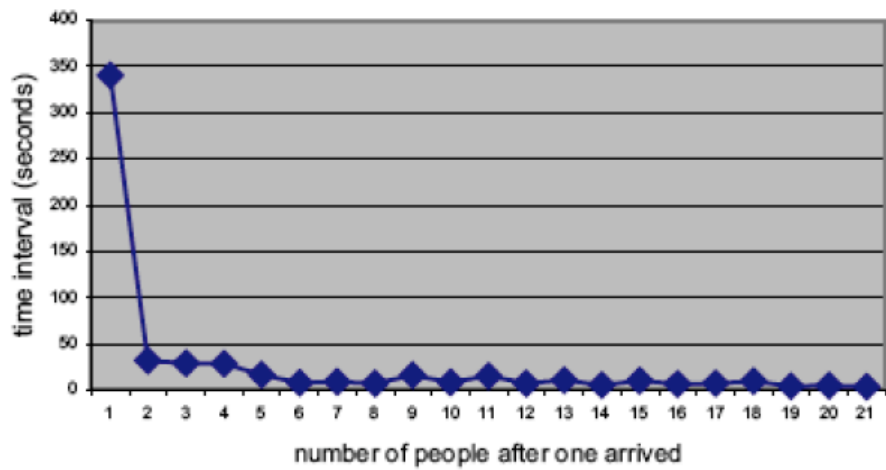


German supermodel Claudia Schiffer gave birth to a baby boy by Caesarian section January 30, 2003, her spokeswoman said. The baby is the first child for both Schiffer, 32, and her husband, British film producer Matthew Vaughn, who was at her side for the birth. Schiffer is seen on the German television show 'Bet It...?!' ('Wetten Dass...?!') in Braunschweig, on January 26, 2002. (Alexandra Winkler/Reuters)



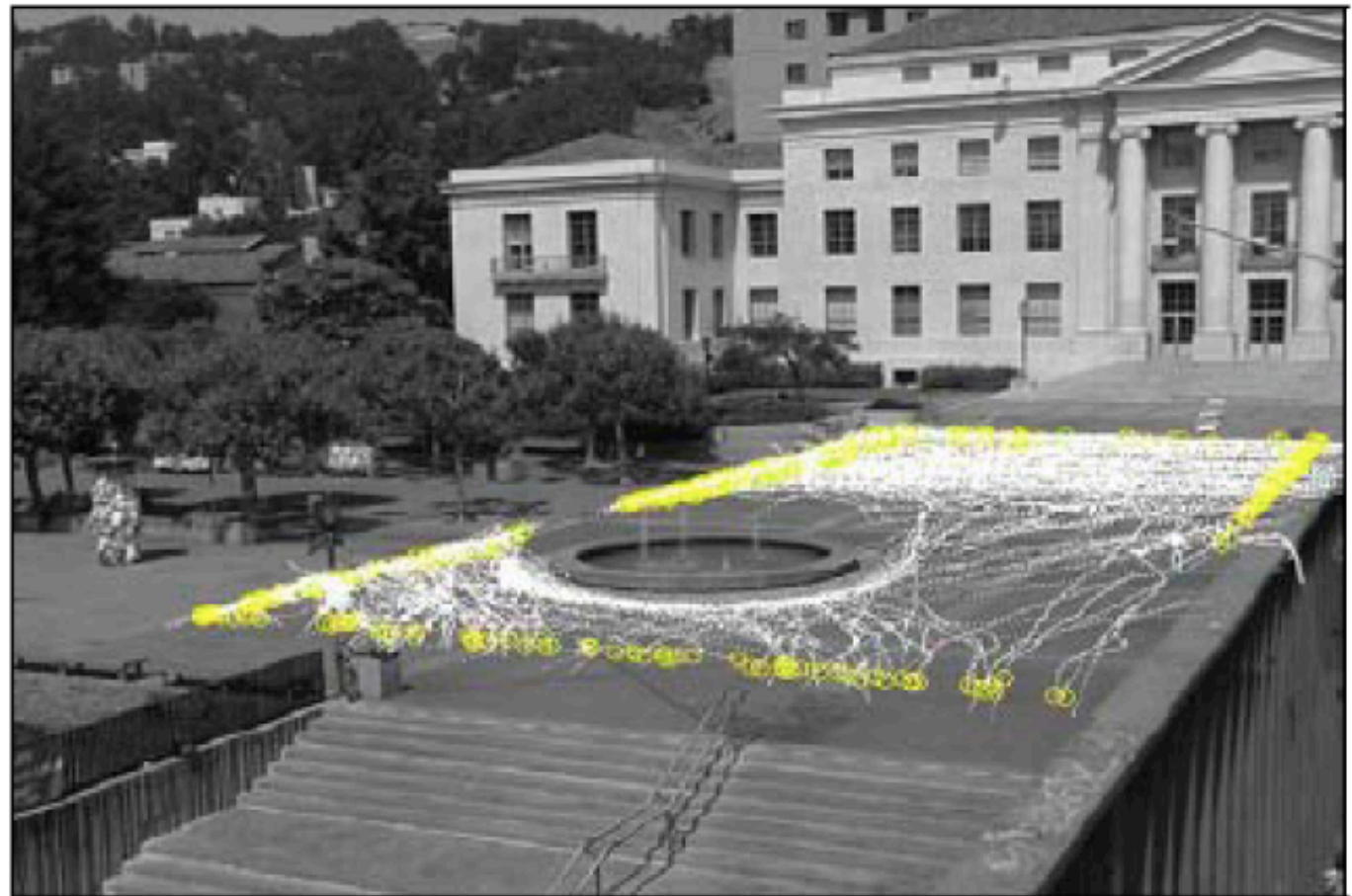
British director Sam Mendes and his partner actress Kate Winslet arrive at the London premiere of 'The Road to Perdition', September 18, 2002. The films stars Tom Hanks as a Chicago hit man who has a separate family life and co-stars Paul Newman and Jude Law. REUTERS/Dan Chung

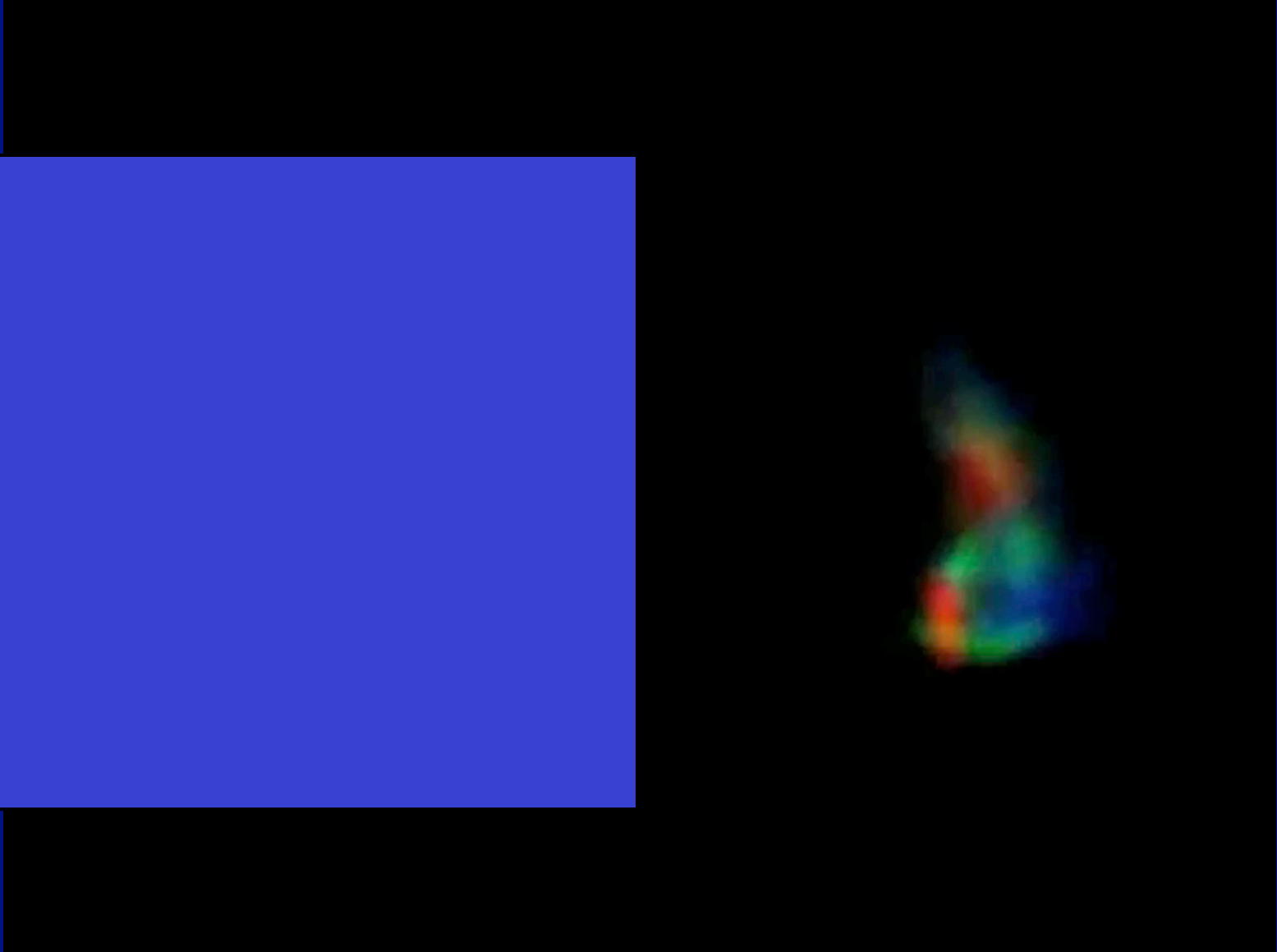
Average time intervals of people arrived the fountain depending on number of people already there



Curious phenomena in public spaces

Yan+Forsyth, 04

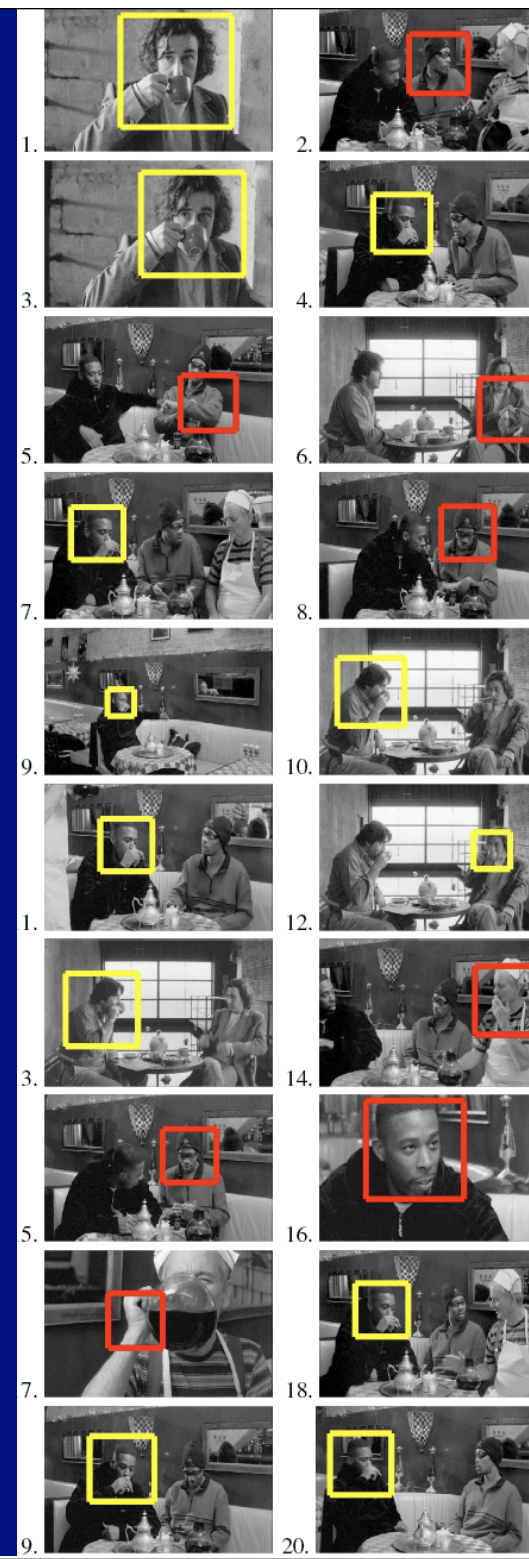
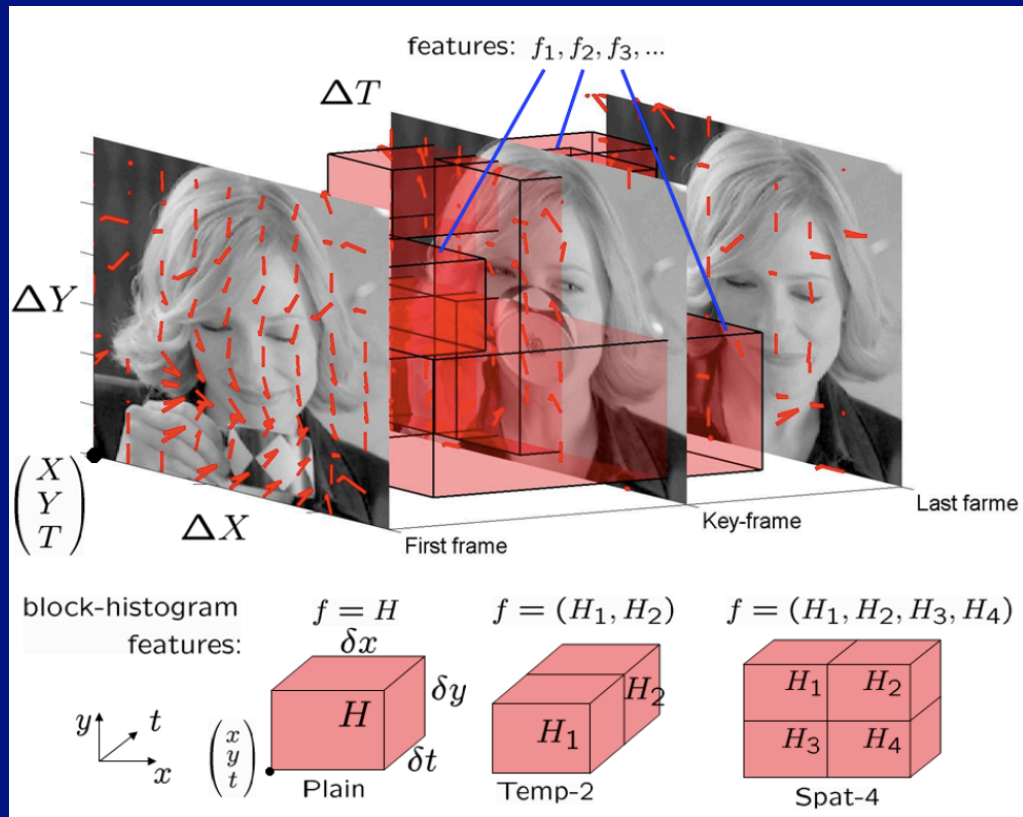




Ramanan, Forsyth and Zisserman CVPR05



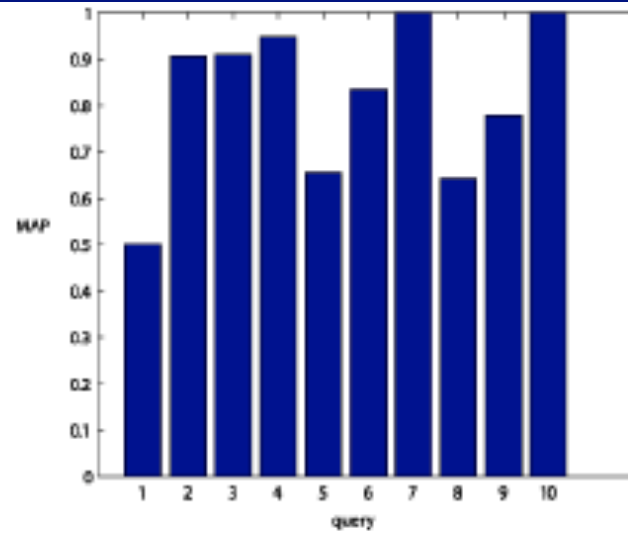
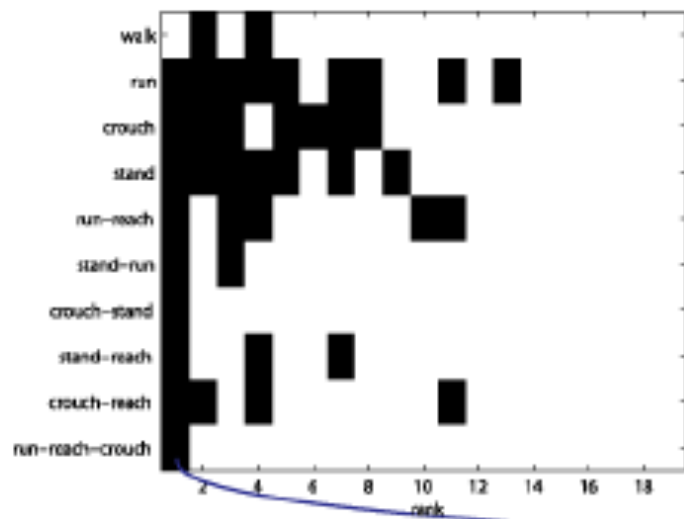
Ramanan, Forsyth and Zisserman CVPR05



### Retrieving actions in movies

I Laptev, P Perez - International Conference on Computer Vision, 2007





the first video retrieved for query "run-reach-couch"



Searching for complex human activities with no visual examples N İkizler, DA Forsyth - IJCV, 2008

# Conclusions

- Two major intertwining themes
  - Reconstruction
    - Build me a model of it
  - Recognition
    - What is this like
- Wildly successful field
  - 20 years ago:
    - eccentric preoccupation of few
  - Now:
    - massive impact, including numerous applications

# Conclusions (2)

- Core technologies
  - Describing local image patches
  - Classification
    - stick in a patch, get yes/no
  - Regression
    - stick in a patch, get out some value
  - Clustering
    - group together data items that are similar