

Computer Vision

cmput 428/615

Lecture 1: Introduction and course overview

Martin Jagersand

Administrivia

- Classes: Tue, Thu 2-3:20pm,
- Labs: csc-235 Tue, Wed 5-7:50pm, tutorials, Q/A, student demos)
- Instructor: Martin Jagersand jag@cs.ualberta.ca
- Labs: Karteek Popuri kpopuri@ualberta.ca
- Prereq: Compulsory math, numerical methods (e.g. 340, 418)
- Textbooks:
 - [Multiple View Geometry in Computer Vision](#)
Richard Hartley and Andrew Zisserman
Cambridge University Press, 2004.
 - [Computer Vision: Algorithms and Applications](#) Richard Szeliski,
Springer 2011 (on-line or printed)
- Webpage:
 - <http://webdocs.cs.ualberta.ca/~vis/courses/CompVis>

On-line Text



Computer Vision: Alg... x

http://research.microsoft.com/en-us/um/people/szeliski/Book/

Gmail Manuscript Central cvpr ac EE364a: Lecture Slides KEEP VID KeepVid: Download ... LBA A-Z

Computer Vision: Algorithms and Applications

(c) [Richard Szeliski](#), Microsoft Research

Welcome to the repository for drafts of my computer vision textbook.

This book is largely based on the computer vision courses that I have co-taught at the University of Washington (2008, 2005, 2001) and Stanford (2003) with [Steve Seitz](#) and [David Fleet](#).

While I am working on the book, I would *love* to have people "test-drive" it in their computer vision courses (or their research) and [send me feedback](#).

The PDFs should be enabled for commenting directly in your viewer. Also, hyper-links to sections, equations, and references are enabled. To get back to where you were, use Alt-Left-Arrow in Acrobat.

This Web site is also a placeholder for the site that will accompany my computer vision textbook once it is published. Once I get further along with the project, I hope to publish supplemental course material here, such as figures and images from the book, slides sets, pointers to software, and a bibliography.

Latest draft

[June 19, 2009](#) (minor updates)

Administrivia

Grading (undergrad)

40% Assignments (6-7%) and in-lab demos/quiz (3-4%) throughout term

25% Midterm Tue Feb 24

35% Final

Graduate

24% Assign/demo, 16% Midterm, 30% Final

5% research article reading and presentation

5%+20% Project proposal P1 and final report/demo P2

Project has a survey and learning part where you read the literature, try some softwares, propose a particular topic and write report P1.

Second part, P2, is a report and demo on an implementation you did.

Groups are encouraged. Each individual identifiable part in a bigger project.

Lab:

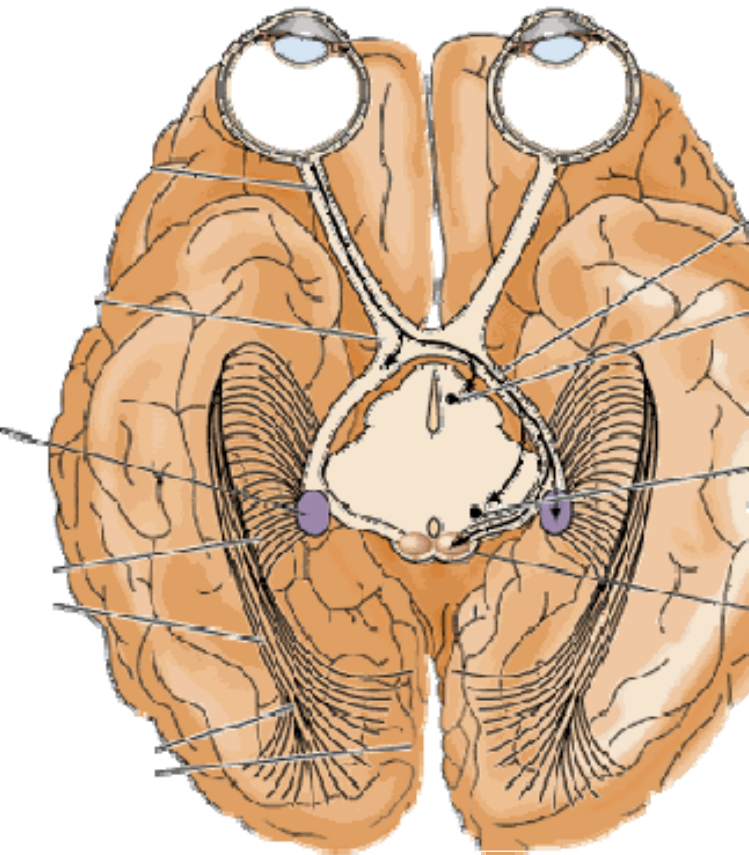
Room csc2-35, SW: Matlab + Mexvision, Linux. PtGrey Grasshopper Cameras

What is Computer Vision?

How to infer salient properties
of 3-D world from 2-D images
or video

- ⌘ What is salient?
- ⌘ How to deal with loss of information going from 3-D to 2-D projection?

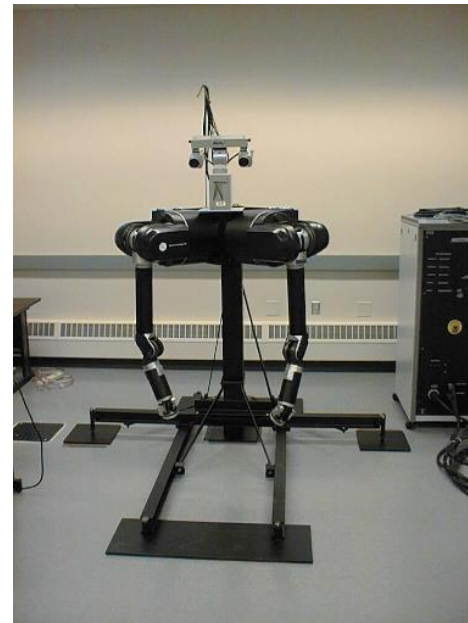
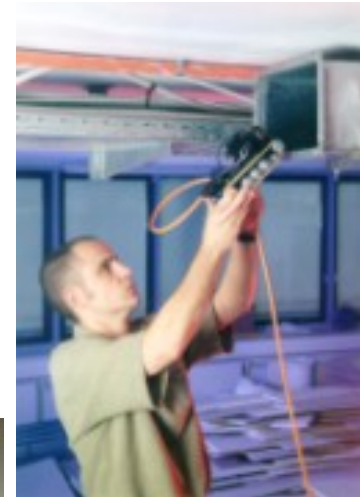
Biological vision



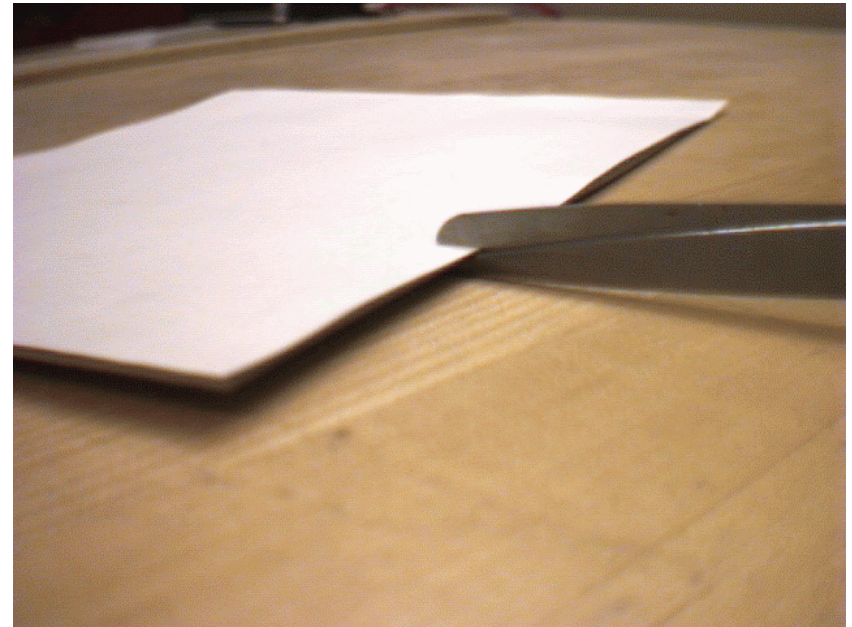
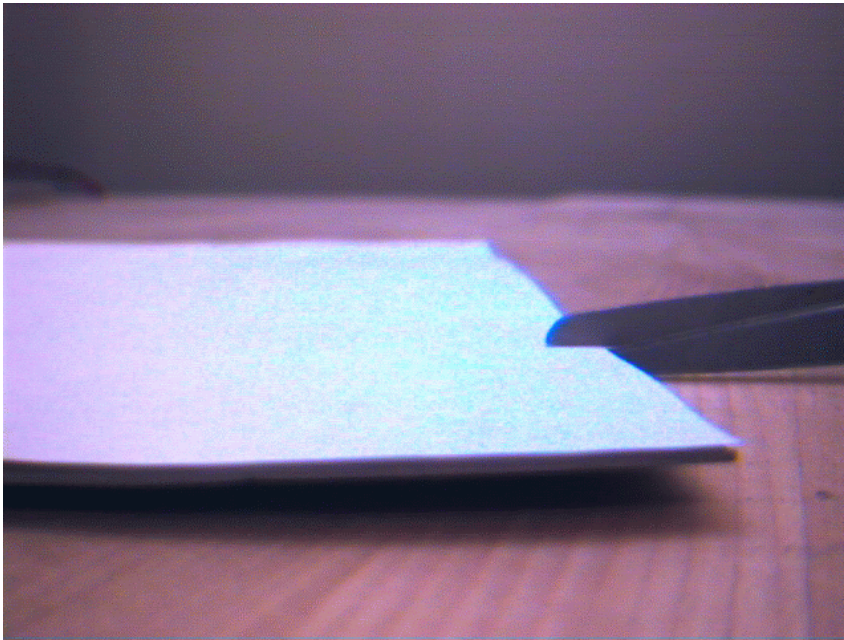
- For humans and animals vision is powerful yet effortless.
- A large part of the brain is devoted to visual processing (40%)

Computer Vision

- There are methods for several subdomains e.g.
 1. 2D, 3D, hom Pose tracking in video
 2. 3D modeling from 2D im/vid
 3. Vision-based motion control (arm, hand, walk, (robots 412)
- But general, human-like vision unsolved/hard
- Easier subdomains
 1. Industrial machine vision 412
 2. Object recognition cmput 399

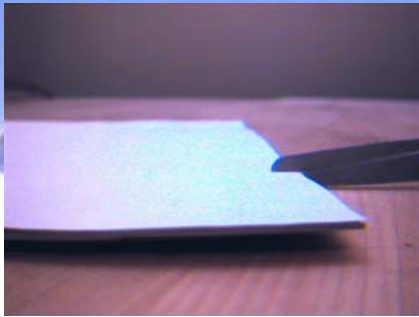


How much “3D” do we really see?



- Will the scissors cut the paper in the middle?

ambiguity



- Will the scissors cut the paper in the middle? **NO!**

Size illusions



Tasks in Vision



Perception:

- **What:** Label what is in a scene: What people, animals, objects...

Action:

- **Where:** Determine the coordinates of where something is. (Mishkin, Ungleider)
- **How:** Use vision to perform some physical manipulation task. (Goodale etc.)

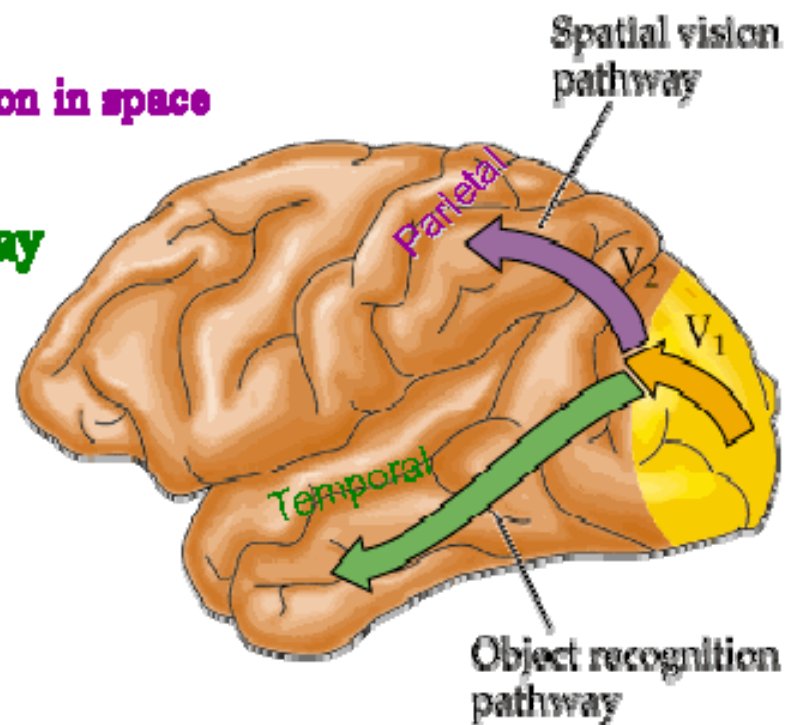
Compare in Human vision: Dorsal and Ventral Pathways

Dorsal (magno) Pathway

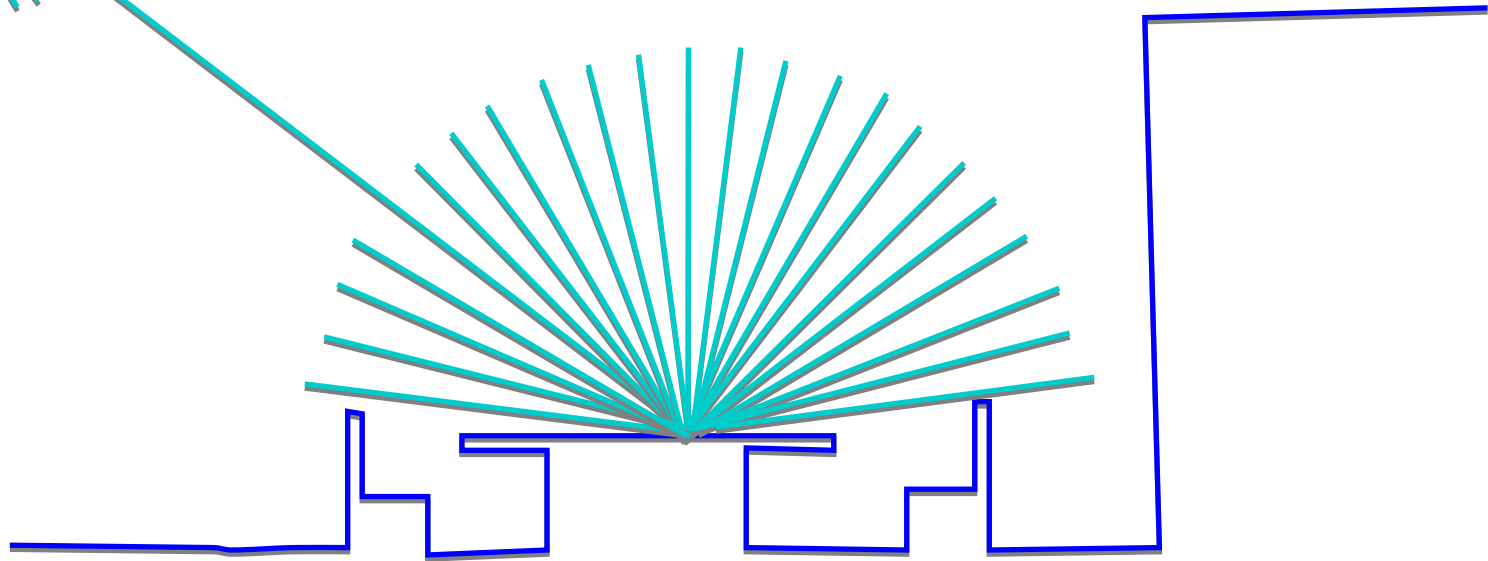
- to parietal lobe
- spatial vision – localization in space
- “WHERE”

Ventral (parvo) Pathway

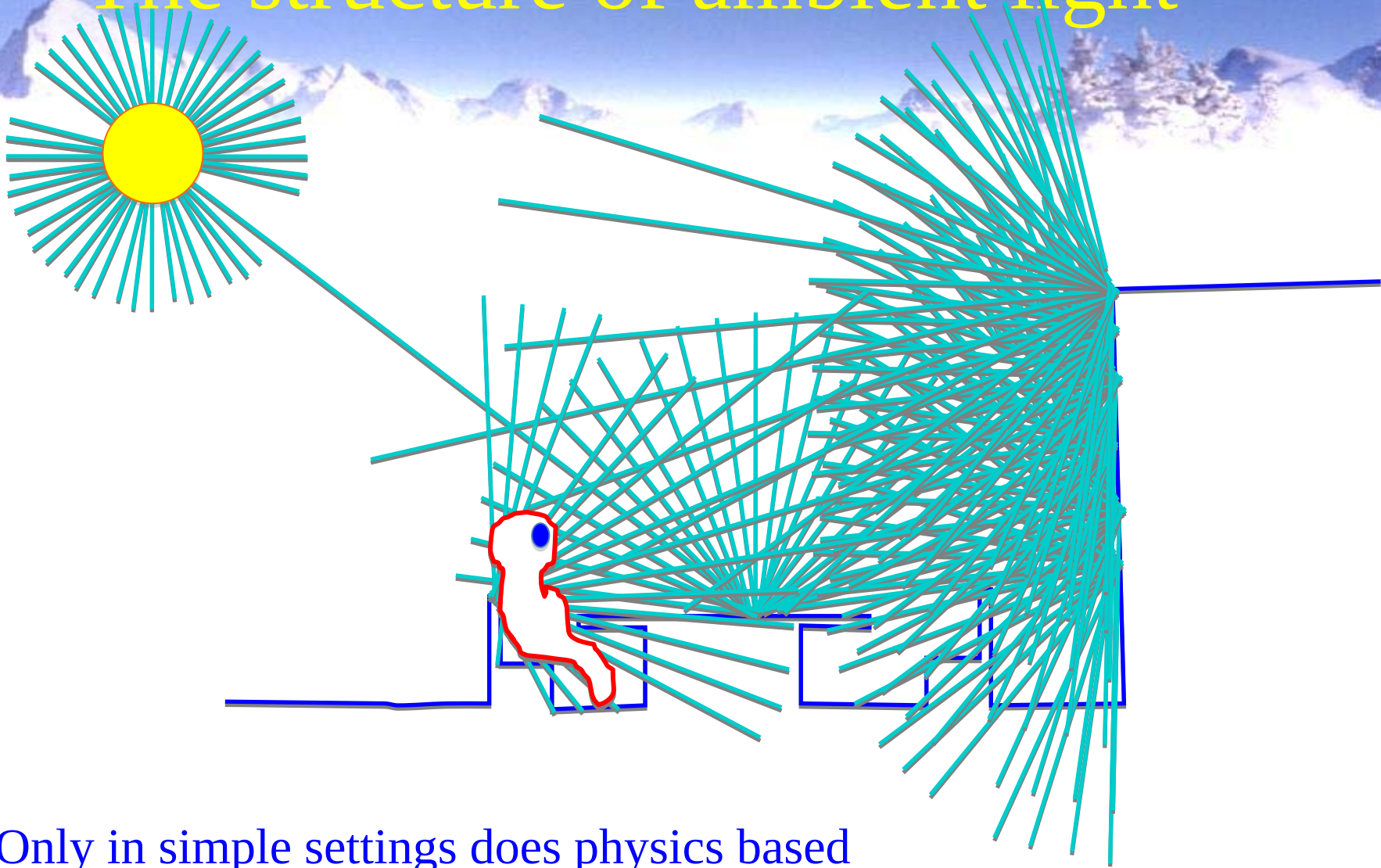
- to temporal lobe
- object recognition
- “WHAT”



The structure of ambient light

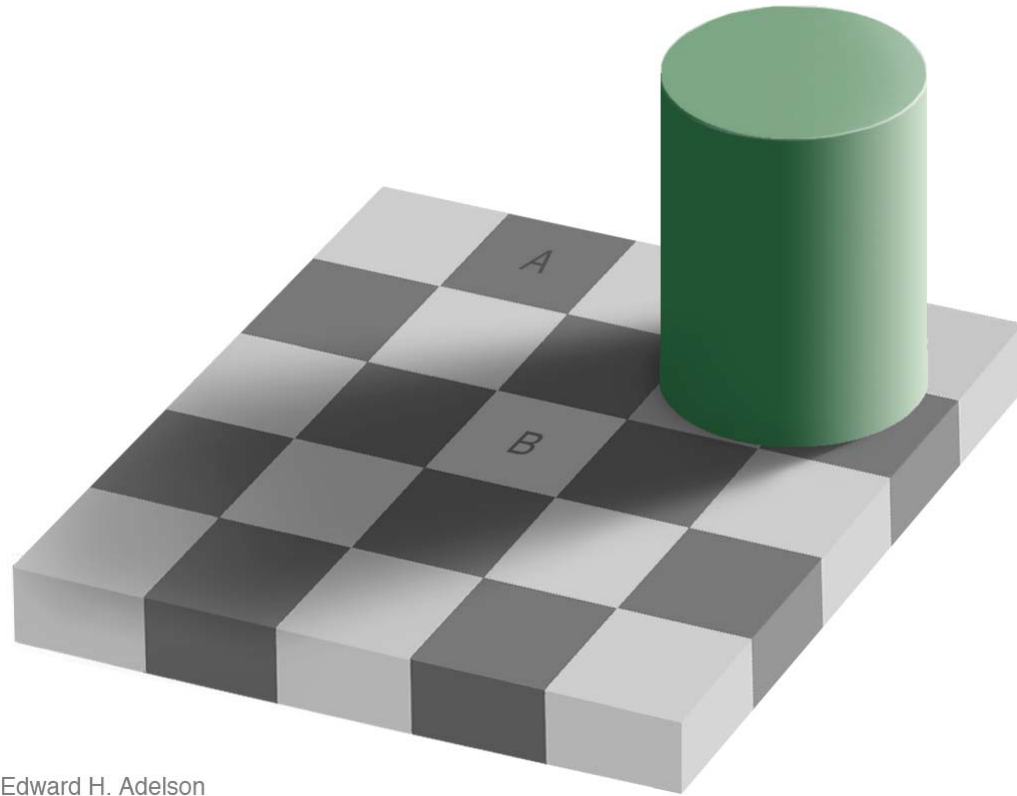


The structure of ambient light



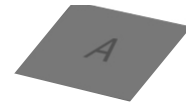
Only in simple settings does physics based
reflectance modeling work

Measuring light vs. measuring scene properties



Edward H. Adelson

Measuring light vs. measuring scene properties



The “Vision Problem”

Input



Output

207 200 199 194 203 126 106 091 113 153 192 196 190 186 175
242 194 213 254 255 114 082 109 097 089 208 206 202 194 185
254 159 187 245 248 128 197 191 166 102 248 251 233 223 246
255 159 191 245 249 123 113 047 124 149 255 253 239 143 250
255 184 191 249 249 126 022 040 115 039 250 255 255 177 252
253 197 190 233 251 054 143 209 196 014 254 254 253 228 251
252 228 176 218 251 070 176 219 200 024 250 255 255 254 195
248 244 163 227 252 091 071 185 079 021 252 251 255 254 138
253 254 169 241 253 141 053 180 005 019 253 253 255 253 201
253 250 170 242 253 138 199 193 216 146 255 253 253 253 233
254 228 164 209 235 144 188 144 161 192 230 250 253 255 252
252 240 140 215 245 119 098 086 139 127 252 234 253 253 251
253 246 169 207 235 120 157 140 188 108 246 249 235 225 255
253 230 167 207 217 113 106 069 168 098 244 246 239 207 254
253 219 170 225 253 122 144 169 124 109 243 235 233 252 252
255 221 179 239 227 123 123 069 125 122 240 249 243 232 253
221 217 180 213 243 126 143 081 181 133 252 249 244 221 210
236 216 178 208 230 225 160 118 187 198 249 249 230 220 221
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223 217 198 162 194 215 192 106 077 255 213 219 194 215 219
224 216 162 189 200 254 217 198 209 216 206 226 186 228 219
215 222 168 202 214 201 117 084 085 111 234 190 248 218 226
219 216 198 165 213 227 014 221 197 183 178 186 216 214 222
222 224 197 146 201 204 108 220 201 210 196 223 200 233 218
226 232 177 184 175 230 214 199 146 255 134 225 205 216 181
253 254 194 192 196 168 032 193 194 196 040 198 190 207 185
045 030 167 163 210 041 206 144 129 170 086 190 161 193 191
200 205 135 143 100 174 027 175 189 113 121 150 190 209 184
202 205 138 213 088 037 164 194 194 182 076 077 107 211 181
196 208 155 063 055 068 180 200 193 160 220 082 070 210 181
161 132 058 146 048 076 172 165 218 189 186 063 004 187 185
157 080 191 119 044 025 089 115 063 192 223 146 116 186 187

020 067 073 058 055 076 069 050 074 064 065 066 066 059 023
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047 125 130 130 122 121 117 142 131 133 134 141 149 144 135
051 139 143 139 147 134 149 069 127 144 139 144 150 161 149
054 136 161 148 147 158 055 052 034 030 158 156 165 163 156
043 144 165 159 154 171 224 191 047 030 171 165 175 164 163
025 161 174 172 167 049 200 193 112 028 120 169 173 177 173
011 091 101 105 177 039 078 060 041 026 073 102 167 208 121
011 091 094 066 094 033 199 184 139 024 060 094 125 152 134
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011 037 064 094 091 026 025 080 066 026 023 071 070 080 060
011 060 077 082 037 023 024 147 140 038 023 037 043 076 037
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013 059 111 072 020 078 200 211 182 061 069 059 043 086 106
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248 251 167 227 252 146 047 073 047 021 252 251 255 255 145
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215 222 033 092 067 063 031 023 070 025 125 055 136 224 226
219 216 076 044 069 119 011 102 078 055 043 054 111 226 222
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098 006 045 033 030 027 036 054 025 072 112 044 029 060 115

The “Vision Problem”

Input



Vision
Algorithm



Output

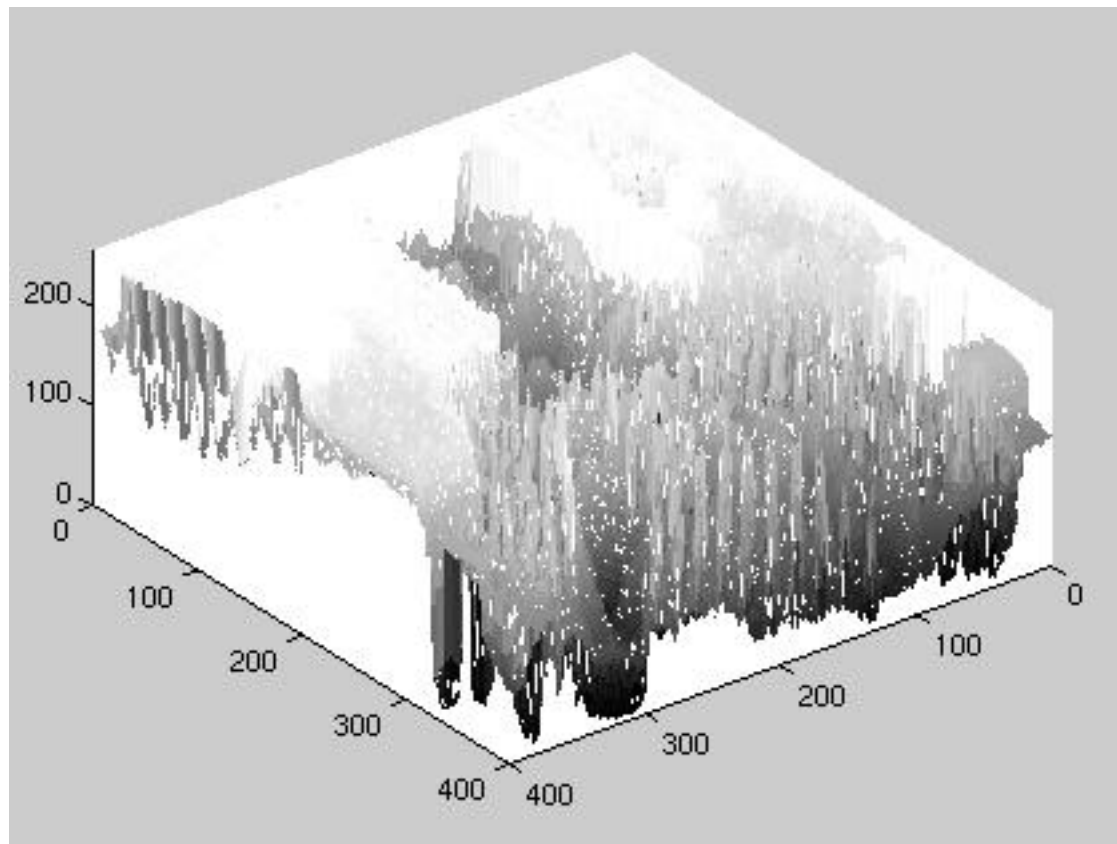
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020 067 073 058 055 076 069 050 074 064 065 066 066 059 023
047 109 107 118 107 115 110 120 120 124 120 128 124 132 131
047 125 130 130 122 121 117 142 131 133 134 141 149 144 135
051 139 143 139 147 134 149 069 127 144 139 144 150 161 149
054 136 161 148 147 158 055 052 034 030 158 156 165 163 156
043 144 165 159 154 171 224 191 047 030 171 165 175 164 163
025 161 174 172 167 049 200 193 112 028 120 169 173 177 173
011 091 101 105 177 039 078 060 041 026 073 102 167 208 121
011 091 094 066 094 033 199 184 139 024 060 094 125 152 134
009 068 072 072 065 031 151 171 075 028 035 072 083 109 063
013 068 074 059 057 037 161 129 062 028 035 071 072 078 056
012 042 063 055 072 033 020 067 031 022 027 082 070 073 060
011 037 064 094 091 026 025 080 066 026 023 071 070 080 060
011 060 077 082 037 023 024 147 140 038 023 037 043 076 037
013 049 076 059 032 028 174 197 182 060 021 021 121 101 062
013 059 111 072 020 078 200 211 182 061 069 059 043 086 106
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020 067 073 058 055 076 069 050 074 064 065 066 066 059 023
025 161 174 172 167 049 200 193 112 028 120 169 173 177 173
```



Recognizing objects

What is an image? What is an object?

207 200 194 194 203 130 105 095 107 153 192 196 190 186 175
242 194 222 254 255 124 074 082 072 076 208 206 202 194 185
254 170 204 255 248 122 153 135 111 081 252 253 233 232 250
255 172 201 255 249 123 092 040 094 106 255 253 239 150 254
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253 210 190 239 250 089 092 149 128 013 254 254 253 229 255
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254 228 169 213 235 146 123 096 090 130 230 250 253 254 254
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221 215 194 100 154 071 008 031 097 010 093 098 148 229 216
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219 216 092 045 074 143 013 171 159 072 087 065 143 217 222
222 224 070 041 074 131 085 150 112 140 139 154 055 231 218
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253 254 079 072 116 089 020 068 103 074 031 130 106 052 161
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191 192 043 153 052 030 078 061 062 054 046 049 054 078 158
184 181 066 019 043 038 046 083 057 050 145 048 035 087 158
138 074 030 082 030 038 076 041 141 046 045 040 009 063 149
135 016 057 071 035 025 040 062 030 084 130 043 059 113 151



Allies and Inspiration



- Math/geometry
- Image Processing
- Cognitive Science
- Physics, Optics
- Engineering
- Biology, Psychology
- Computer Science
- Graphics, AI, NNets, ...

What: Recognizing people and objects

How do we determine that these are the same objects?

Two approaches:

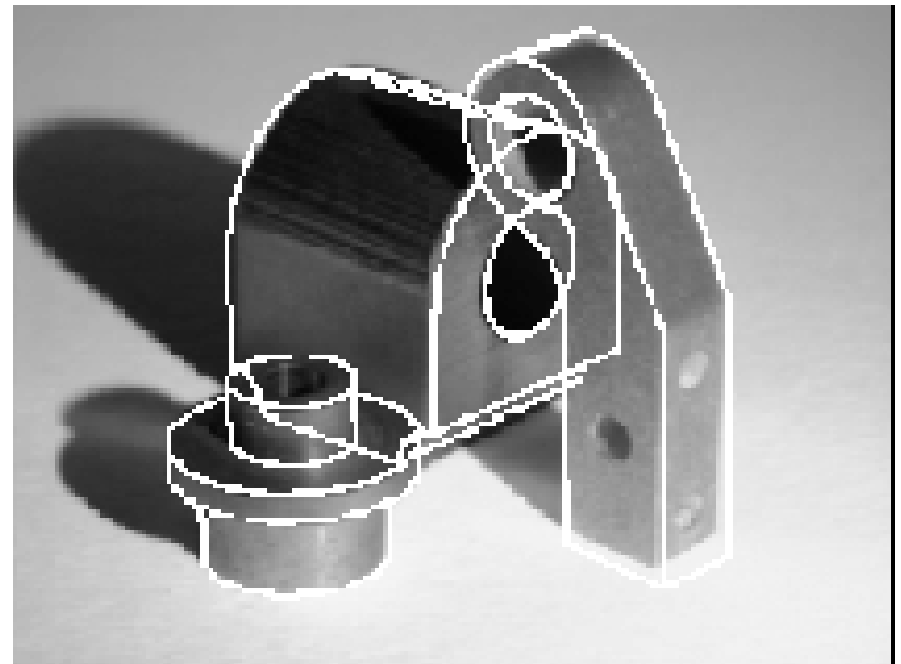
1. Shape
2. Texture



Model based recognition: Find and match the shape

Example:

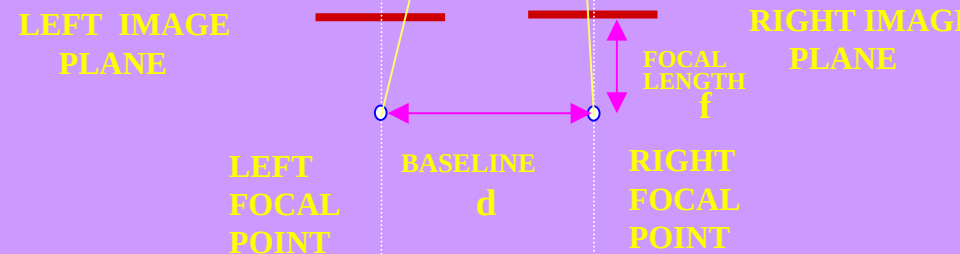
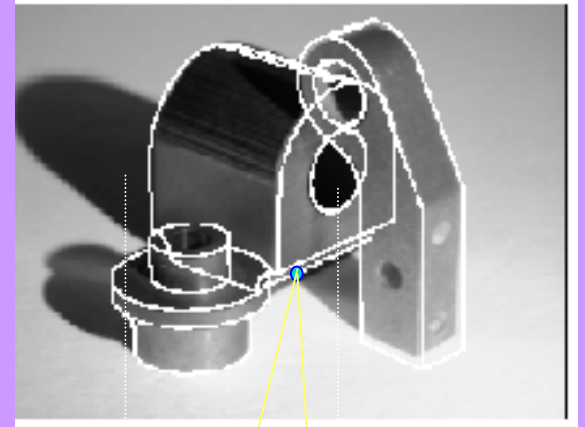
- Find the outlines of objects.
- Try to generate 3D or some pseudo 3D geometric description
- Check database for a similar geometric object



Model based recognition: Techniques.

Stereo:

- From two (or more) images, determine the geometry of the scene by *matching* corresponding areas of the images

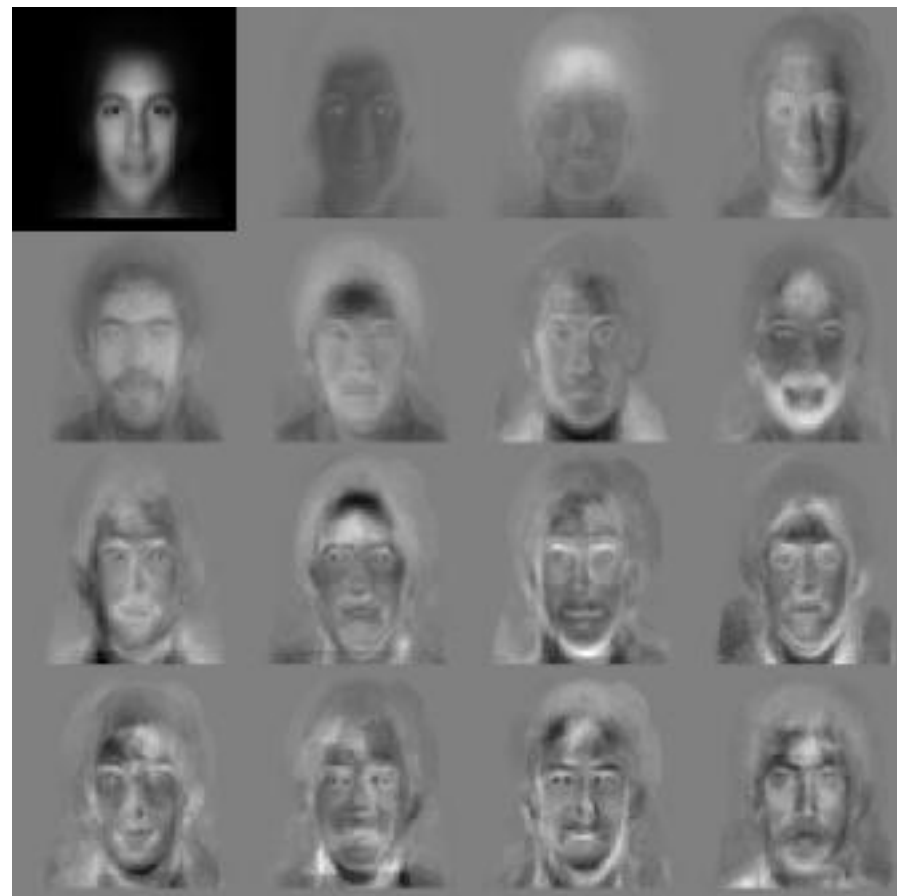


Apperance based recognition

Match the 2D visual “texture”

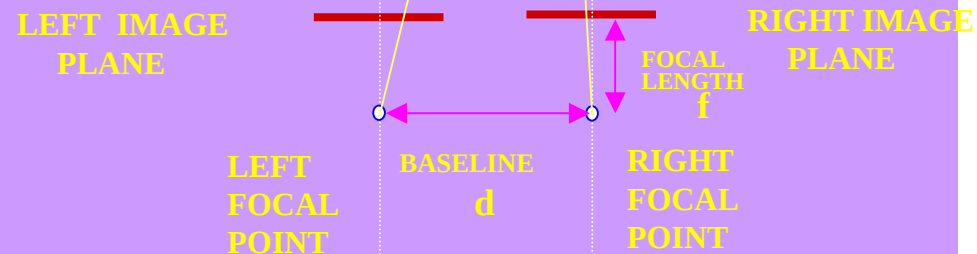
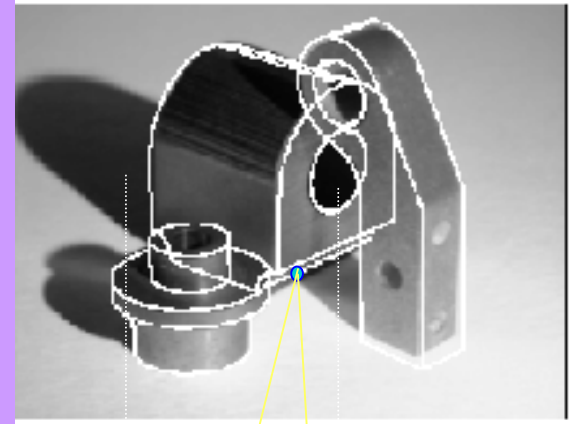
Methods:

1. **Spatial:** Determine “likeness” by convolution. (Like solving a puzzle)
2. **“Frequency”:** Transform and measure in fourier or KL Basis space.



Where

- Use stereo to determine 3D location with respect to camera.
- If we know where the camera is we can determine 3D world position



How (to act in the world)?



Commercial products integrates tidbits of computer vision

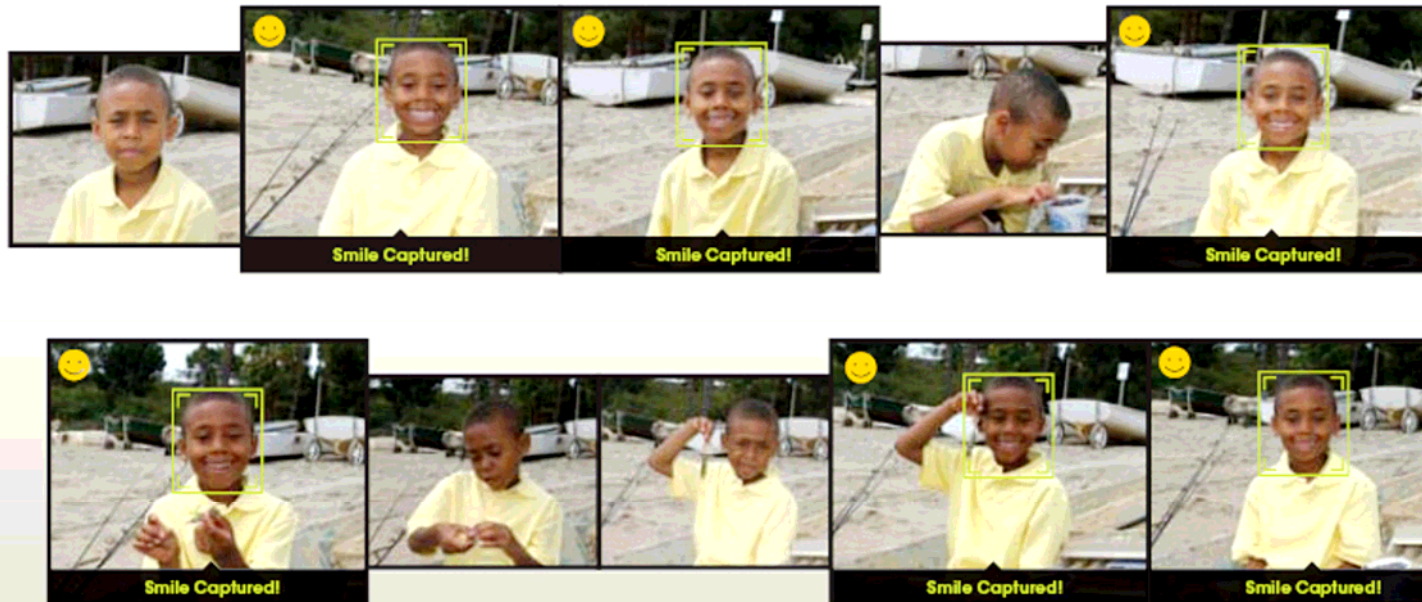


- Many new digital cameras now detect faces
 - Canon, Sony, Fuji, ...

Smile detection?

The Smile Shutter flow

Imagine a camera smart enough to catch every smile! In Smile Shutter Mode, your Cyber-shot® camera can automatically trip the shutter at just the right instant to catch the perfect expression.



Sony Cyber-shot® T70 Digital Still Camera

Object recognition (in supermarkets)



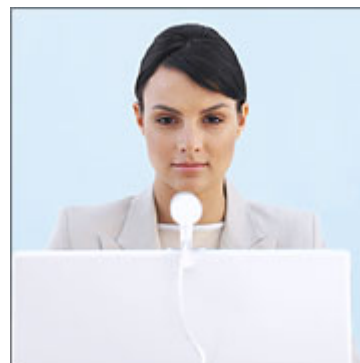
LaneHawk by EvolutionRobotics

“A smart camera is flush-mounted in the checkout lane, continuously watching for items. When an item is detected and recognized, the cashier verifies the quantity of items that were found under the basket, and continues to close the transaction. The item can remain under the basket, and with LaneHawk, you are assured to get paid for it...”

Login without a password...

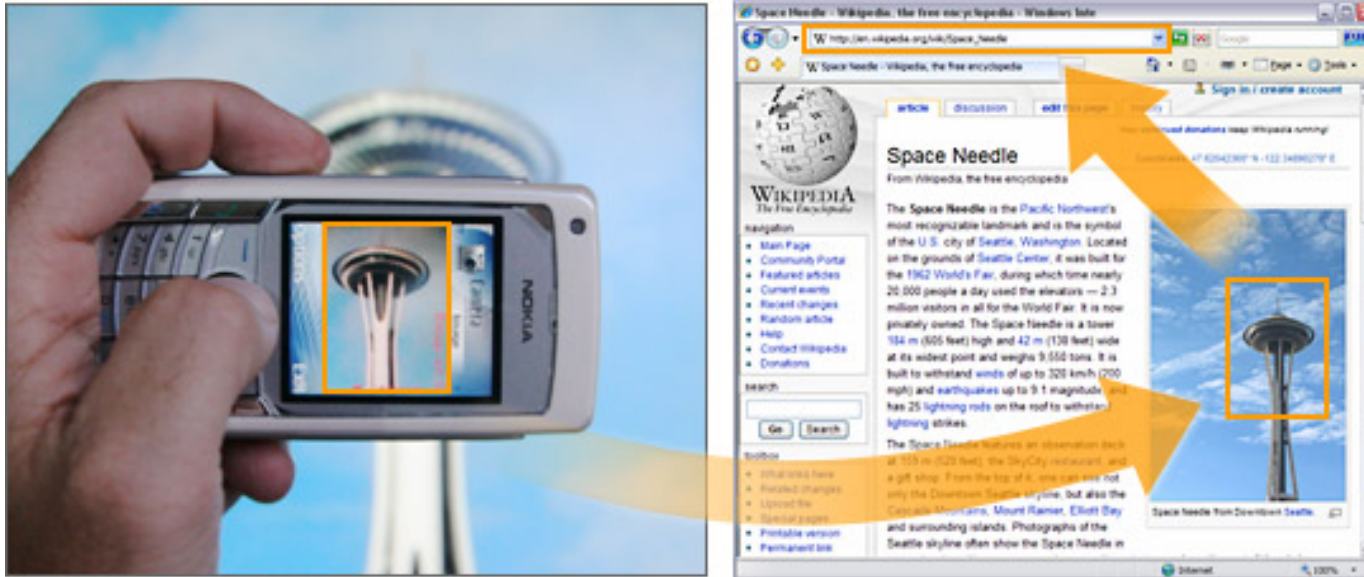


Fingerprint scanners on
many new laptops,
other devices



Face recognition systems now
beginning to appear more widely
<http://www.sensiblevision.com/>

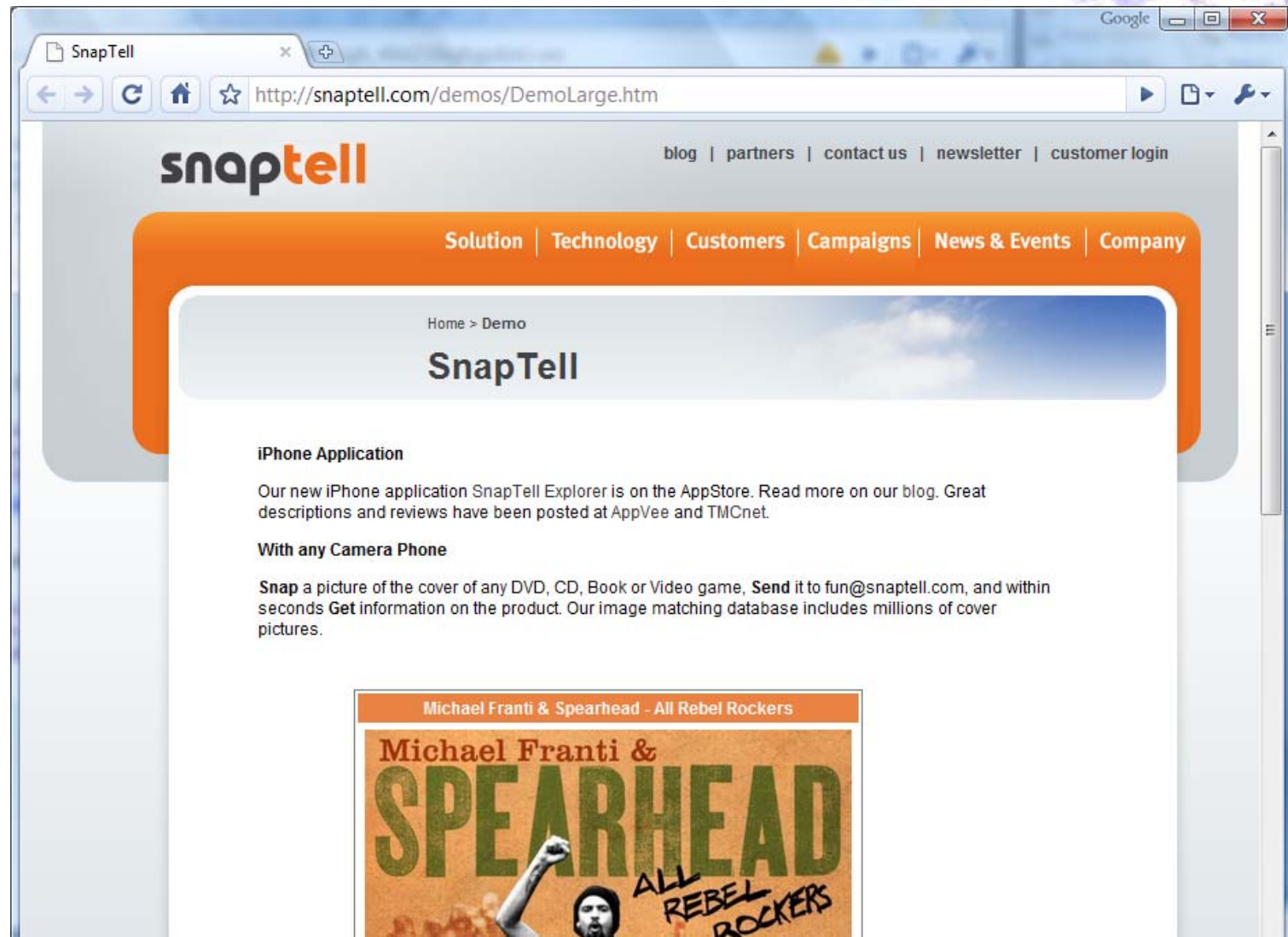
Object recognition (in mobile phones)



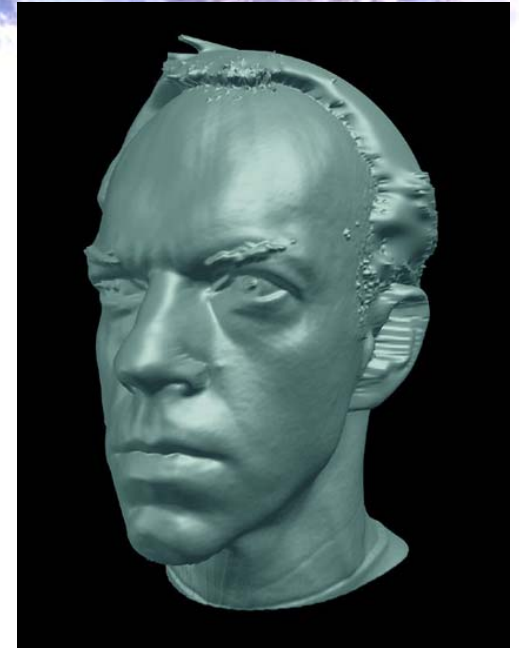
- This is becoming real:
 - **Lincoln** Microsoft Research
 - Point & Find, Nokia
 - SnapTell.com (now amazon)

SnapTell

<http://snaptell.com/demos/DemoLarge.htm>



Special effects: shape capture



The Matrix movies, ESC Entertainment, XYZRGB, NRC

Special effects: motion capture



Pirates of the Caribbean, Industrial Light and Magic

[Click here for interactive demo](#)

Sports



Sportvision first down line
Nice [explanation](http://www.howstuffworks.com) on www.howstuffworks.com

Smart cars

[▶▶ manufacturer products](#) [consumer products ◀◀](#)

Our Vision. Your Safety.



rear looking camera

forward looking camera

side looking camera

EyeQ Vision on a Chip

[> read more](#)

Vision Applications



Road, Vehicle, Pedestrian Protection and more

[> read more](#)

AWS Advance Warning System

[> read more](#)

News

- > [Mobileye Advanced Technologies Power Volvo Cars World First Collision Warning With Auto Brake System](#)
- > [Volvo: New Collision Warning with Auto Brake Helps Prevent Rear-end](#)

[> all news](#)

Events

- > [Mobileye at Equip Auto, Paris, France](#)
- > [Mobileye at SEMA, Las Vegas, NV](#)

[> read more](#)

- Mobileye

- Vision systems currently in high-end BMW, GM, Volvo models
- By 2010: 70% of car manufacturers.
- Video demo

Smart cars

▶▶ manufacturer products

consumer products ◀◀

Our Vision. Your Safety.

rear looking camera

forward looking camera

side looking camera

EyeQ Vision on a Chip

> read more

Vision Applications

Road, Vehicle, Pedestrian Protection and more

> read more

AWS Advance Warning System

> read more

News

- > Mobileye Advanced Technologies Power Volvo Cars World First Collision Warning With Auto Brake System
- > Volvo: New Collision Warning with Auto Brake Helps Prevent Rear-end

> all news

Events

- > Mobileye at Equip Auto, Paris, France
- > Mobileye at SEMA, Las Vegas, NV

Mobileye (C) 1999-2002

96.4m

0.0014 0.05

- Mobileye

- Vision systems currently in high-end BMW, GM,
- By 2010: 70% of car manufacturers.
- Video demo

Vision-based interaction (and games)



Nintendo Wii has camera-based IR tracking built in. See [Lee's work at CMU](#) on clever tricks on using it to create a [multi-touch display](#)!



[Digimask](#): put your face on a 3D avatar.



[“Game turns moviegoers into Human Joysticks”](#), CNET
Camera tracking a crowd, based on [this work](#).

Vision in space

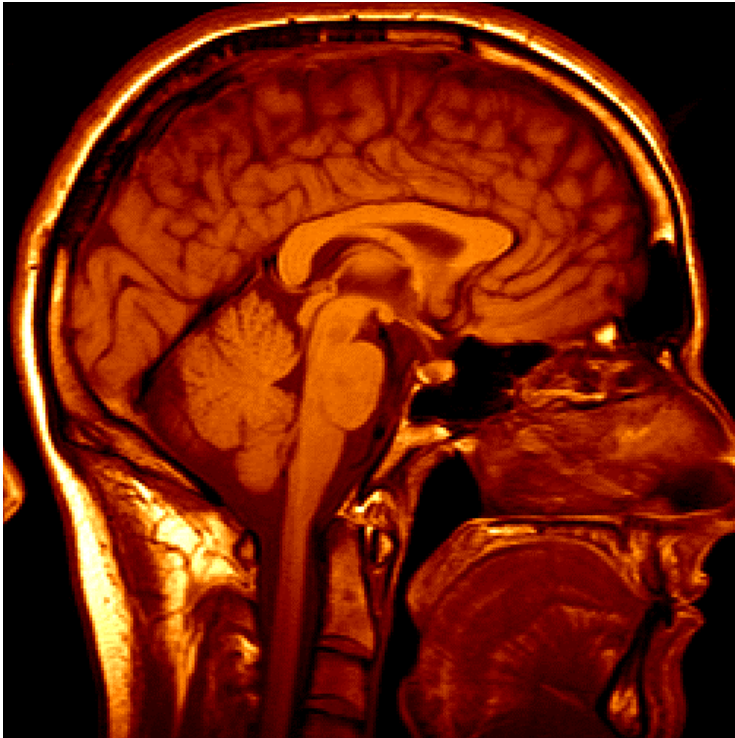


NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

Vision systems (JPL) used for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- For more, read “Computer Vision on Mars” by Matthies et al.

Medical imaging

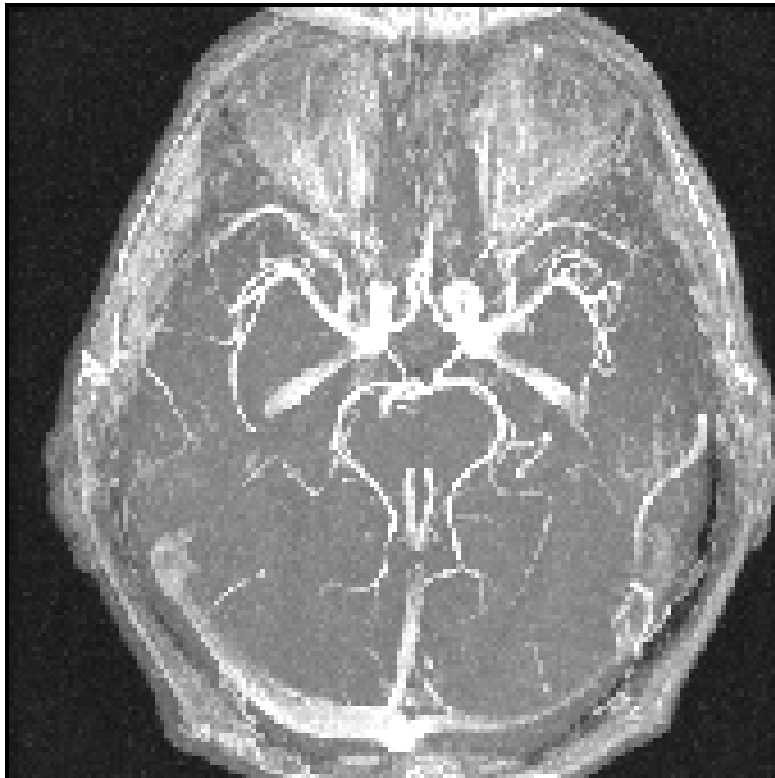


3D imaging
MRI, CT



Image guided surgery
Grimson et al., MIT

Applications of Computer Vision: Medical Imaging



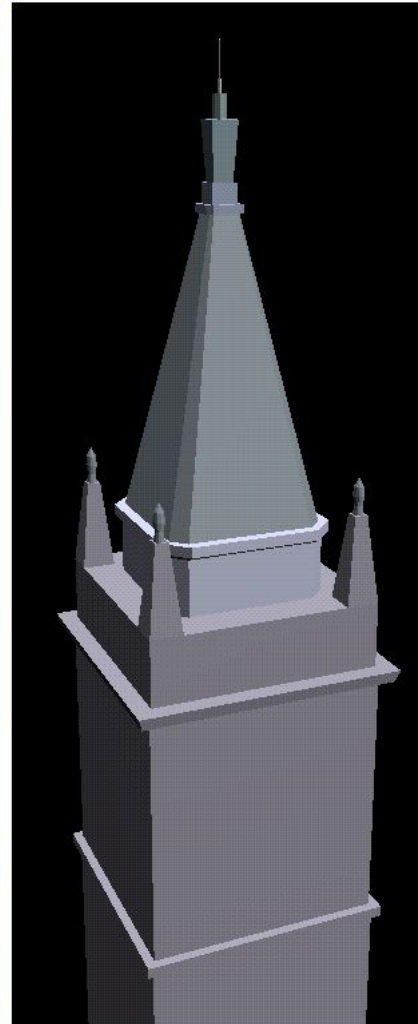
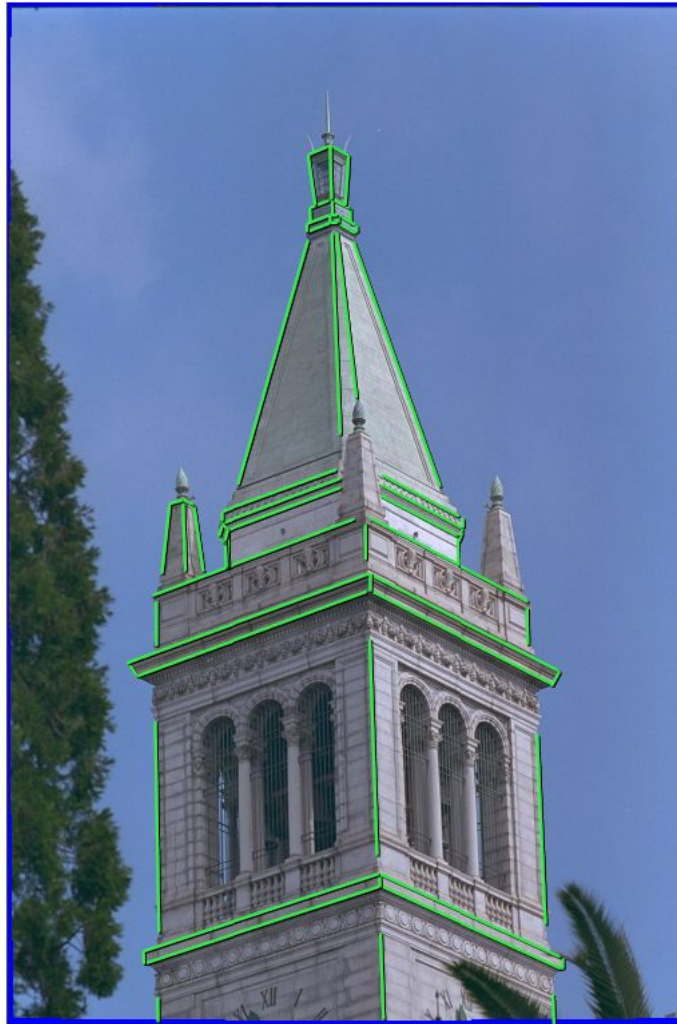
Applications of Computer Vision: Image Databases

(Courtesy D. Forsyth & J. Ponce)



From a search
for horse pix
in 100 horse
images and
1086 non-horse
images

Applications of Computer Vision: Data Acquisition



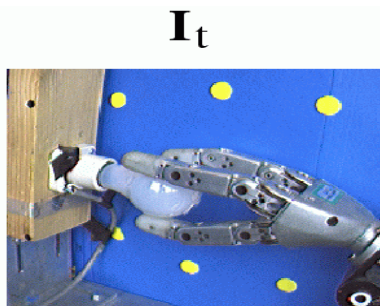
3D Computer vision uses

Use increases every year.

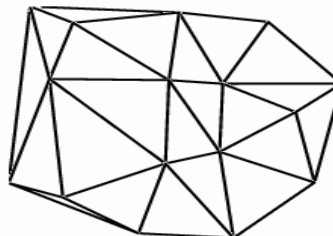
Current and emerging applications are e.g.:

1. Scientific, engineering, industrial
2. Movie special effects
3. Computer games
4. Tele-presence
5. Capture and visualization of cultural and natural heritage.

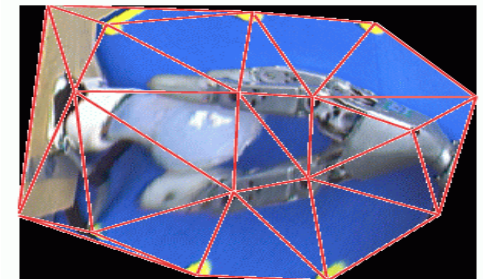
etc.



=

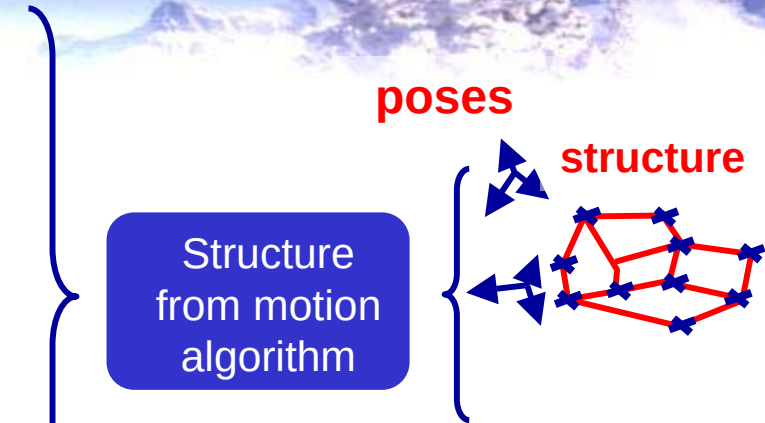
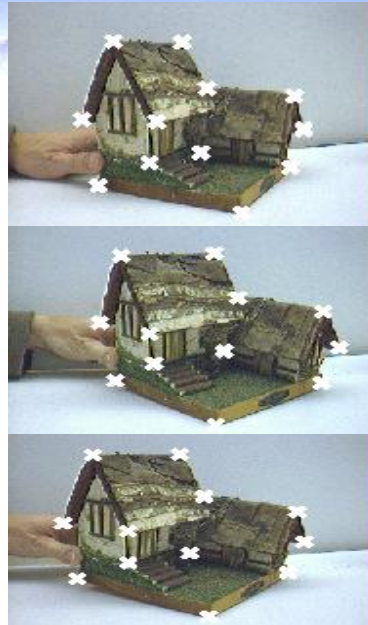


+



Vision-based modeling and rendering

1. Collect input views
2. Compute 3D geometry and appearance
3. Integrate models
4. Render new views



See: <http://www.cs.ualberta.ca/~vis/ibmr>

Case Study: Virtual heritage Modeling Inuit Artifacts

Results:

1. A collection of 3D models of each component

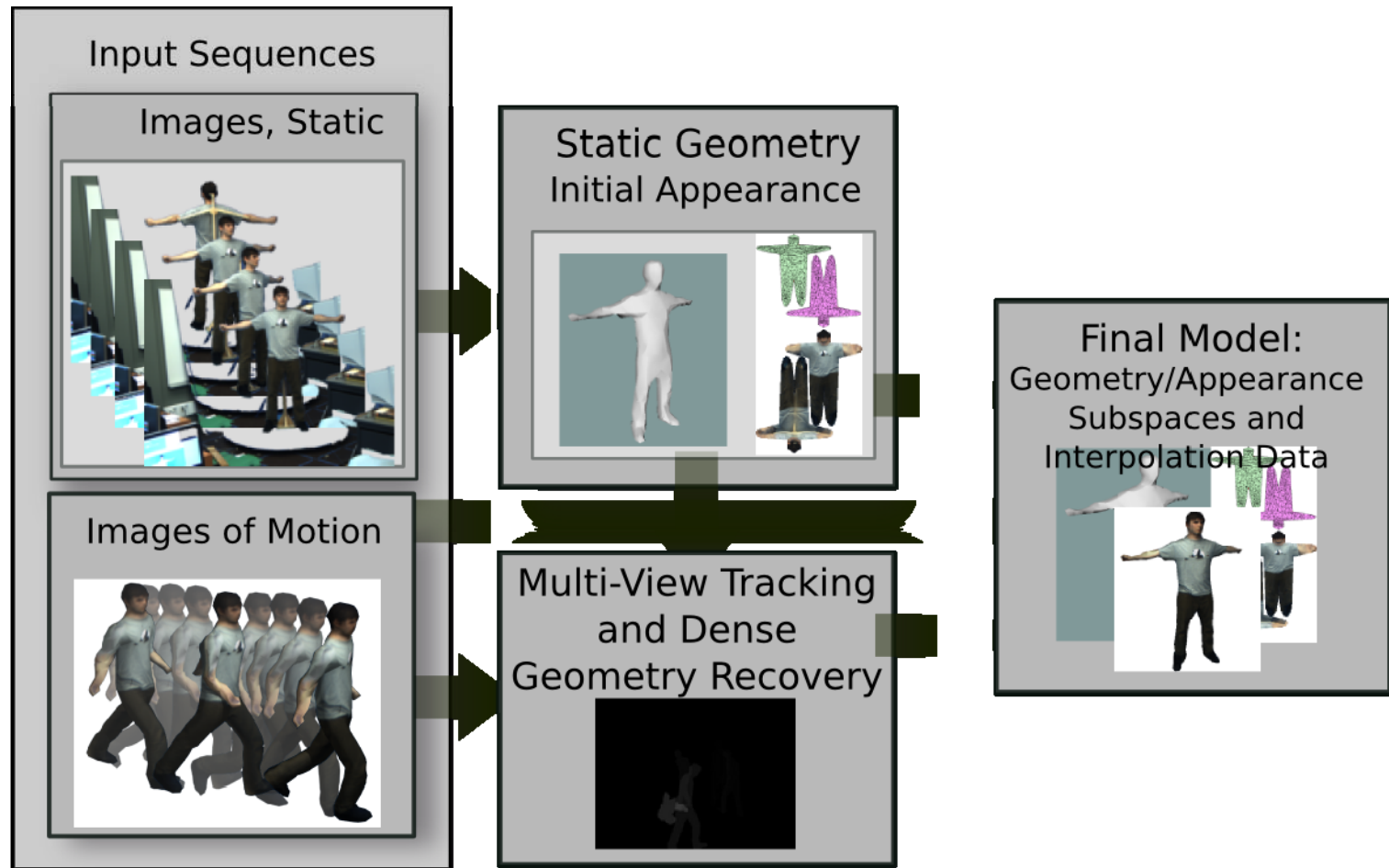


2. Assembly of the individual models into animations and Internet web study material.



Capturing non-rigid animatable models

current PhD project, Neil Birkbeck



Questions?

More information:

- System demo video

www.cs.ualberta.ca/~vis/ibmr/movies/capsys_1min.avi

- Downloadable renderer+models

www.cs.ualberta.ca/~vis/ibmr

- IEEE VR tutorial text + Capturing software

www.cs.ualberta.ca/~vis/VR2003tut

- Related papers references:

Jagersand et al “Three Tier Model” 3DPVT 2008

Jagersand “Image-based Animation...” CVPR 1997

- More papers: www.cs.ualberta.ca/~jag

Questions?

CAMERA-BASED 3D CAPTURE SYSTEM

- Dow

- Cap

- Mai

- More papers: www.cs.ualberta.ca/~jag