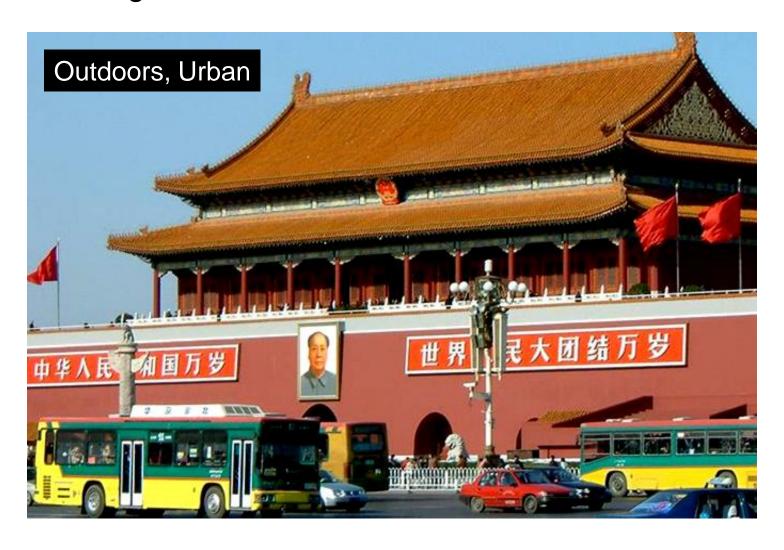
# Computer Vision Dr Krystian Mikolajczyk

# **What is Computer Vision?**

• Extracting information from pictures using a computer



• Scene categorization: Is this inside or outside?



Location: Where is this?



Object category recognition: Is that a bus?



Object category detection: Are there any cars?



Object matching: Is that my friend's car?



• Person identification: Who is that?



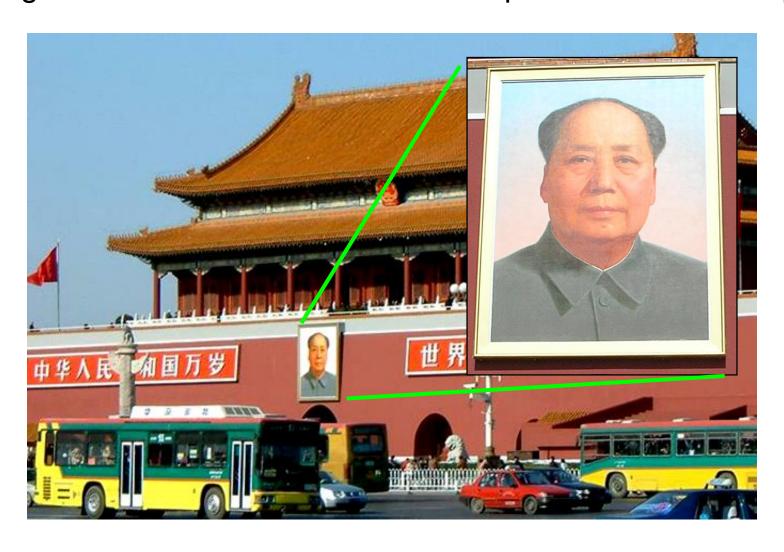
• Optical character recognition: What does that say?



• 3-D measurements: How far away is that portrait, how big?



• Image enhancement: How would that portrait look close up?

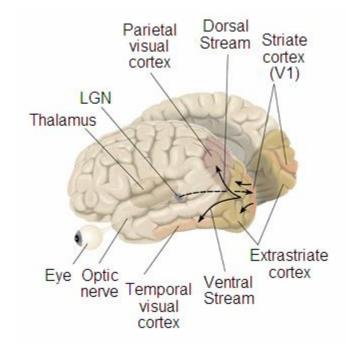


Interacting with the scene: Can I cross the road safely?



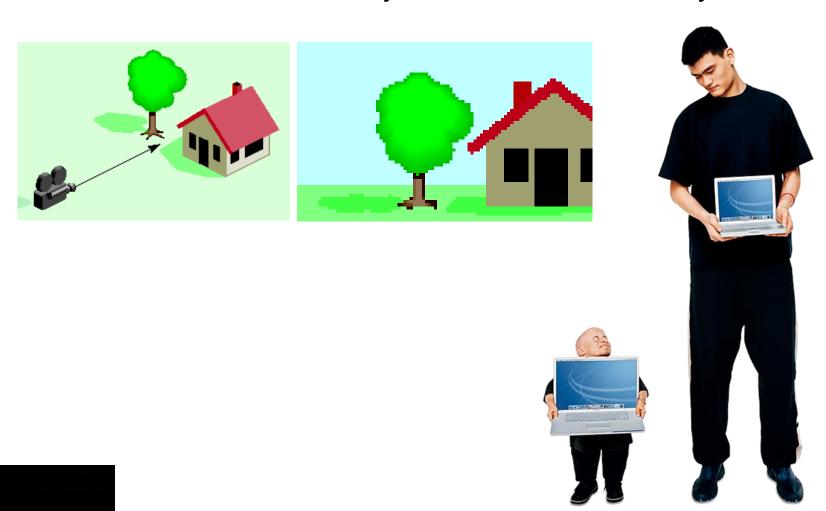
# Isn't all this stuff easy?

- Humans are pretty great at vision...
- You don't need to be good at chess to be good at vision...



But behind the scenes, there is a lot of clever stuff...
 and we don't really know how it works...

• The world is 3-D, but an eye or camera sees only 2-D



• Variation in **3-D pose** makes objects look very different



















Variation in lighting makes objects look very different



 Faces of different people with the same lighting look much more similar than faces of the same person with different lighting

• Some objects change **shape** significantly

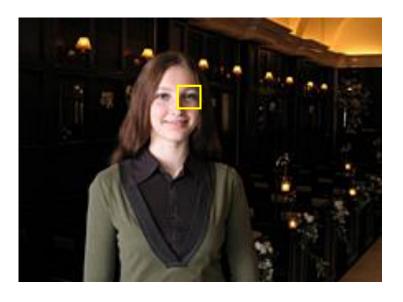


• Some object "categories" vary greatly in appearance



# What makes vision difficult for a computer?

- All the computer "sees" is a HUGE array of numbers...
  - -2 mega-pixel image =  $\sim$ 6,000,000 numbers
  - a bit more than the complete works of Shakespeare



200       200       201       210       219       213       201       199       216       199       203       213       216       214       221       230       233       225       224         191       193       194       201       211       212       210       212       226       234       227       220       217       218       218       222       226       227       223       220         190       192       192       195       203       209       213       217       229       239       237       233       227       222       222       229       226       215       217       225         190       190       190       190       192       198       203       206       208       218       225       229       226       225       225       228       222       220       213       226         190       189       191       193       193       189       181       164       188       187       179       178       188       192       187       197       214       199       204         176       178       181       1																					
190       192       192       195       203       209       213       217       229       239       237       233       227       222       229       226       215       217       225         190       190       190       192       198       203       206       208       218       225       229       226       225       225       228       222       220       213       226         190       189       191       193       194       195       194       192       186       188       187       179       179       188       192       187       197       214       199       204         186       187       191       193       193       189       181       164       134       109       90       85       88       90       84       90       116       144       175         176       178       181       184       188       192       182       163       133       83       55       52       59       61       66       68       66       65       81       97         173       172       171       172       176 <td< td=""><td>200</td><td>200</td><td>201</td><td>210</td><td>219</td><td>213</td><td>201</td><td>199</td><td>219</td><td>216</td><td>199</td><td>203</td><td>213</td><td>216</td><td>214</td><td>221</td><td>230</td><td>233</td><td>225</td><td>224</td><td>225</td></td<>	200	200	201	210	219	213	201	199	219	216	199	203	213	216	214	221	230	233	225	224	225
190         190         190         192         198         203         206         208         218         225         229         226         225         228         222         220         213         226           190         189         191         193         194         195         194         192         186         188         187         179         178         187         197         214         199         204           186         187         191         193         193         189         181         164         134         109         90         85         88         90         84         90         116         144         175           176         178         181         184         188         192         182         163         133         83         55         52         59         61         66         68         66         65         81         97           173         172         171         172         176         180         162         132         94         51         39         50         64         71         79         81         80         70         69         7	191	193	194	201	211	212	210	212	226	234	227	220	217	218	218	222	226	227	223	220	224
190       189       191       193       194       195       194       192       186       188       187       179       179       188       192       187       197       214       199       204         186       187       191       193       193       193       189       181       164       134       109       90       85       88       90       84       90       116       144       175         176       178       181       184       188       192       182       163       133       83       55       52       59       61       66       68       66       65       81       97         173       172       171       172       176       180       162       132       94       51       39       50       64       71       79       81       80       70       69       71         155       158       158       158       164       163       132       94       50       51       72       82       89       94       100       93       83       73         142       141       146       154       163       13	190	192	192	195	203	209	213	217	229	239	237	233	227	222	222	229	226	215	217	225	218
186       187       191       193       193       189       181       164       134       109       90       85       88       90       84       90       116       144       175         176       178       181       184       188       192       182       163       133       83       55       52       59       61       66       68       66       65       81       97         173       172       171       172       176       180       162       132       94       51       39       50       64       71       79       81       80       70       69       71         155       158       158       158       164       163       122       104       98       49       50       51       72       82       89       94       100       93       83       73         142       141       146       154       163       136       95       114       127       86       74       72       95       89       94       102       109       114       113       110         131       130       134       136       146	190	190	190	192	198	203	206	208	218	225	229	229	226	225	225	228	222	220	213	226	230
176       178       181       184       188       192       182       163       133       83       55       52       59       61       66       68       66       65       81       97         173       172       171       172       176       180       162       132       94       51       39       50       64       71       79       81       80       70       69       71         155       158       158       158       164       163       122       104       98       49       50       51       72       82       89       94       100       93       83       73         142       141       146       154       163       136       95       114       127       86       74       72       95       89       94       102       109       114       113       110         131       130       134       136       146       113       95       147       157       114       64       74       129       101       98       111       123       127       124       131         10       112       118       120	190	189	191	193	194	195	194	192	186	188	187	179	179	188	192	187	197	214	199	204	222
173       172       171       172       176       180       162       132       94       51       39       50       64       71       79       81       80       70       69       71         155       158       158       158       164       163       122       104       98       49       50       51       72       82       89       94       100       93       83       73         142       141       146       154       163       136       95       114       127       86       74       72       95       89       94       102       109       114       113       110         131       130       134       136       146       113       95       147       157       114       64       74       129       101       98       111       123       127       124       131         110       112       118       120       127       99       108       173       165       80       21       57       137       118       110       120       131       134       134       141         95       97       98       112<	186	187	191	193	193	193	189	181	164	134	109	90	85	88	90	84	90	116	144	175	196
155       158       158       158       164       163       122       104       98       49       50       51       72       82       89       94       100       93       83       73         142       141       146       154       163       136       95       114       127       86       74       72       95       89       94       102       109       114       113       110         131       130       134       136       146       113       95       147       157       114       64       74       129       101       98       111       123       127       124       131         10       112       118       120       127       99       108       173       165       80       21       57       137       118       110       120       131       134       134       141         95       97       98       112       121       88       109       180       153       50       38       81       122       118       123       132       138       141       147       152         87       93       86	176	178	181	184	188	192	182	163	133	83	55	52	59	61	66	68	66	65	81	97	115
142       141       146       154       163       136       95       114       127       86       74       72       95       89       94       102       109       114       113       110         131       130       134       136       146       113       95       147       157       114       64       74       129       101       98       111       123       127       124       131         110       112       118       120       127       99       108       173       165       80       21       57       137       118       110       120       131       134       134       141         95       97       98       112       121       88       109       180       153       50       38       81       122       118       123       132       138       141       147       152         87       93       86       98       111       83       97       161       144       50       21       55       87       109       141       138       134       136       138       145         74       81       79 <t< td=""><td>173</td><td>172</td><td>171</td><td>172</td><td>176</td><td>180</td><td>162</td><td>132</td><td>94</td><td>51</td><td>39</td><td>50</td><td>64</td><td>71</td><td>79</td><td>81</td><td>80</td><td>70</td><td>69</td><td>71</td><td>77</td></t<>	173	172	171	172	176	180	162	132	94	51	39	50	64	71	79	81	80	70	69	71	77
131       130       134       136       146       113       95       147       157       114       64       74       129       101       98       111       123       127       124       131         110       112       118       120       127       99       108       173       165       80       21       57       137       118       110       120       131       134       134       141         95       97       98       112       121       88       109       180       153       50       38       81       122       118       123       132       138       141       147       152         87       93       86       98       111       83       97       161       144       50       21       55       87       109       141       138       134       136       138       145         74       81       79       85       94       82       80       122       110       66       24       37       62       88       123       122       119       125       130       131         53       47       52       58<	155	158	158	158	164	163	122	104	98	49	50	51	72	82	89	94	100	93	83	73	72
110     112     118     120     127     99     108     173     165     80     21     57     137     118     110     120     131     134     134     141       95     97     98     112     121     88     109     180     153     50     38     81     122     118     123     132     138     141     147     152       87     93     86     98     111     83     97     161     144     50     21     55     87     109     141     138     134     136     138     145       74     81     79     85     94     82     80     122     110     66     24     37     62     88     123     122     119     125     130     131       53     47     52     58     59     60     52     82     88     72     58     50     53     79     87     96     96     99     109     110	142	141	146	154	163	136	95	114	127	86	74	72	95	89	94	102	109	114	113	110	108
95     97     98     112     121     88     109     180     153     50     38     81     122     118     123     132     138     141     147     152       87     93     86     98     111     83     97     161     144     50     21     55     87     109     141     138     134     136     138     145       74     81     79     85     94     82     80     122     110     66     24     37     62     88     123     122     119     125     130     131       53     47     52     58     59     60     52     82     88     72     58     50     53     79     87     96     96     99     109     110	131	130	134	136	146	113	95	147	157	114	64	74	129	101	98	111	123	127	124	131	153
87     93     86     98     111     83     97     161     144     50     21     55     87     109     141     138     134     136     138     145       74     81     79     85     94     82     80     122     110     66     24     37     62     88     123     122     119     125     130     131       53     47     52     58     59     60     52     82     88     72     58     50     53     79     87     96     96     99     109     110	110	112	118	120	127	99	108	173	165	80	21	57	137	118	110	120	131	134	134	141	161
74     81     79     85     94     82     80     122     110     66     24     37     62     88     123     122     119     125     130     131       53     47     52     58     59     60     52     82     88     72     58     50     53     79     87     96     96     99     109     110	95	97	98	112	121	88	109	180	153	50	38	81	122	118	123	132	138	141	147	152	155
53 47 52 58 59 60 52 82 88 72 58 50 53 79 87 96 96 99 109 110	87	93	86	98	111	83	97	161	144	50	21	55	87	109	141	138	134	136	138	145	151
	74	81	79	85	94	82	80	122	110	66	24	37	62	88	123	122	119	125	130	131	136
64 65 75 76 63 55 44 52 60 55 52 47 42 48 60 66 75 79 86 89	53	47	52	58	59	60	52	82	88	72	58	50	53	79	87	96	96	99	109	110	107
01 00 70 70 00 00 11 02 00 00 02 11 12 10 00 00 70 70 00 00	64	65	75	76	63	55	44	52	60	55	52	47	42	48	60	66	75	79	86	89	86
17 25 39 49 52 60 59 65 62 56 54 52 48 51 55 54 56 53 51 50	17	25	39	49	52	60	59	65	62	56	54	52	48	51	55	54	56	53	51	50	49
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16 15 14 18 16 11 9 10 11 12 17 20 19 17 15 11 11 9 7 8	16	15	14	18	16	11	9	10	11	12	17	20	19	17	15	11	11	9	7	8	10
28 24 19 21 23 19 16 12 15 14 14 12 10 11 13 14 12 12 13 15	28	24	19	21	23	19	16	12	15	14	14	12	10	11	13	14	12	12	13	15	15

The meaning of the image is very well "hidden"

# **Enough with the pessimism...**

What might we do with computer vision, and can we do it?

# **Computer Vision**

#### Science

- Foundations of vision. How do we model visual phenomena?
- Artificial intelligence, Robotics, Vision and speech analysis

#### Engineering

How do we build systems that perceive the world ( AI )

#### Applications

- Medical analysis, surveillance, entertainment, ...
- Cars, robots, military, toys
- Communication, Mass Media, Broadcasting companies,
   Entertainment, Movie production, archives, security (Police, Internet)

# **Computer Vision**

The aim is to offer an in depth course on the basic principles of Computer Vision which may form the foundation for a variety of diverse disciplines like Remote Sensing, Robot Vision, Image and Vision Understanding, Medical Imaging, Digital Broadcast etc.

- Segmentation thresholding, watershed algorithm, clustering algorithms, segmentation algorithms.
- Motion Analysis motion models, tracking methods, motion based segmentation.
- Geometry homogenous coordinates, geometric image transformations, camera model, camera calibration, stereo vision.
- Feature Detection basic image structures, features, feature detection algorithms, image descriptors, similarity measures.
- Image registration, matching algorithms, transformation estimation,

CV is about algorithms and programming Manual calculation done only when designing and debugging