

*Introduction to*  
**Computational and Biological Vision**

CS 202-1-5261

Computer Science Department, BGU

Ohad Ben-Shahar

## *Some necessary administrivia*

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<b>Office:</b>	37/114 (Alon High-Tech Building)
<b>Office hours:</b>	Tuesdays 10:00-11:30 (or email me for an appointment)
<b>Course web page :</b>	<a href="http://www.cs.bgu.ac.il/~icbv161">http://www.cs.bgu.ac.il/~icbv161</a>
<b>TA :</b>	Boaz Arad (boazar@cs.bgu.ac.il)
<b>Grading :</b>	נוכחות חובה!!
	15% Homework assignments
	40% Final exam (must pass!)
	40% Project
	5% Participation in 1-2 human vision lab sessions. (If no experiment is done, these 5% goes to HW)

# Course home page

## <http://www.cs.bgu.ac.il/~icbv161>



The screenshot shows a Mozilla Firefox browser window displaying the course home page. The address bar shows the URL [www.cs.bgu.ac.il/~ben-shahar/Teaching/Computational-Vision/index.php](http://www.cs.bgu.ac.il/~ben-shahar/Teaching/Computational-Vision/index.php). The page features a blue header with the text "Introduction to Computational and Biological Vision" and a logo on the left. A sidebar on the left contains navigation links: "Course Home", "Administration", "Syllabus", "References", "Lecture Notes", "Readings", "Assignments", "Lab sessions", "Projects", "Resources", and "Comments? Ideas?". The main content area is titled "Course announcements for the Fall 2013 semester (icbv131)" and contains two tables of announcements.

**Introduction to**  
*Computational and Biological Vision*

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### Course announcements for the Fall 2013 semester (icbv131)

Date	Recent announcements
28/02/2013	The two faculties which you come from (Natural and Engineering sciences) have graciously agreed to extend the deadline for the submission of your final grades. We will therefore add two full weeks to your project submission deadline and meet to present your projects on Friday, March 22, 9:00 in seminar room 201. Please follow this page for any possible changes. Please read the instructions on the course web page and remember that you have 10 minutes max to present your project. Make sure to also submit your project as per the instruction no later than that date.

Date	Past announcements
21/02/2013	Project presentation day is set tentatively to March 8, 9:00 in seminar room 201. Please follow this page for any possible changes. Please read the instructions on the course web page and remember that you have 10 minutes max to present your project. Make sure to also submit your project as per the instruction no later than that date.
20/02/2013	Moad Alef has been graded and grades have been published. Please note that your final grades in the course still wait for your project grade.
04/01/2013	Final (Moed Alef) is schedule for Feb 14. No open material is allowed. You are welcome to access selected final and quizzes <a href="#">in this folder</a> . Good luck!
04/01/2013	Assignment #3 is now posted on the see <a href="#">Assignments Page</a> .
04/01/2013	Assignment #2 is now posted on the see <a href="#">Assignments Page</a> .
04/10/2012	Assignment #1 due date was postponed to 16/12 (see <a href="#">Assignments Page</a> ).
28/10/2012	Assignment #1 is now posted in the <a href="#">Assignments Page</a> .
28/10/2012	Please read all three pieces mentioned in the Sensing section in the <a href="#">Lecture Notes Page</a> .
26/10/2012	One more room change announcement: All practical sessions (Tirgulim) will be given in lab 4 in building 92. Please make sure to show up at the right place.
21/10/2012	Room change announcement: All practical sessions (Tirgulim) will be given in lab 119 in building 33. Please make sure to show up at the right place.
17/10/2012	Welcome to Introduction to Computational and Biological Vision ICBV131. First lecture will be held on Oct 21.

## *Project guidelines*

<b>What about :</b>	Hardly any restrictions as long as it is related to class material. Application of class material to other disciplines is particularly welcome. Some project themes may be suggested by the staff of the course.
<b>Max team size :</b>	1 or 2 depending on enrollment
<b>What is expected of you :</b> (all due at the end of exam period)	<ul style="list-style-type: none"><li>• Written report.</li><li>• Implementation of the idea.</li><li>• 10 minutes oral presentation</li><li>• Self contained web presentation.</li><li>• See the course web page for additional instructions and examples of past projects</li></ul>

# *References*

**No prescribed text. However, the following books will be consulted as needed:**

- **A Guided Tour of Computer Vision,**  
by V. S. Nalwa, Addison-Wesley, 1993.
- **Computer Vision – A Modern approach,**  
by D.A. Forsyth and J. Ponch, Prentice Hall, 2003.
- **Computer Vision: Algorithms and Applications**  
by Richard Szeliski, Microsoft Research, 2010.  
Online version available at <http://szeliski.org/Book/>
- **Vision Science,**  
by S.E. Palmer, MIT Press, 1999.
- **Visual Intelligence,**  
by D.H.Hoffman, W.W. Norton and Company, 1998.
- **Vision,**  
by D. Marr, W.H.Freeman, 1982.
- **Organization in Vision – Essays on Gestalt Perception,**
- by G. Knizsa, Praeger Publishers, 1979.

*What is **Computational vision** all about ?*



*A short step back...*

*What is **Visual Perception** all about ?*

**“The plain man’s answer (and Aristotle’s too) would be, **to know what is where by looking**. In other words, vision is the process of discovering from images what is present in the world, and where it is”.**

**[David Marr, 1982]**

*A short step back...*

*What is **Visual Perception** all about ?*

**The acquisition of knowledge  
about  
objects and events in the environment  
through  
information processing  
of  
light emitted or reflected from objects**



What is *Computational vision* all about ?

The ultimate goal - making computers “see”

But what does it mean?

Typical “definitions” include 4 components

*Automatic inference* (?) of *properties* (?) of the *world* (?) from *images* (?)

# What is *Computational vision* all about ?

*Automatic inference* (?) of *properties* (?) of the *world* (?) from *images* (?)

<b>Automatic inference:</b>	<ul style="list-style-type: none"><li>• Inference without (or minimal) human intervention.</li></ul>
<b>The world:</b>	<ul style="list-style-type: none"><li>• The real unconstrained 3D physical world</li><li>• Constrained/Engineered environments</li></ul>
<b>Image:</b>	<ul style="list-style-type: none"><li>• 2D projection of the electromagnetic signal provided by the world.</li></ul>
<b>Properties:</b>	<ul style="list-style-type: none"><li>• Geometric: shape, size, location, distance,</li><li>• Material : color, texture, reflectivity, transparency</li><li>• Temporal: direction of motion (in 3D), speed, events</li><li>• Illumination: light source specification, light source color</li><li>• Symbolic: objects' class, object's ID</li></ul>

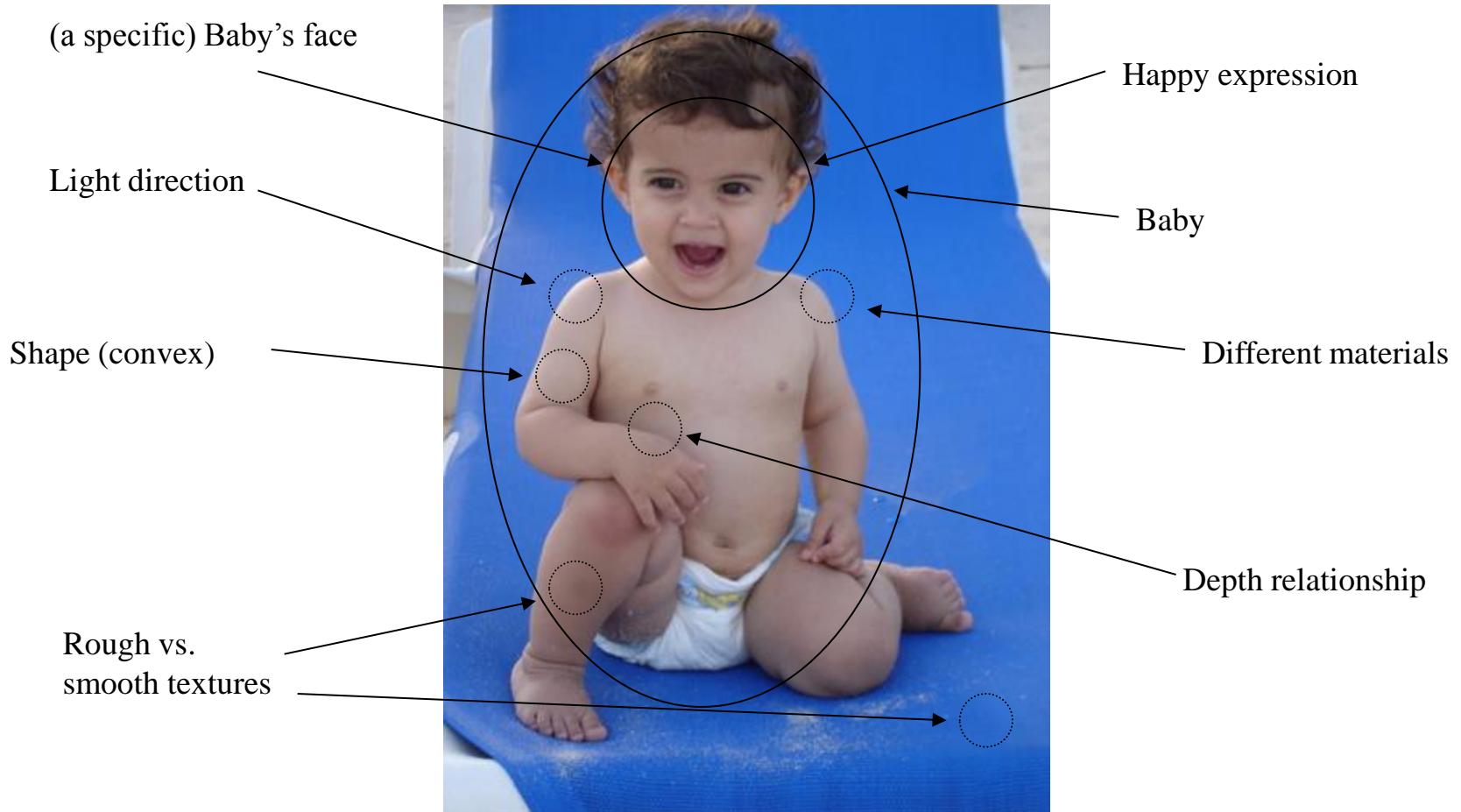
# *What is Computational vision all about ?*

*Automatic inference* (?) of *properties* (?) of the *world* (?) from *images* (?)



# What is *Computational vision* all about ?

*Automatic inference* (?) of *properties* (?) of the *world* (?) from *images* (?)



## *Computational vision must be very easy (!)*

- **All people can “see” equally well (but only few can solve hard mathematical problems, play good soccer, or play good chess)**
- **Babies can “see”**
- **Really primitive animals can “see”**
- **We “see” effortlessly (at least it feels this way)**
- **Vision is immediate**
- **Vision appears to be flawless**

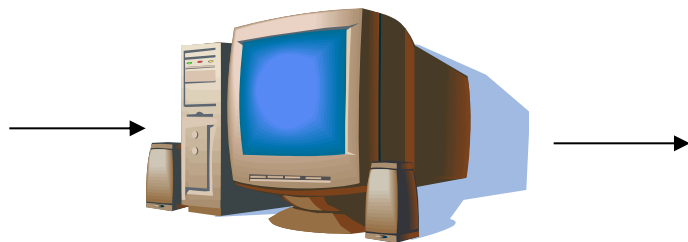
# *Computational vision must be very easy (?)*

## Homework assignment #1

INPUT

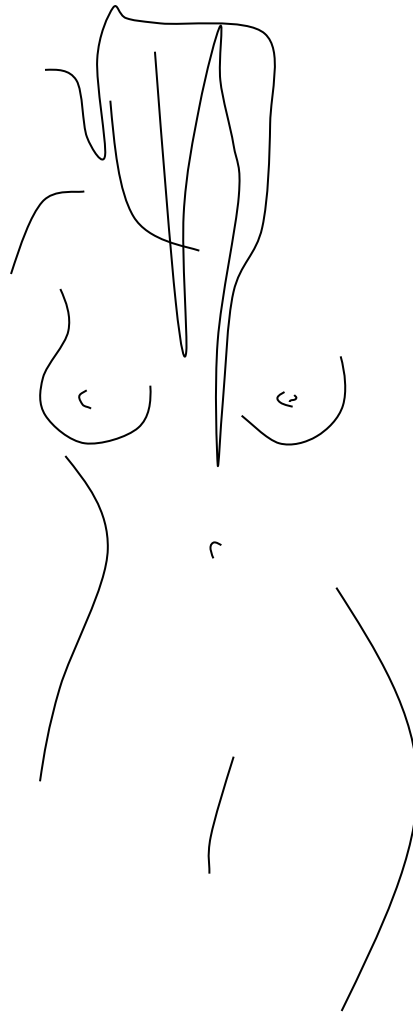
```
32 48 57 98 142 158 160 151 155 153
161 160 155 163 159 166 159 176 153 156
143 116 99 114 100 105 132 148 132 108
124 124 110 93 96 78 38 42 66 62
197 196 199 200 196 200 199 195 203 201
150 144 125 119 118 108 144 164 227 81
162 163 171 174 172 165 175 171 193 188
201 152 184 110 89 136 119 100 120 183
93 137 155 173 172 164 162 159 171 157
203 179 174 173 138 117 100 107 107 118
188 145 111 169 160 135 107 74 59 63
198 193 182 192 198 203 200 196 201 192
183 179 156 128 128 157 169 174 159 208
161 165 174 164 163 164 156 157 156 162
130 154 173 112 190 174 153 179 187 161
46 85 89 68 167 154 155 163 155 158
191 198 191 205 192 190 156 105 106 122
180 170 200 160 166 184 159 144 113 75
192 192 190 195 191 190 195 194 196 196
168 151 171 185 181 170 149 167 174 177
157 156 171 153 147 157 162 159 156 163
112 162 168 155 180 188 172 162 186 185
67 67 49 69 92 87 111 156 160 158
202 193 195 196 198 196 193 196 198 162
192 198 191 201 201 197 198 188 173 144
155 156 198 198 194 190 192 194 192 190
182 171 163 161 162 176 186 195 161 154
```

OUTPUT



This is my baby. She is sitting on a beach bench, with the sun shining from behind, her right arm on her right leg. She is smiling.

*Computational vision must be very easy (??)*



*After Zilon (Canada)*

*Computational vision must be very easy (????)*





*Computational vision must be very easy (?????)*



## *(Computational) vision is extremely hard !!*

- **Vision needs to reverse the imaging process which is a many-to-one mapping (...recover lost information).**
- **Vision needs to cope with an inherently imperfect imaging process (...recover lost information)**
- **Vision needs to cope with discretized images of a practically continuous world (...recover lost information).**
- **The mere complexity of the task is enormous!**
- **Huge portion of our brain is dedicated to visual perception.**

*(Computational) vision in extremely hard !!*

**Can we hope to solve it?**

**There exist a computational system that works (our own)!!**

**What can be used to approach the problem computationally?**

- **Constrain/simplify the world**
- **Constrain/simplify the task (i.e., the desired output)**
- **Devise universal guiding assumptions or heuristics**
- **Incorporate explicit knowledge**
- **Use experience (learning)**

## *What is Computational Vision good for?*

**Ultimately: everything we use our eyes for (and more)!!**

### **Applications:**

- **Automated navigation with obstacle avoidance**
- **Object/target detection and recognition**
- **Place/scene recognition**
- **Manufacturing and assembly**
- **Document processing**
- **Quality control**
- **Biomedical applications**
- **Accessibility tools**
- **Human computer interfaces**

**and countless many others...**

*Introduction to*

# Computational and **Biological** Vision



**Why then is this also a part of the course?**

**Biological → Computational**

- Biological vision systems provide a proof of existence
- Learn from nature's (i.e., evolution's) designs (and mistakes)
- Biological/Human vision is being investigated for centuries
- Gain insight toward computational mechanisms
- Inspires computational building blocks

*Introduction to*

# Computational and **Biological** Vision



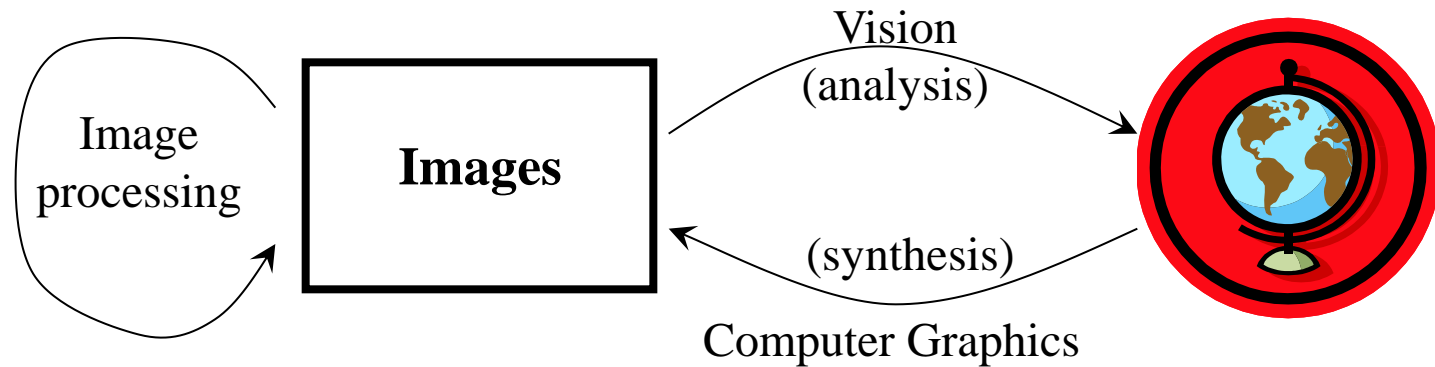
**Why then is this also a part of the course?**

**Biological**  $\longrightarrow$  **Computational**

- Offers insight into biological mechanisms
- Assists in understanding human vision
- Defines new directions for biological vision research
- Provides rigorous explanations for biological findings
- Test models of biological vision
- Generates predictions

## *Related fields and disciplines*

- **Image processing**
- **Computer graphics**
- Pattern recognition
- Artificial intelligence
- Robotics
- Physics/Optics
- Psychology (of perception)
- Physiology
- Brain studies
- Philosophy (epistemology)



## *Properties of the “vision” sense*

- **Our most important and most informative sense.**
- **All animals “see” (albeit differently).**
- **Accurate remote sensing (huge survival implications).**
- **Passive.**
- **Non destructive.**
- **Huge bandwidth.**
- **Sensitive to a small subset of the electromagnetic spectrum.**
- **Veridical (truthful) perception (?)**

*Actually, despite a strong feeling of robustness*

- **What you see is **NOT** necessarily what is out there!!**



## *Visual illusions*

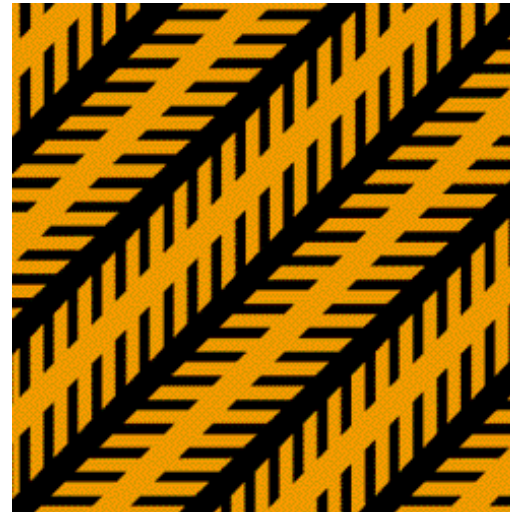
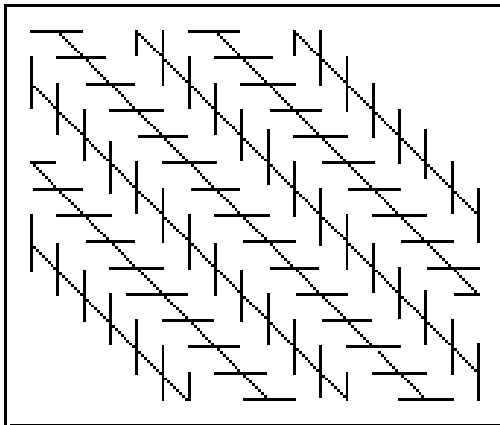
***Illusion*** [il·lu·sion]

**noun.**

**An erroneous perception of reality.**

# *Visual illusions*

## **Structure/Geometrical illusions**



**Zöllner illusion**

# *Visual illusions*

## **Structure/Geometrical illusions**



**Café wall illusion**

# *Visual illusions*

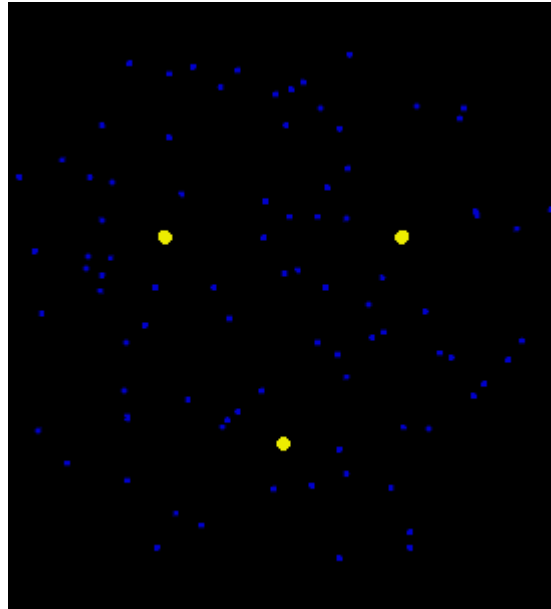
## **Shape and shading illusions**



**San Juan River, *UT, USA***

# *Visual illusions*

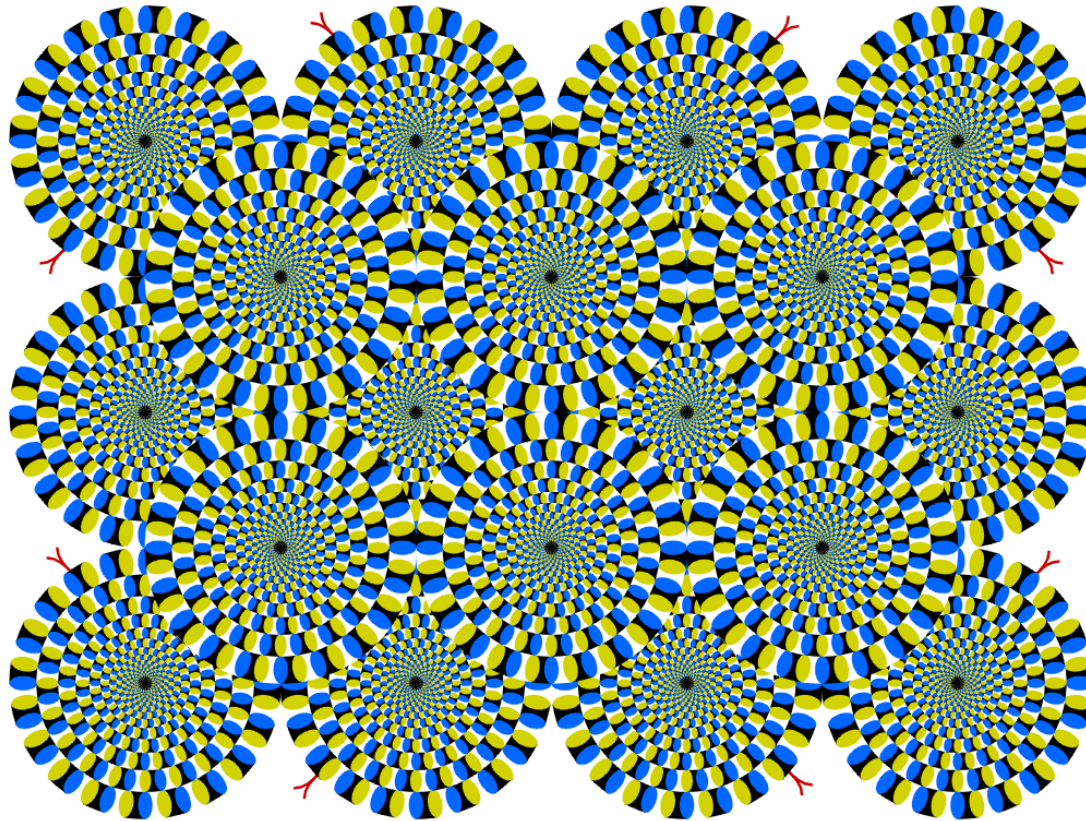
## **Motion related illusions**



*Motion induced blindness illusion (Boneh et al, 2001)*

# *Visual illusions*

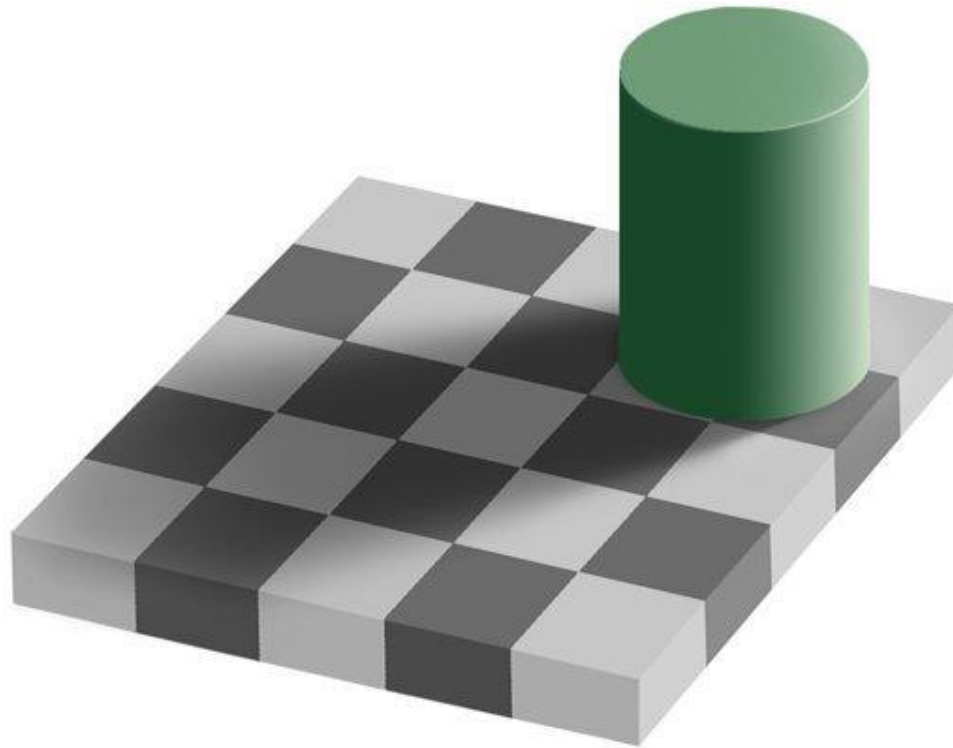
## **Motion related illusions**



**Akiyoshi Kitaoka, *Japan***

# *Visual illusions*

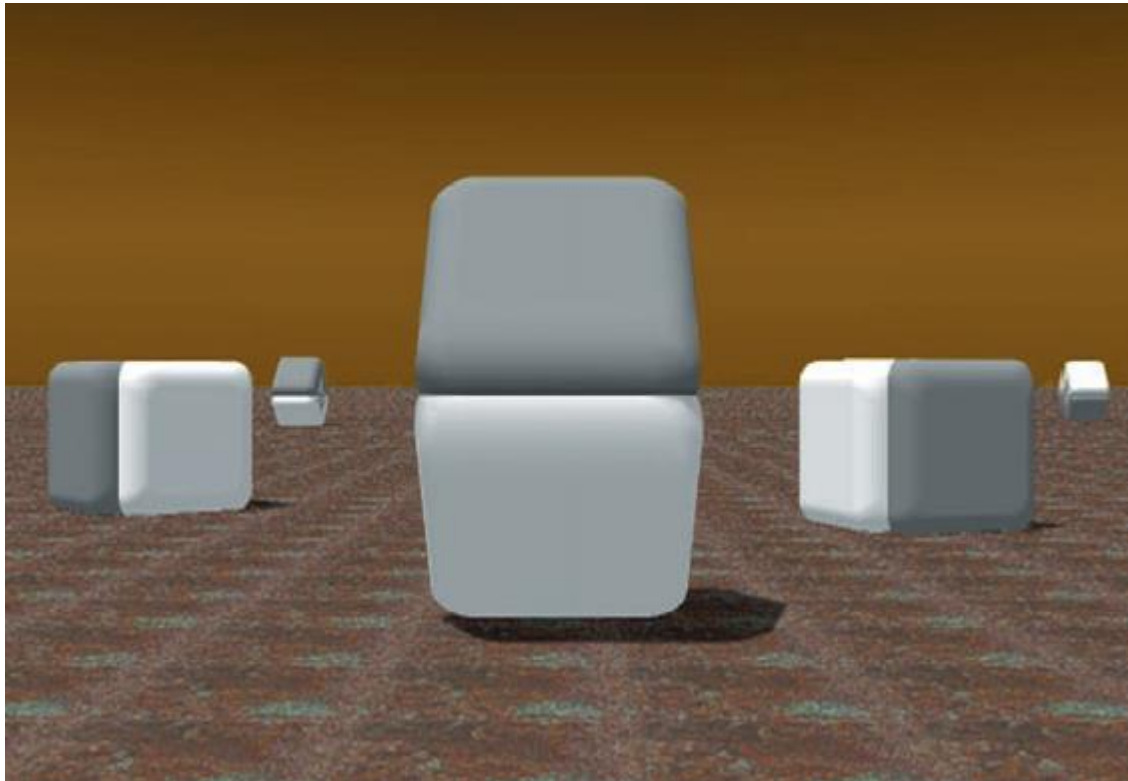
## **Shading illusions**



**Ted Adelson, *MIT***

# *Visual illusions*

## **Shading illusions**

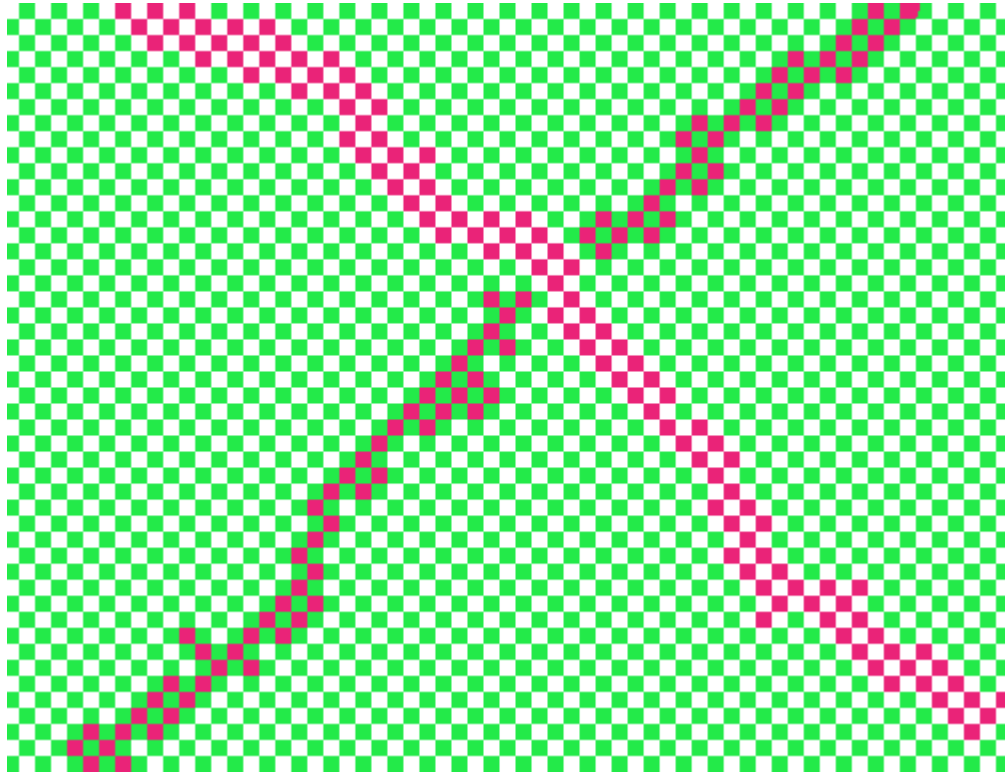


**Purves and Lotto, 1999**



# *Visual illusions*

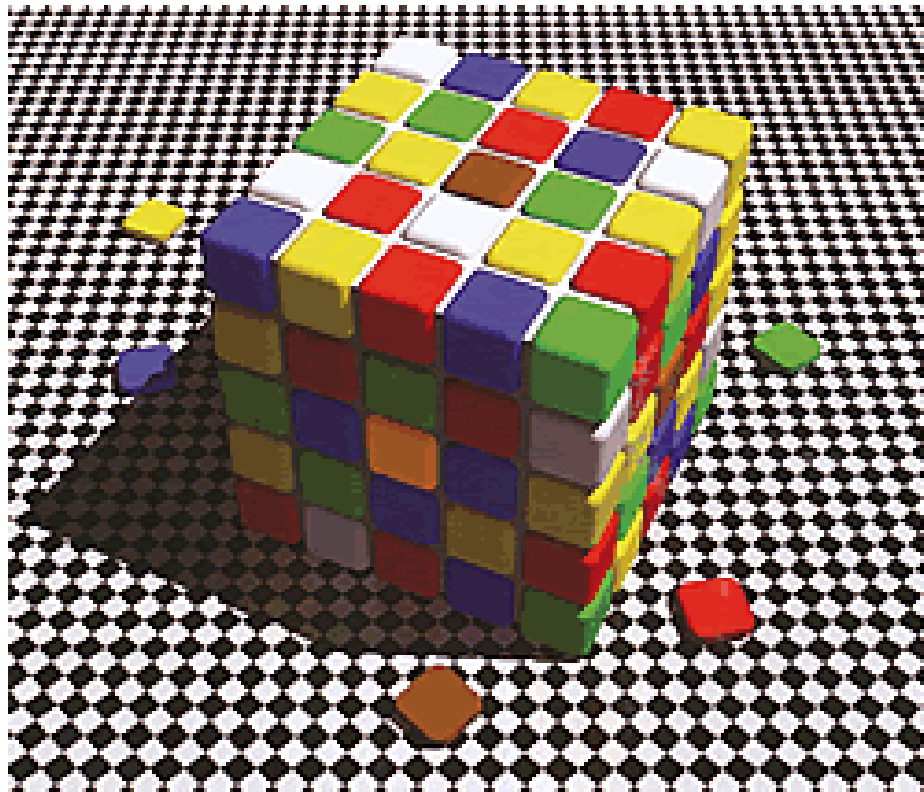
## **color illusions**



*Contextual effects*

# *Visual illusions*

## **color illusions**



*Contextual effects*

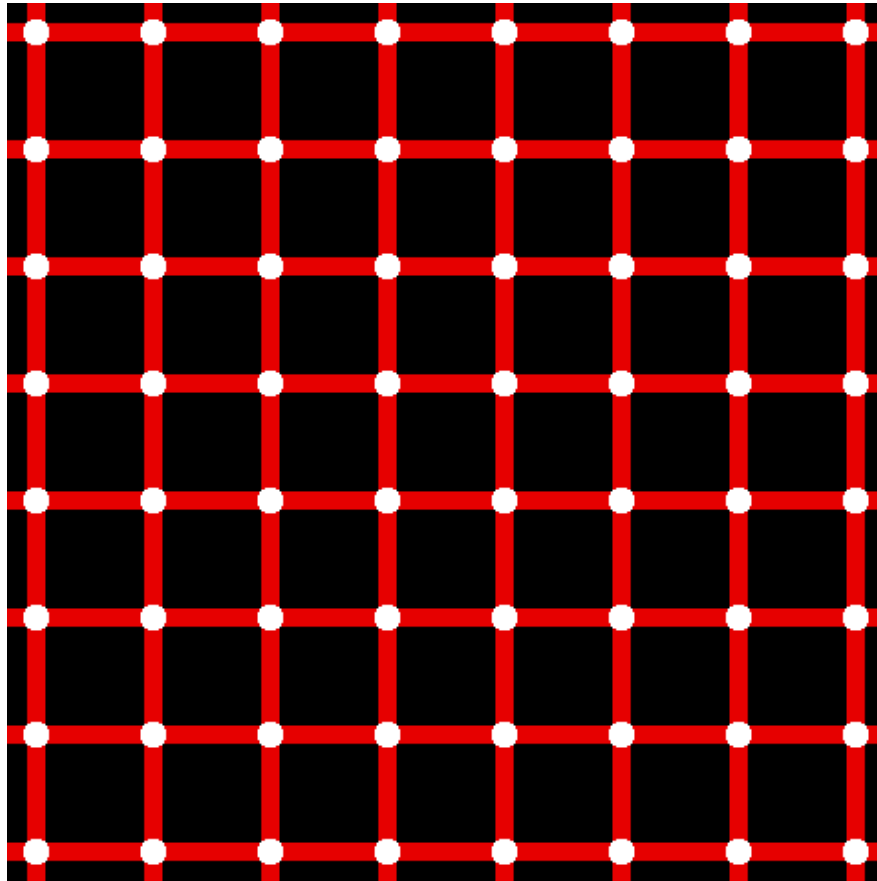
# *Visual illusions*

## **color illusions**



# *Visual illusions*

## **Color and shading illusions**



**The Scintillating Grid Illusion**

## *Visual illusions*

*What do visual Illusions tell us (or good for)?*

- **Vision is not completely accurate (veridical)**
- **Vision is not just a simple registration of objective reality**

*Therefore it must be the case that*

- **Vision is an *interpretive* process**
- **Vision is a *constructive* act**

## *Visual illusions*

### **Ambiguity in scene interpretation**



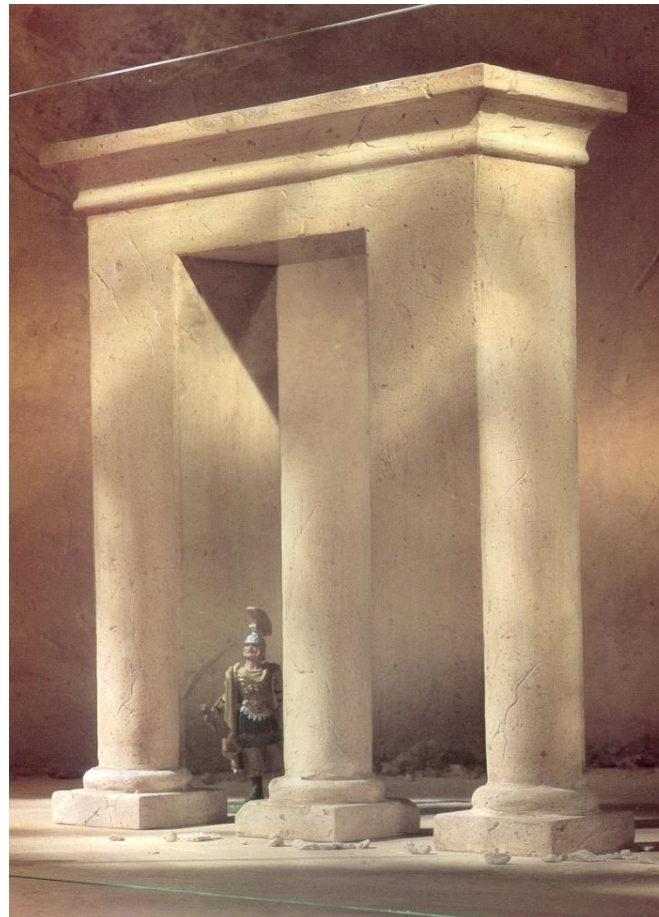
## *Visual illusions*

### **Ambiguity in scene interpretation**



# *Visual illusions*

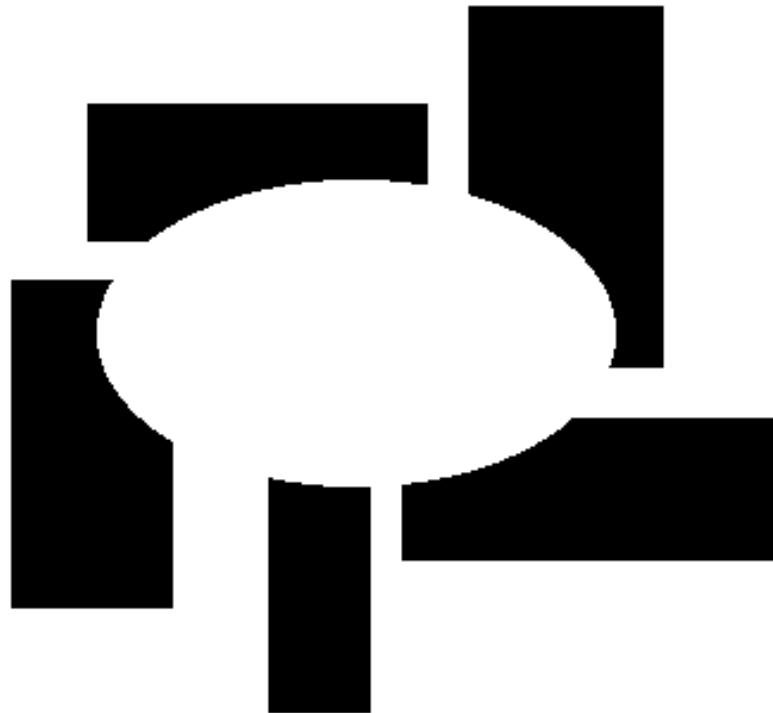
## **Impossible objects**





# *Visual illusions*

## **Visual completion**



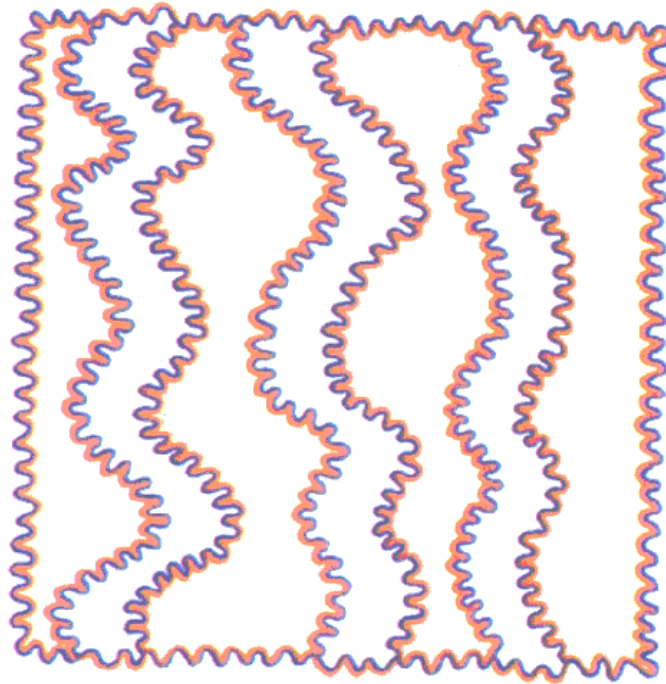
# *Visual illusions*

## **Visual completion**



# *Visual illusions*

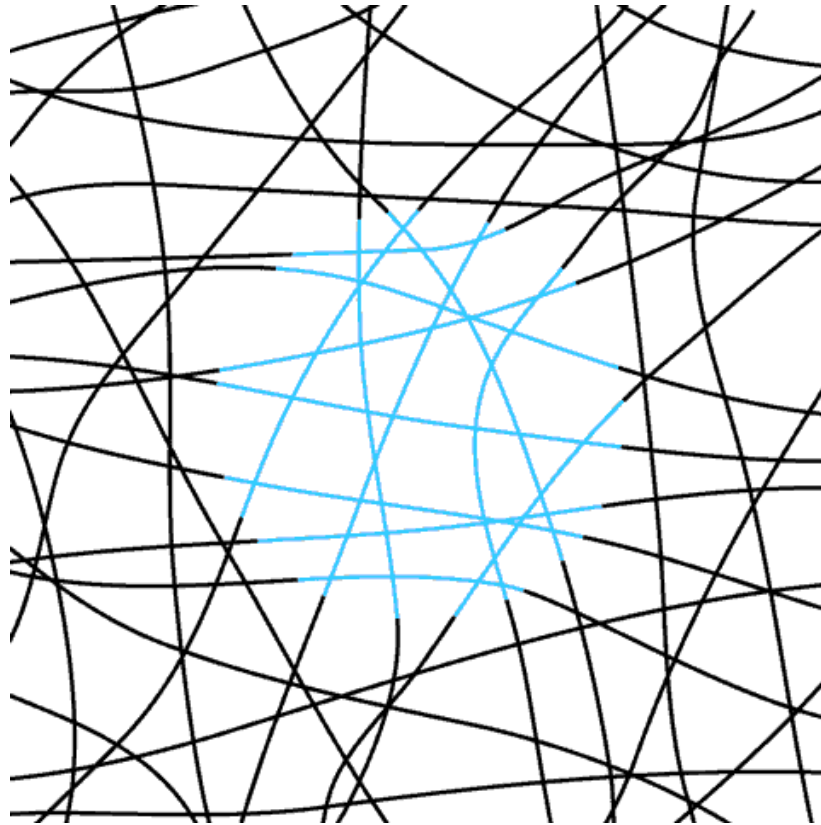
## **Color filling in**



**The watercolor effect, *Pinna et al. 2001***

# *Visual illusions*

## **Color filling in**



**Neon color spreading illusion**