Introduction to

Computational and Biological Vision

CS 202-1-5261

Computer Science Department, BGU

Ohad Ben-Shahar

Some necessary administrivia

Lecturer :	Ohad Ben-Shahar
Email address :	ben-shahar@cs.bgu.ac.il
Phone:	(08-64) 77868
Office:	37/114 (Alon High-Tech Building)
Office hours:	Tuesdays 10:00-11:30 (or email me for an appointment)
Course web page :	http://www.cs.bgu.ac.il/~icbv161
TA :	Boaz Arad (boazar@cs.bgu.ac.il)
Grading :	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

Project guidelines

What about :	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.
Max team size :	1 or 2 depending on enrollment
What is expected of you : **(all due at the end of exam period)**	• Written report. • Implementation of the idea. • 10 minutes oral presentation • Self contained web presentation. • See the course web page for additional instructions and examples of past projects

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* (?)

Automatic inference:	• Inference without (or minimal) human intervention.
The world:	• The real unconstrained 3D physical world • Constrained/Engineered environments
Image:	• 2D projection of the electromagnetic signal provided by the world.
Properties:	•Geometric: shape, size, location, distance, •Material : color, texture, reflectivity, transparency •Temporal: direction of motion (in 3D), speed, events •Illumination: light source specification, light source color •Symbolic: objects' class, object's ID

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* (?)

(a specific) Baby's face

Happy expression

Light direction

Baby

Shape (convex)

Different materials

Rough vs.
smooth textures

Depth relationship
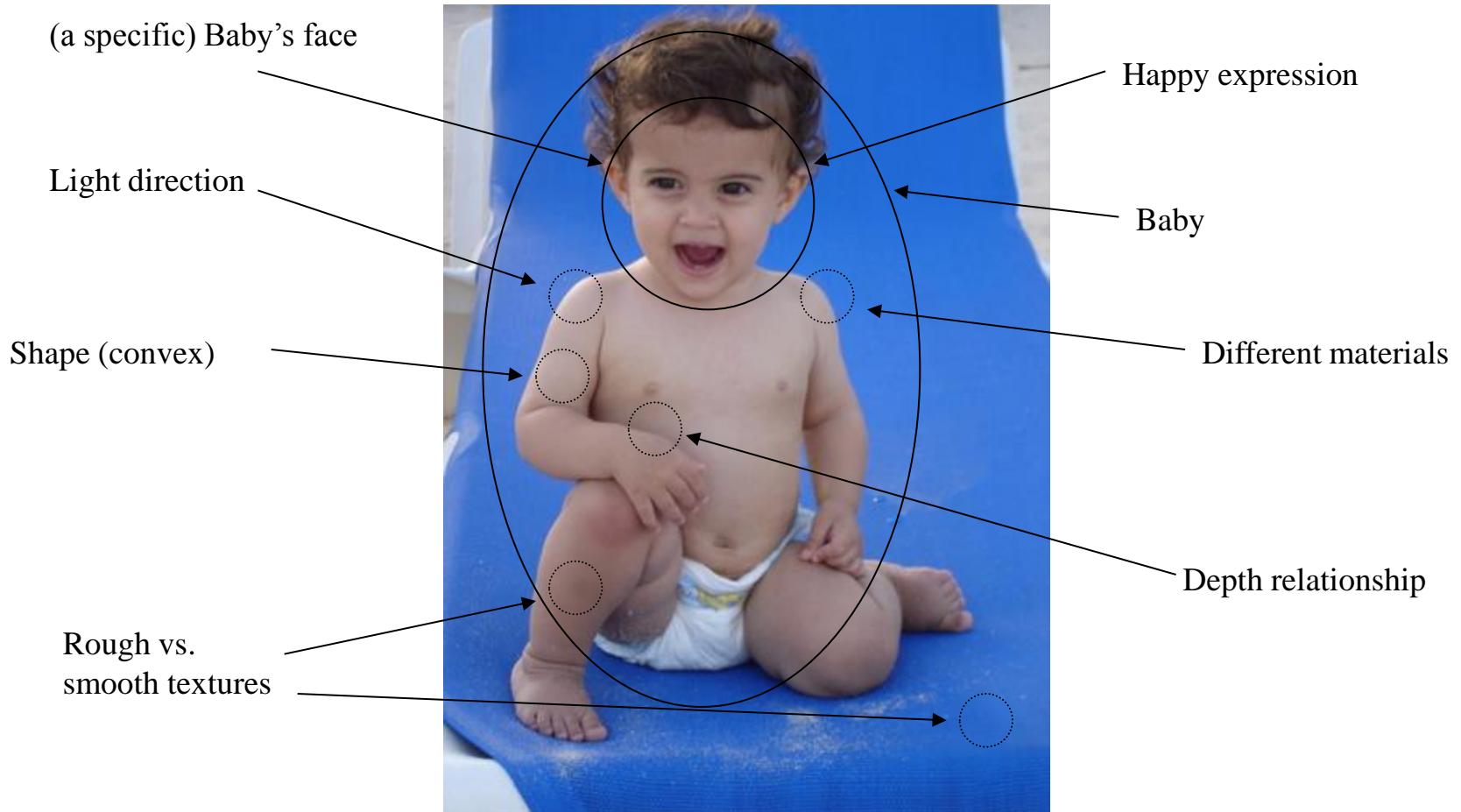
Computational vision must be very easy (!)

- 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

OUTPUT


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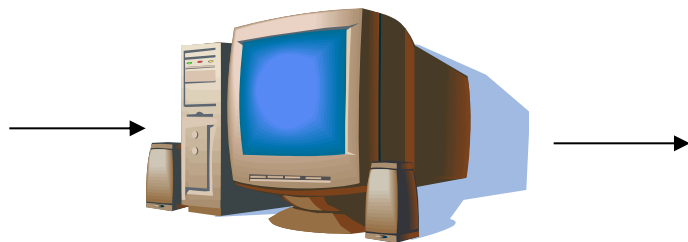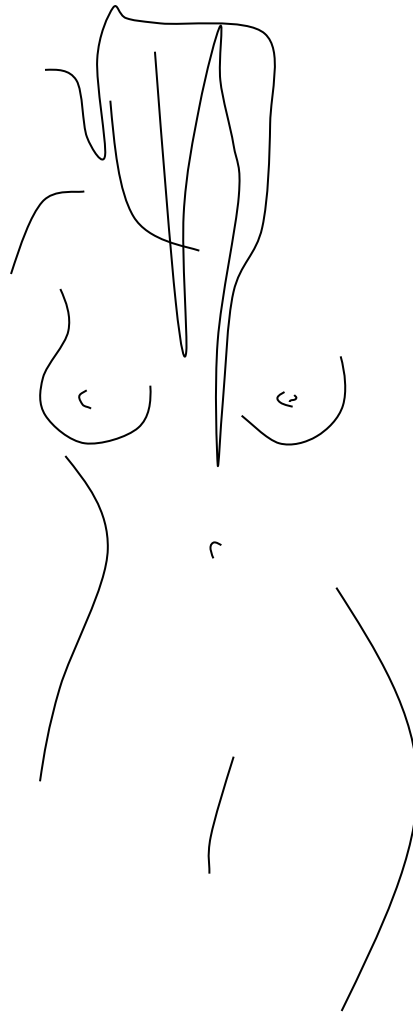
This is my baby. She is sitting on a beach bench, with the sun shining from behind, her right arm on her right leg. She is smiling.

Computational vision must be very easy (??)

After **Zilon** *(Canada)*

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

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

(Computational) vision in 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 ⟶ **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)

Image processing → **Images**

Vision (analysis) →

← (synthesis)

Computer Graphics
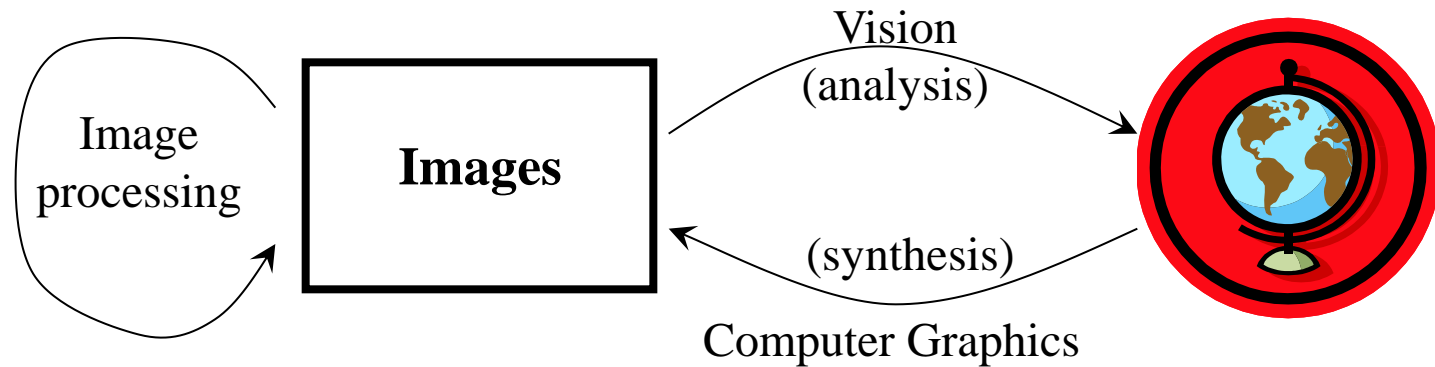
Properties of the "vision" sense

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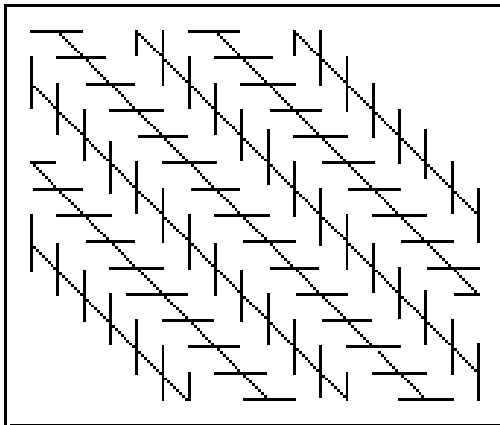
- **What you see is NOT necessarily what is out there!!**

Visual illusions

Illusion [il·lu·sion]
noun.

An erroneous perception of reality.

Visual illusions

Structure/Geometrical illusions
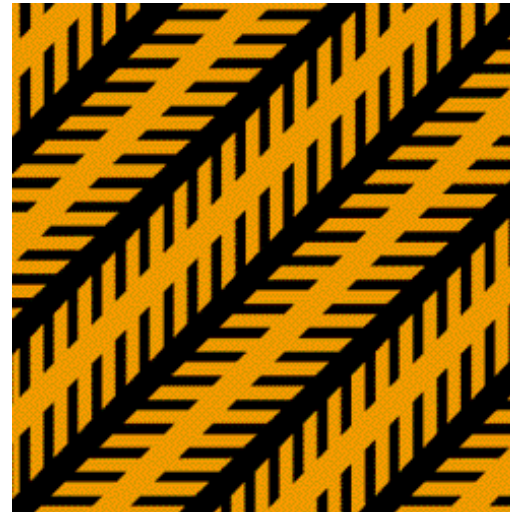
Zohlner illusion

Visual illusions

Structure/Geometrical illusions

Café wall illusion

Visual illusions

Shape and shading illusions
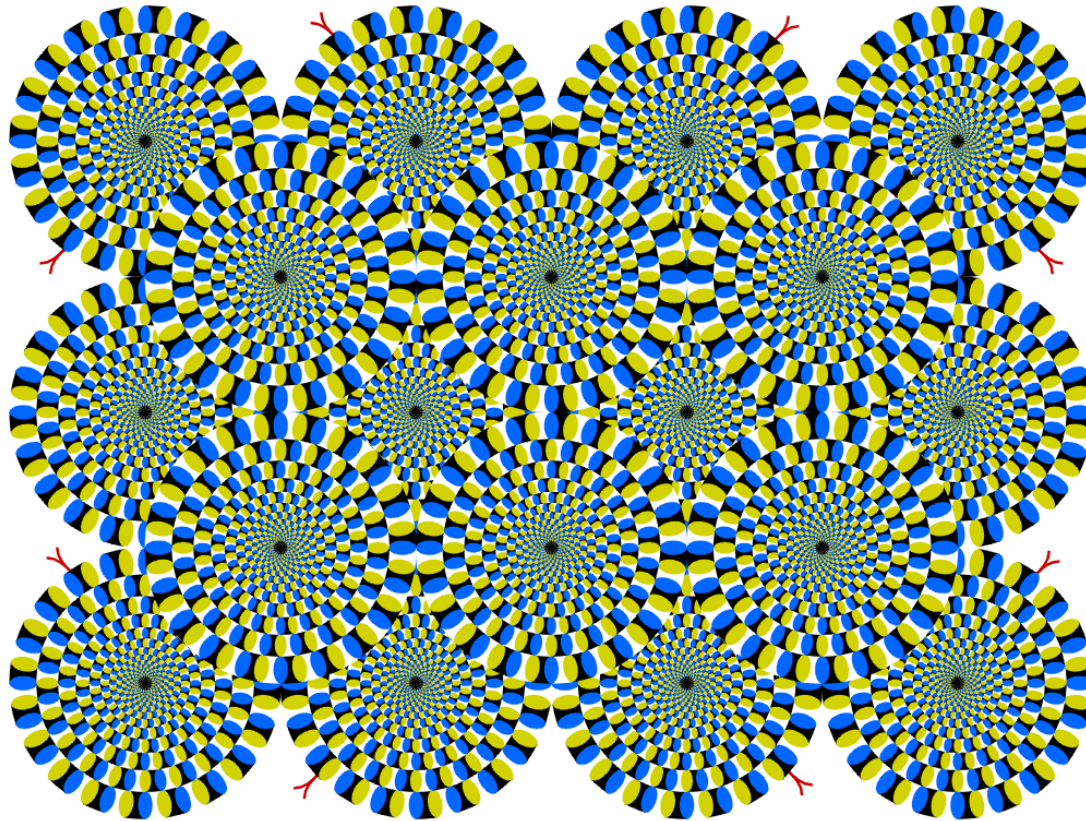

San Juan River, *UT, USA*

Visual illusions

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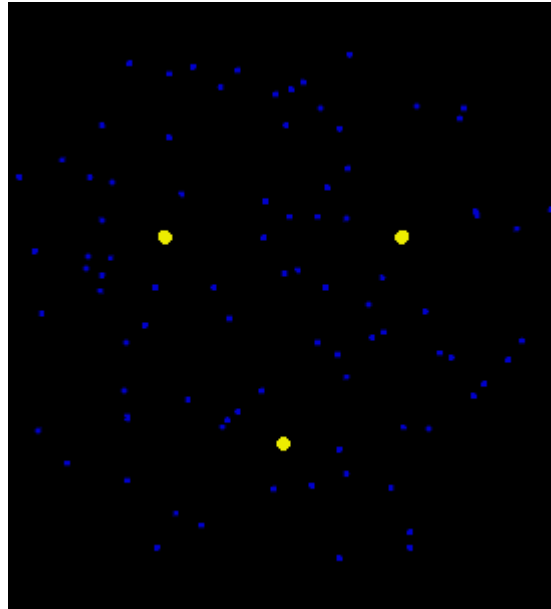
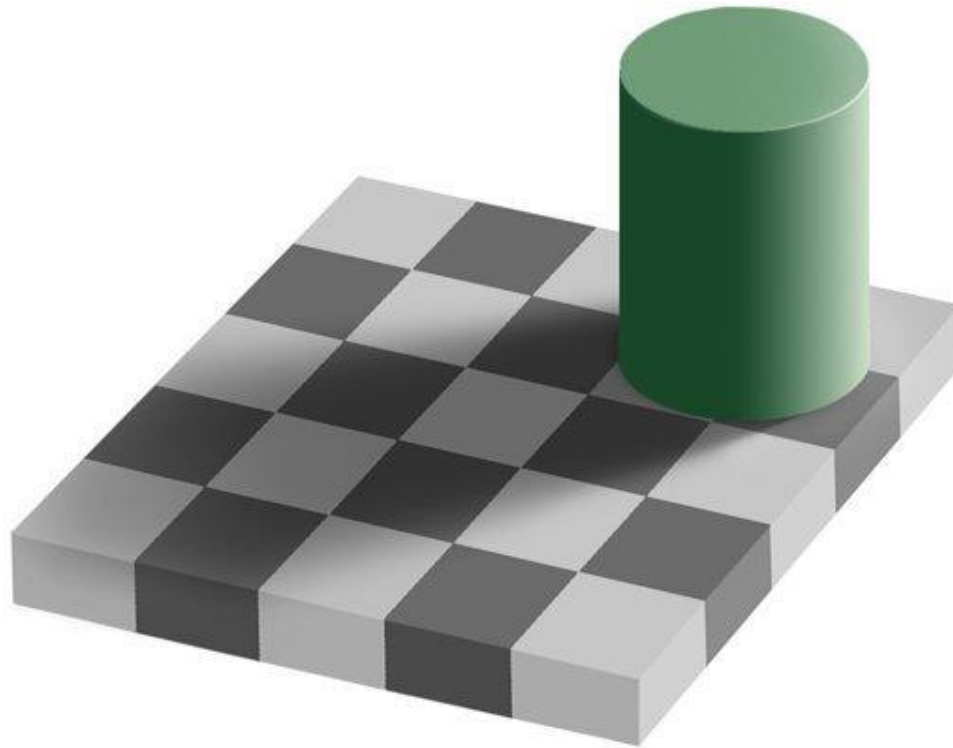***Motion induced blindness illusion*** *(Boneh et al, 2001)*

Visual illusions

Motion related illusions
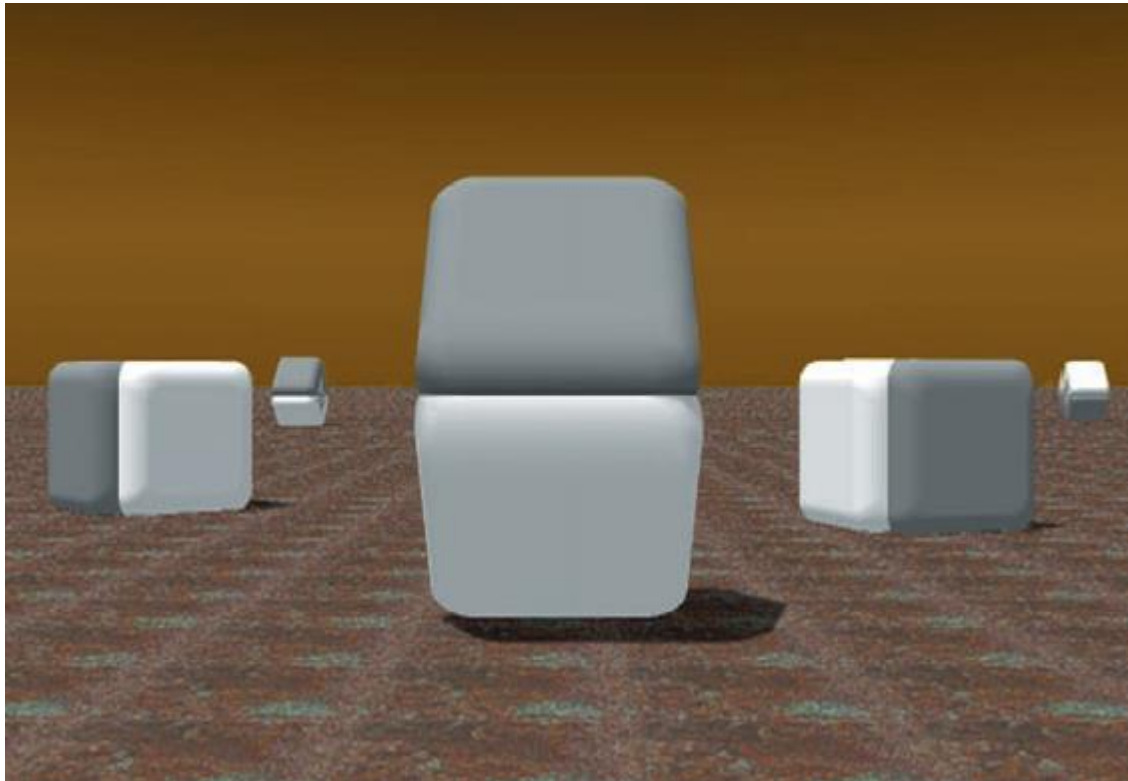

Akiyoshi Kitaoka, *Japan*

Visual illusions

Shading illusions

Ted Adelson, *MIT*
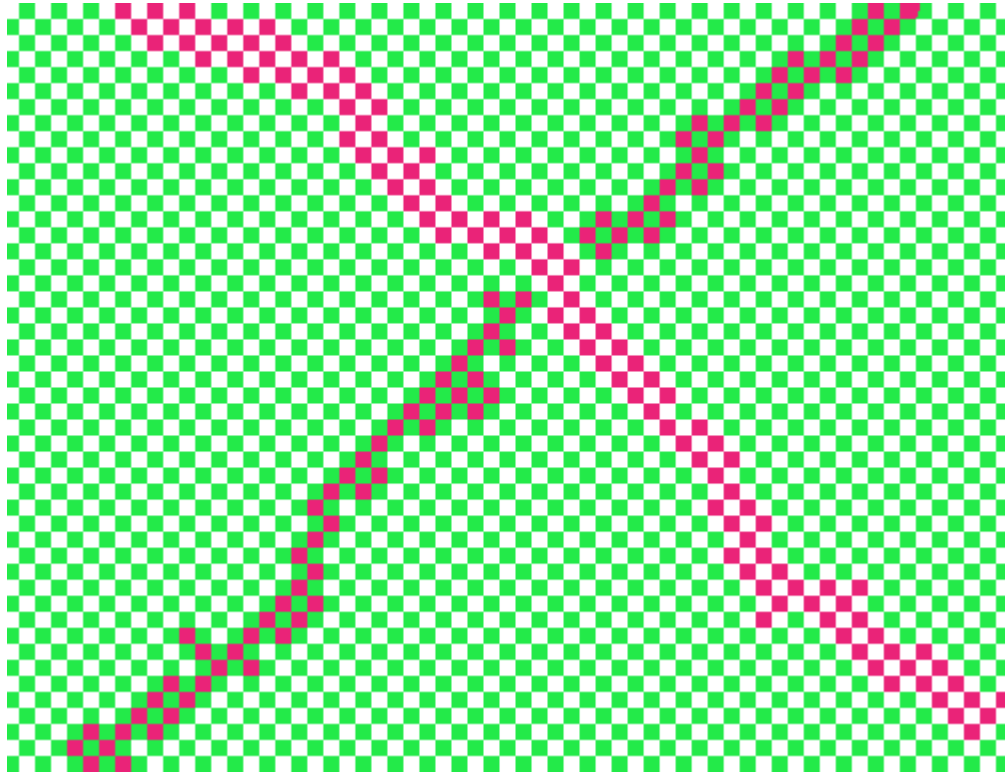
Visual illusions

Shading illusions
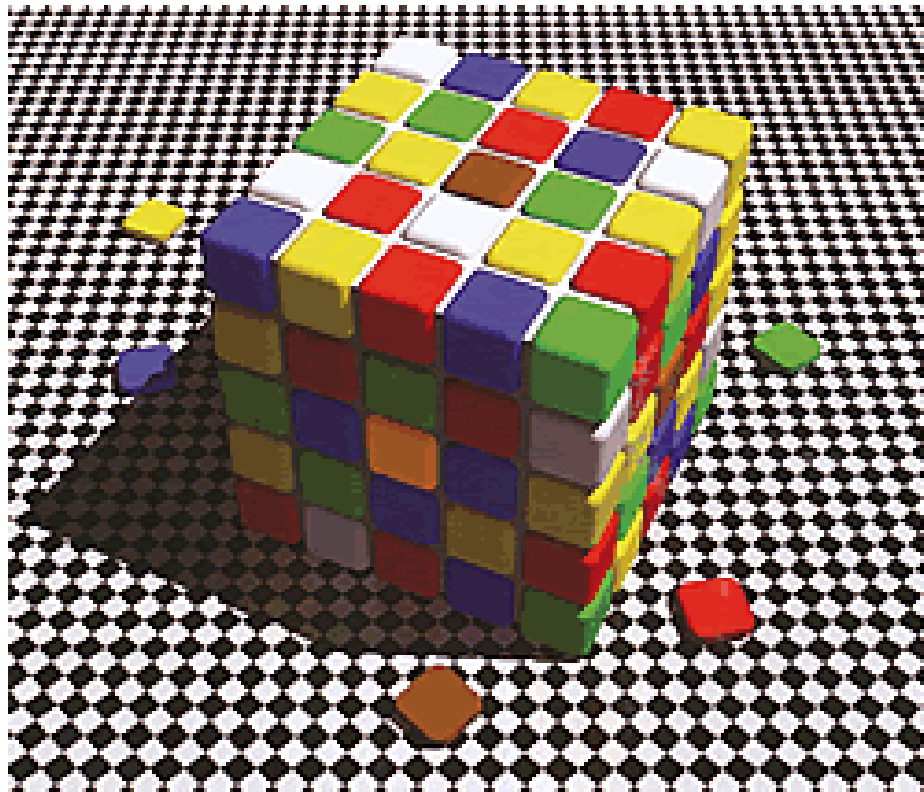

Purves and Lotto, 1999

Visual illusions

color illusions

Contextual effects

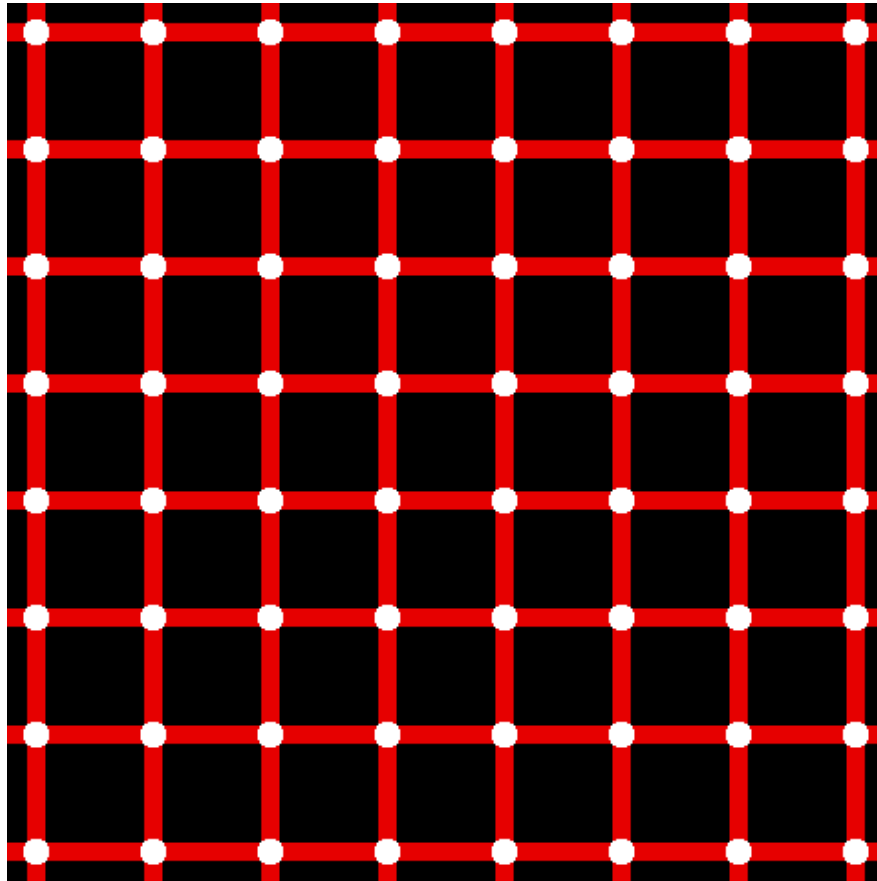# *Visual illusions*

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**
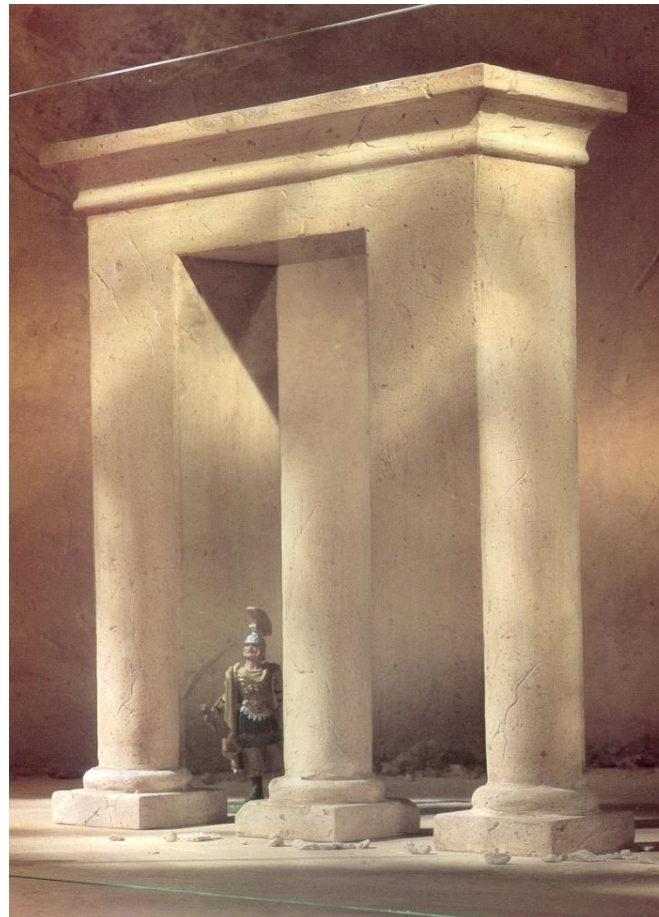
Visual illusions

Ambiguity in scene interpretation

Visual illusions

Ambiguity in scene interpretation

Visual illusions

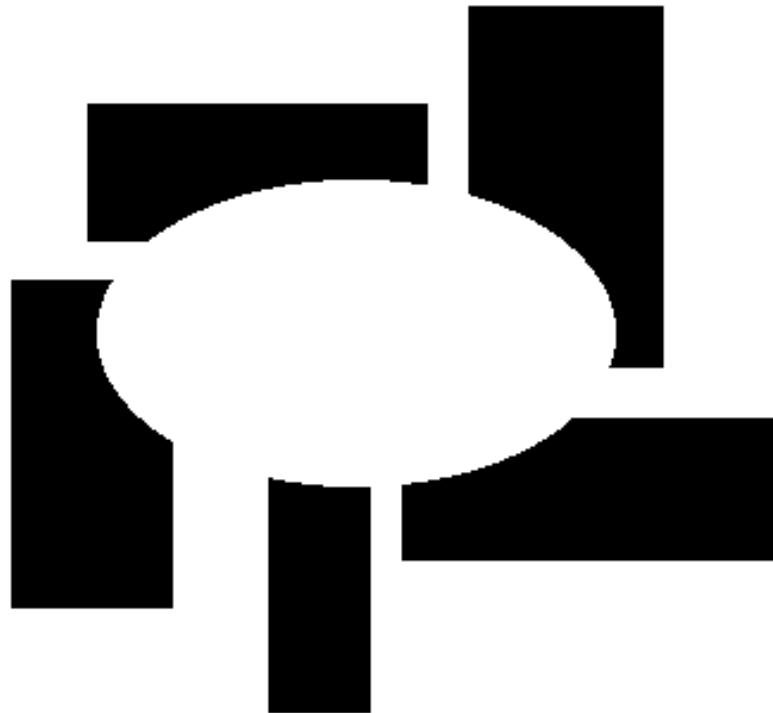## Impossible objects

Visual illusions

Visual completion
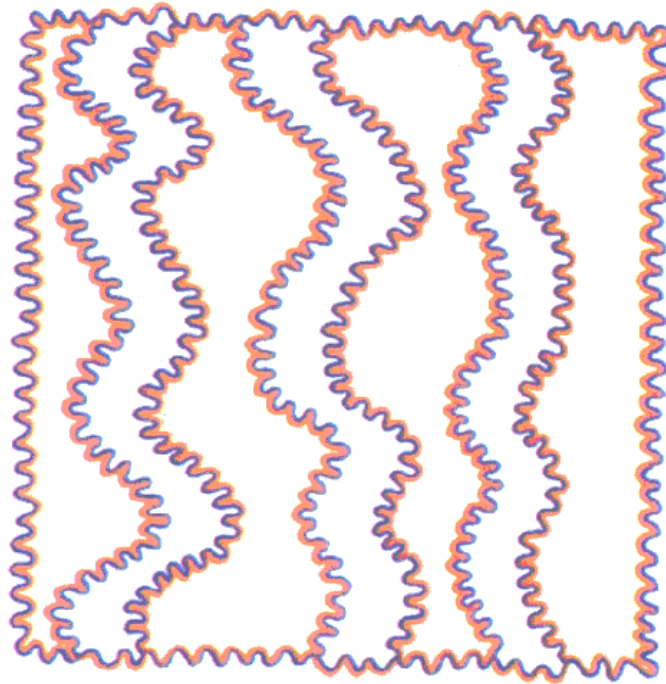
Visual illusions

Visual completion

Visual illusions

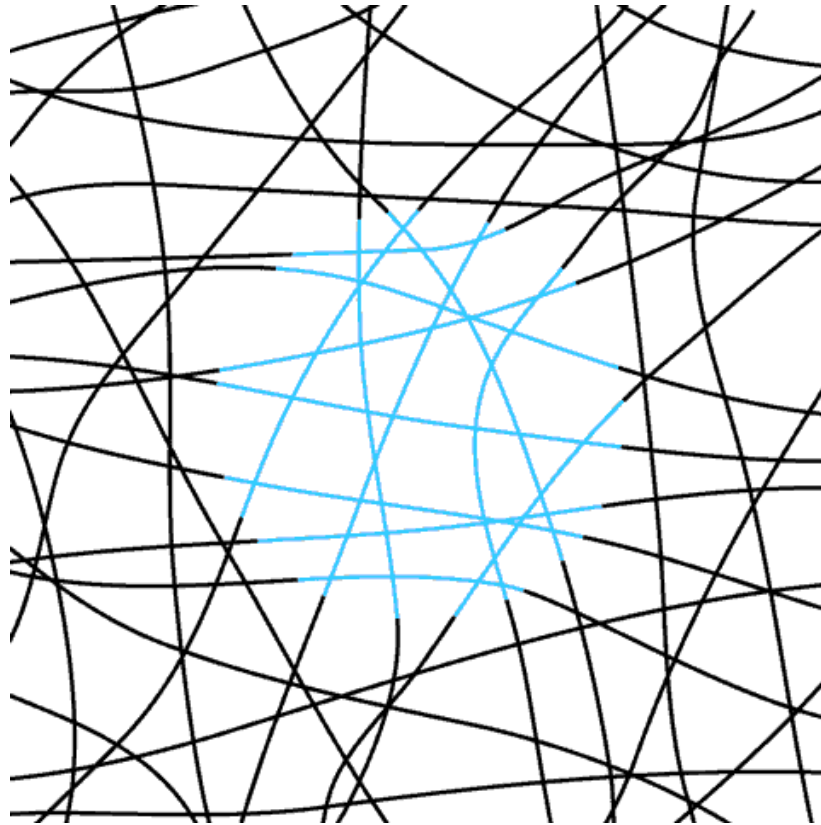## Color filling in

The watercolor effect, *Pinna etal. 2001*

Visual illusions

Color filling in

Neon color spreading illusion