Introduction to

Computational and Biological Vision

CS 202-1-5261

Computer Science Department, BGU

Ohad Ben-Shahar
# Some necessary administrivia

<table>
<thead>
<tr>
<th>Lecturer</th>
<th>Ohad Ben-Shahar</th>
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<tbody>
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<tr>
<td>Office hours</td>
<td>Mondays 14-16 (or email me for an appointment)</td>
</tr>
<tr>
<td>Course web page</td>
<td><a href="http://www.cs.bgu.ac.il/~icbv151">http://www.cs.bgu.ac.il/~icbv151</a></td>
</tr>
<tr>
<td>TA</td>
<td>Boaz Arad (<a href="mailto:boazar@cs.bgu.ac.il">boazar@cs.bgu.ac.il</a>)</td>
</tr>
<tr>
<td>Grading</td>
<td>נוכחות חובה!!</td>
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<tr>
<td></td>
<td>15% Homework assignments</td>
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<td>40% Final exam</td>
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<td>40% Project</td>
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<td>5% Participation in 1-2 human vision lab sessions. (If no experiment is done, these 5% goes to HW)</td>
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</table>
Course home page
http://www.cs.bgu.ac.il/~icbv141

Introduction to
Computational and Biological Vision

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 Aref 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 (Moad Aref) is schedule for Feb 14. No open material is allowed. You are welcome to access selected final and quizzes [in this folder]. Good luck!
04/01/2013 | Assignment #3 is now posted on the see [Assignments Page]
04/01/2013 | Assignment #2 is now posted on the see [Assignments Page]
04/10/2012 | Assignment #1 due date was wasponed to 16/12 (see [Assignments Page])
28/10/2012 | Assignment #1 is now posted in the [Assignments Page]
28/10/2012 | Please read all three pieces mentioned in the Sensing section in the Lecture Notes Page.
26/10/2012 | One more room change announcement. At practical sessions (Tigrum) 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 (Tigrum) 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

<table>
<thead>
<tr>
<th>What about:</th>
<th>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.</th>
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<tbody>
<tr>
<td><strong>Max team size:</strong></td>
<td>1 or 2 depending on enrollment</td>
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</table>
| **What is expected of you:**| • 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 |
| **(all due at the end of exam period)** |                                                                                                                                                                                                  |
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,**  
- **Computer Vision: Algorithms and Applications**  
  Online version available at [http://szeliski.org/Book/](http://szeliski.org/Book/)
- **Vision Science,**  
- **Visual Intelligence,**  
- **Vision,**  
- **Organization in Vision – Essays on Gestalt Perception,**  
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.

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

*(a specific) Baby’s face*
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

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 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?

- 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

Zohlner illusion
Visual illusions

Structure/Geometrical illusions

St. Michael’s Hill, Bristol, UK

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 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