The Visual Brain

Over 50% of the human brain is dedicated to vision and visual representations,
- decoding visual information
- high-level processing of visual information
- thinking with visual metaphors

Input Device: The Eye

Sensor: The Cones and Rods

Two types of receptors on retina:
- rods and cones

Rods:
- spread all over the retinal surface (75 - 150 million)
- low resolution, no color vision, but very sensitive to low light (scotopic or dim-light vision)

Cones:
- a dense array around the central portion of the retina, the fovea centralis (6 - 7 million)
- high-resolution, color vision, but require brighter light (photopic or bright-light vision)
**Wiring: The Visual Pathways**

*Figure 10: Binocular vision, showing visual pathways in the brain*

**Processing Unit: The Visual Cortex (V1, V2)**

Visual cortex breaks input up into different aspects:
- color, shape, motion, depth

LGN = Lateral Geniculate Nucleus

**Pre-Attentive Processing**

If you want it or not: some features are always detected
And fast – within 200 ms or less

Vision is a MASSIVELY parallel processor dedicated to
- detect
- analyze
- recognize
- reason with
visual input

**Pre-Attentive Processing**

Why is it so fast?

Well, because 50% of the brain is dedicated to vision
Pre-Attentive Processing

Sensitivity to differences in:
- color, orientation, size, shape, motion, shading, 3D depth, ...

But there are limits: conjunctions don’t work well

quick: find the blue circle

Pre-Attentive Processing

Some features/cues are stronger than others:

Look at the chart and say the **COLOUR** not the word

**YELLOW**  **BLUE**  **ORANGE**  
**BLACK**  **RED**  **GREEN**  
**PURPLE**  **YELLOW**  **RED**  
**ORANGE**  **GREEN**  **BLACK**  
**BLUE**  **RED**  **PURPLE**  
**GREEN**  **BLUE**  **ORANGE**

Left – Right Conflict
Your right brain tries to say the **colour** but your left brain insists on reading the word.

Words are patterns, which form strong pre-attentive features
- this would have been different if this had been done in Arabic

There are limits, however
- let’s see the next experiment
Pre-Attentive Processing

Reading 1
According to research at an English university, it doesn't matter in what order the letters in a word are. The only important thing is that the first and last letter is in the right place. The rest can be a total mess and you can still read it without problem. This is because we do not read every letter by itself but the word as a whole.

Now, is this true? Read on….

Pre-Attentive Processing

Reading 2
According to card carrying linguistics professionals at an unnamed university in British Columbia, and contrary to the dubious claims of the uncited research, a slip, machine, is seen as the ready for the ecosystem.
Pre-Attentive Processing

Reading 2

According to card carrying linguistics professionals at an unnamed, university in British Columbia, and contrary to the dubious claims of the uncited research, a simple, mechanical inversion of internal characters appears sufficient to confuse the everyday onlooker.

What To Learn From This

The human visual system (HSV) tolerates (visual) noise very well
  - it can read the randomly garbled text very well
  - machines (equipped with computer vision) are poor at this

Humans have only limited computational capacity
  - hard to execute a fixed rule to decipher text
  - especially once the text gets longer (7±2 rule of working memory)
  - this is where computers excel

The fact that computers deal poorly with noisy patterns is exploited in CAPTCHA
  - **CAPTCHA**: Completely Automated Public Turing Test to tell Computers and Humans Apart
  - used to ensure that an actual human is interacting with a system
  - some examples:
    - creating a new gmail or yahoo account (prevent spammer accounts)
    - submitting files, data, email

CAPTCHA

CAPTCHA: noisy and vastly distorted patterns that are difficult to recognize by machines

New Field: Visual Analytics

... and this is also the motivation for a new emerging field:

**Visual Analytics** = the science of reasoning with visual information

Pairs machine intelligence (computing, bit-representations) with human intelligence (creativity, visual representations)
CAPTCHA: One More

But computer vision algorithms have become more sophisticated at CAPTCHA character recognition
* the latest approach is object recognition

Pre-Attentive Processing

Count the black dots!

Pre-Attentive Processing

More Optical Illusions
Optical Illusions

Are the horizontal lines parallel or do they slope?

Optical Illusions

How many legs does this elephant have?

Optical Illusions

Keep staring at the black dot. After a while the gray haze around it will appear to shrink.
Are the purple lines straight or bent?

Which circle in the middle is bigger?

Follow the instructions:
1) Relax and concentrate on the 4 small dots in the middle of the picture for about 30-40 secs.
2) Then, take a look at a wall near you (any smooth, single coloured surface)
3) You will see a circle of light developing
4) Start blinking your eyes a couple of times and you will see a figure emerging...
5) What do you see? Moreover, who do you see?
Optical Illusions

Do you see gray areas in between the squares? 
Now where did they come from?

Optical Illusions

You should see a man's face and also a word... 
Hint: Try tilting your head to the right, the world begins with 'L'

Optical Illusions: Sidewalk Art

Julian Beever

Optical Illusions: Sidewalk Art

Julian Beever
Optical Illusions: Sidewalk Art

Julian Beever
The Power of the Visional System

So the human visual system (HSV) is not perfect, but it's extremely powerful.

Vision is an integral part of life.

Vision is the gateway to higher-level regions of the brain.

Exploit this fast and powerful processor for:
- complex data analyses, creative tasks, communicating ideas

→ The science of visualization
Visualization Examples

Map of artificial sky brightness over Europe

This is synonymous to light pollution: black (even faintest stars are visible) .... red (only very few stars are visible).

Visualization Examples

Non-destructive exploration and dissection of:
- prehistoric artifacts (dinosaur eggs, fossils in a chunk of soil)
- artifacts from ancient cultures (mummies, the ‘frozen man’)

old procedure:
destructive unwrapping of the mummy

Visualization Examples

Your entire disk drive in a box:

Visualization Examples

• Classic application for volume rendering since datasets are inherently volumetric
• Modalities are: CT, MRI, PET, SPECT, Ultrasound (more on these later)
• Doctors use volume rendering to visualize organs, structures, and tissue of interest
  - can render unimportant structures (semi-)transparent and emphasize important ones
  - for example: render a brain tumor opaque and the surrounding brain tissue as a faint hull

• The medical check-up of the future:
  - get a full body scan with CT and MRI
  - specialist doctors use volume visualization to investigate the state of the discretized patient:
    a cardiologist checks coronary arteries for arteriosclerotic plaque
    a radiologist/protocolist flies through the virtual colon and checks for cancerous polyps
  - simulate and plan a surgery or procedure on the digital patient if necessary
  - keep the scan as a digital record of the patient for future reference and statistics
**Visualization Examples**

- Digital (virtual) colonoscopy
  - Segmentation (3D region growing)
  - Cull remainder
  - Centerline (flight path)
  - Cancerous polyp
  - Segmented colon

- 3D Colon - acquired via helical CT

Virtual biopsy - looking inside the polyp:

**Visualization Examples**

- Industrial CT
  - Reverse engineering
  - Inspection for structural failures

- Security
  - Airport luggage CT

- Engine

- Drug detection

**Visualization Examples**

- Illustration and art:
  - M.C. Escher

- Motion hints

- Ghosting

- 20,000 years ago...

- Visual story telling