Introduction to Computer Vision

Taught by

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- Prof. Ender Konukoglu

- Guest starring by prof Orçun Göksel

The course comes with a course text that covers most – but not all ! – material.
Slide decks for all lectures will be made available on eDoz or similar

We got questions about which course to take

Computer Vision (D-INFK), or
Image Analysis and Computer vision (this course)

IN ANY CASE, DO NOT TAKE BOTH !

If you took the introductory course on CV at D-INFK,
then best take *Computer Vision*

If you did not take that course,
then best take *Image Analysis and Computer Vision*

… it is crucial …

Vision is important

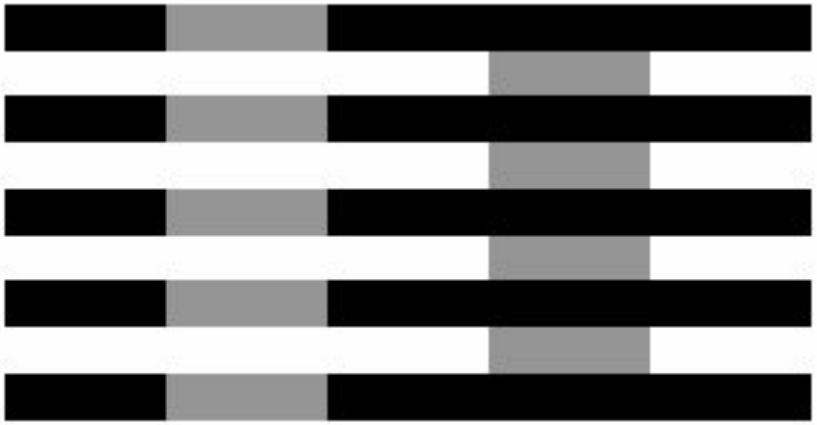
- half our brain is devoted to it
- developed many times during evolution
- it is non-contact
- it can be implemented with high resolution
- works with ambient E-M waves
- yields colour, texture, depth, motion, shape

The central take-home message:

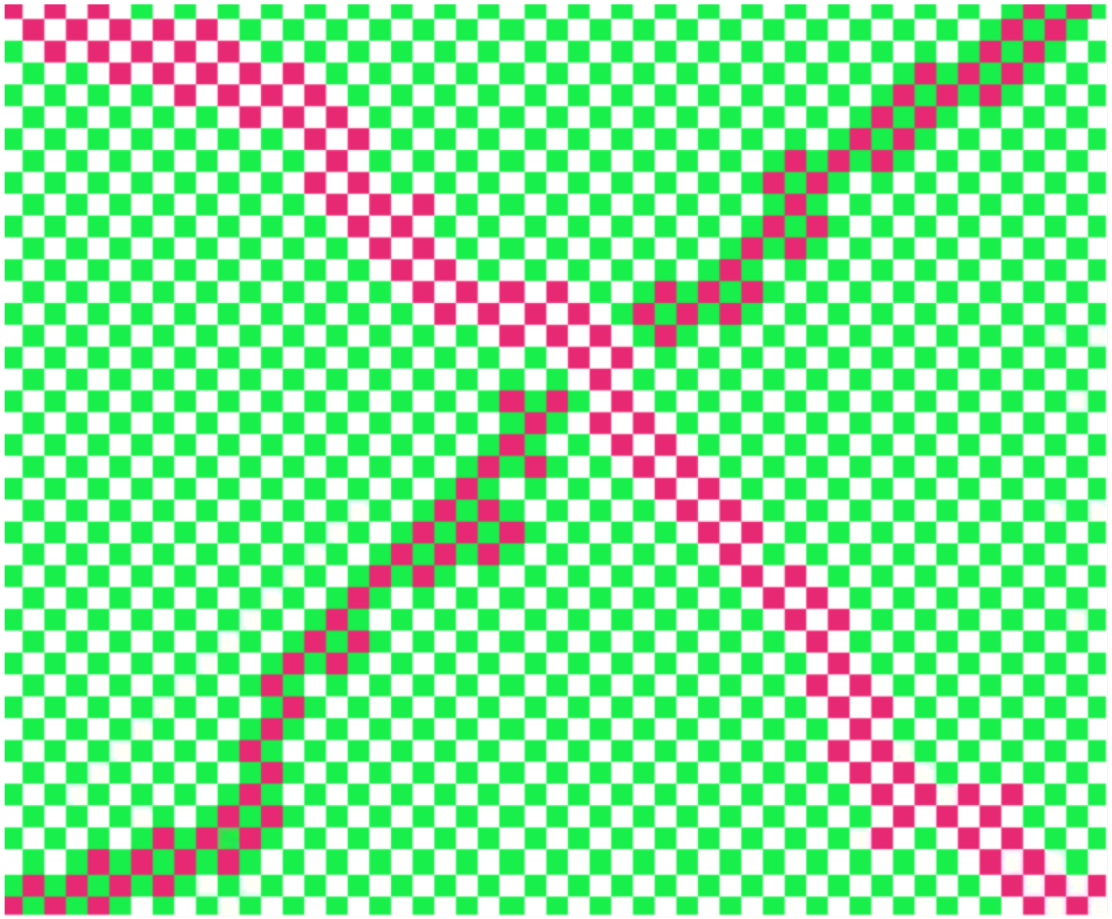
For people vision is their most crucial sense, for good reason

… it is intriguing …

The perception of intensity

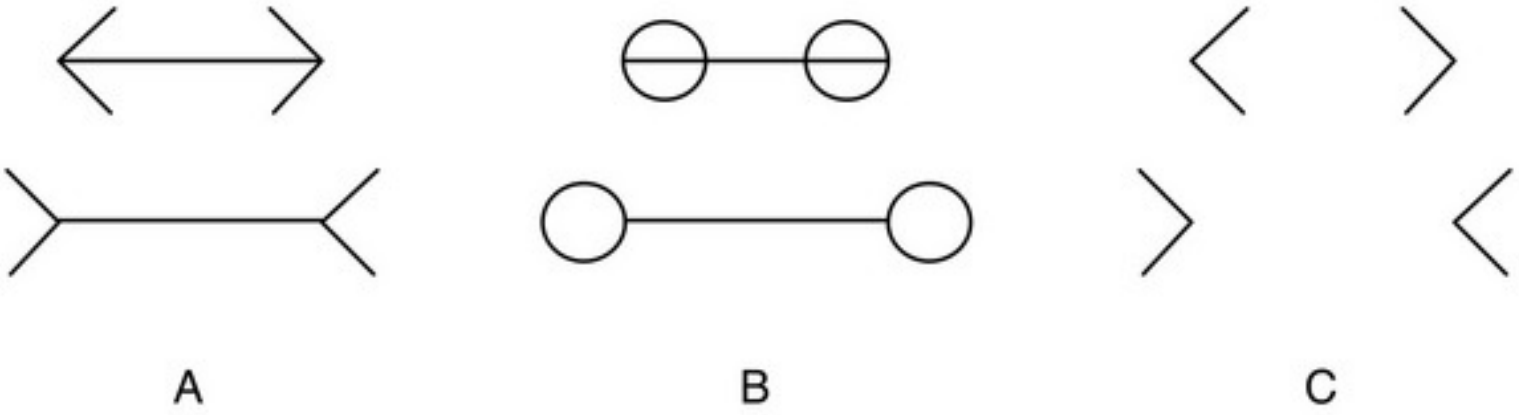


The perception of color

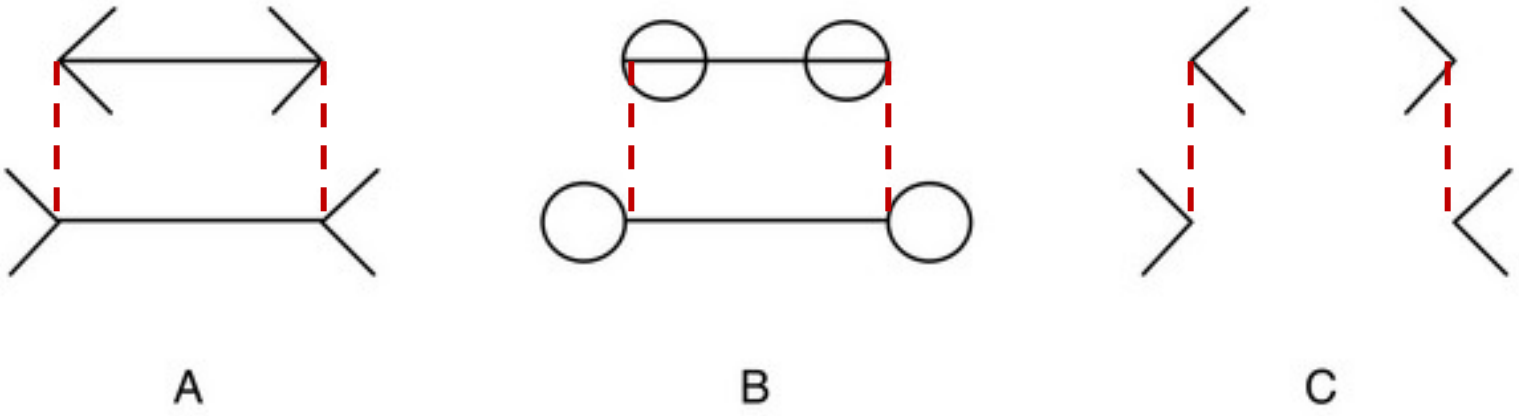


The red squares have equal color…

The perception of length

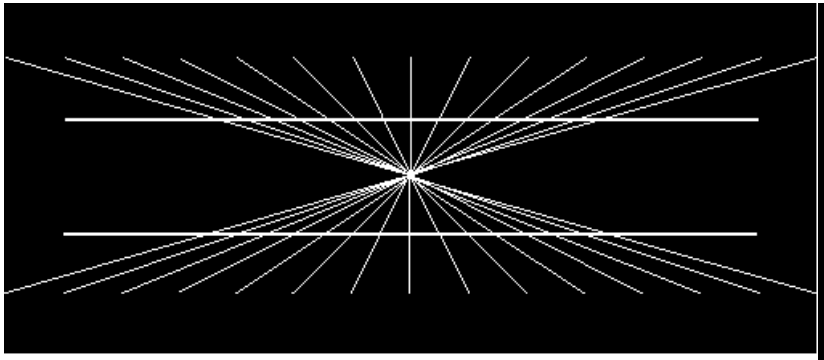


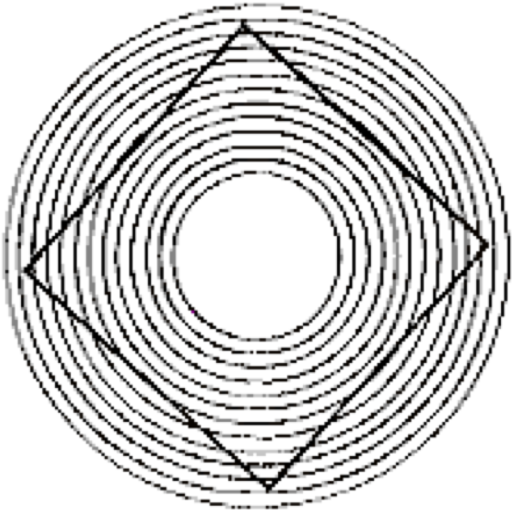
The perception of length

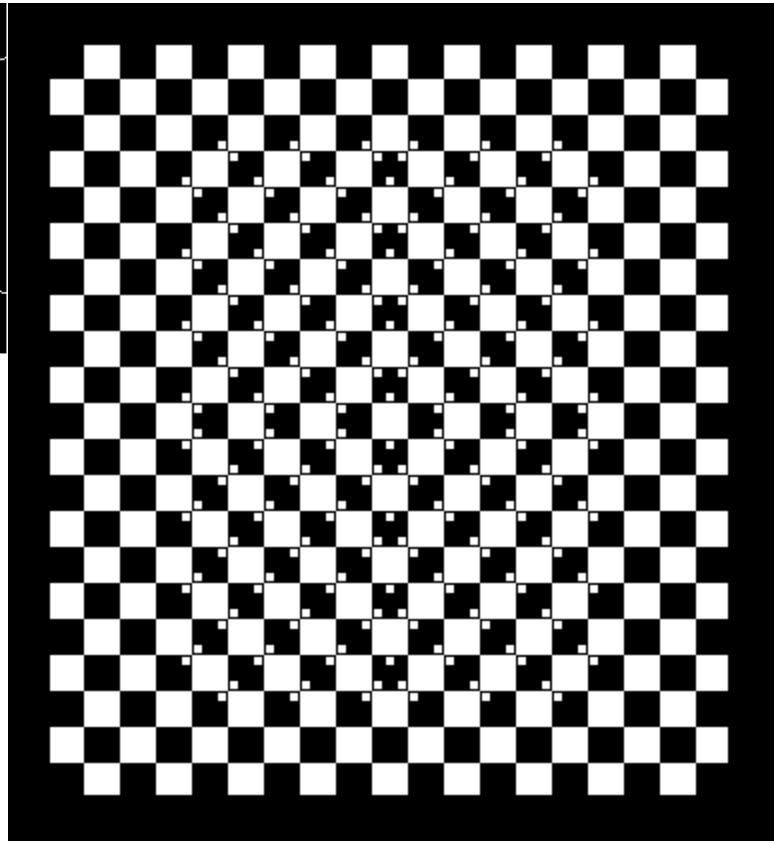


The horizontal lines are equally long…

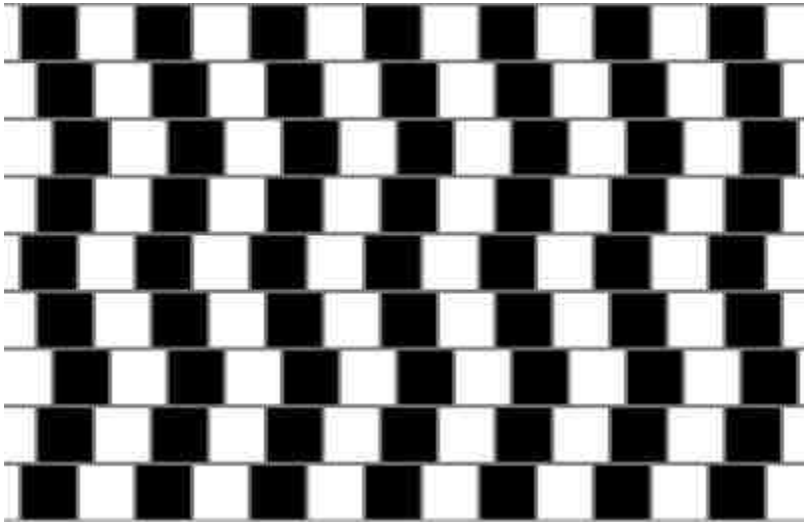
The perception of lines being straight

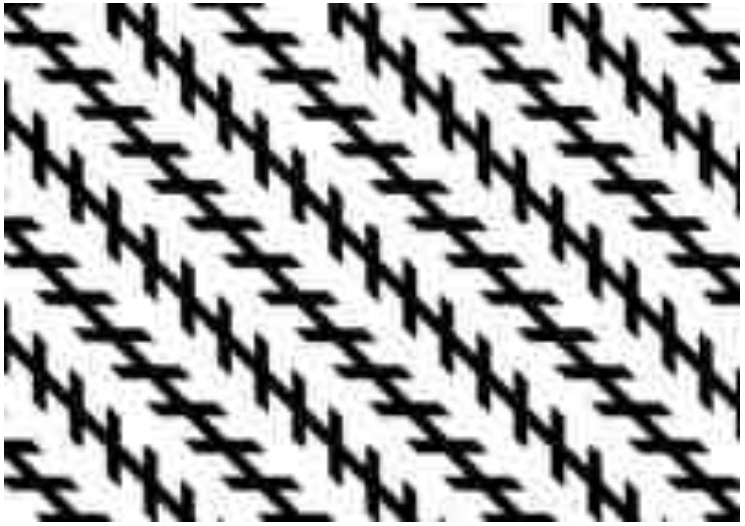


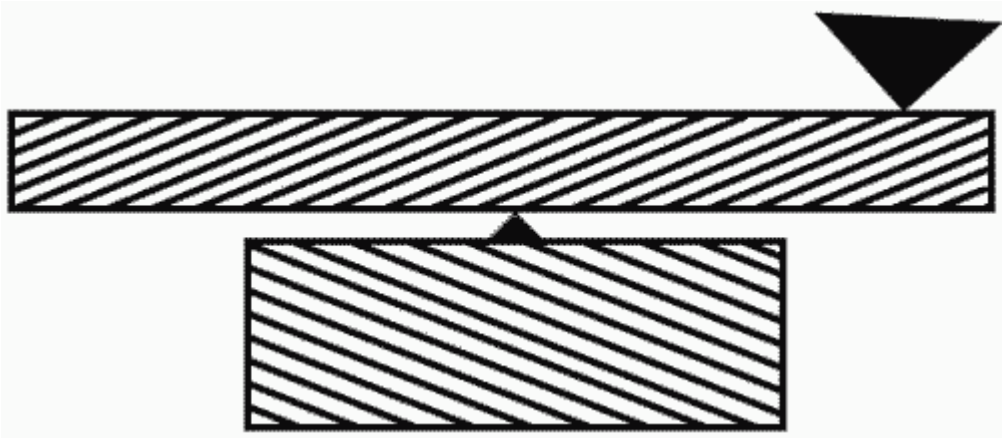




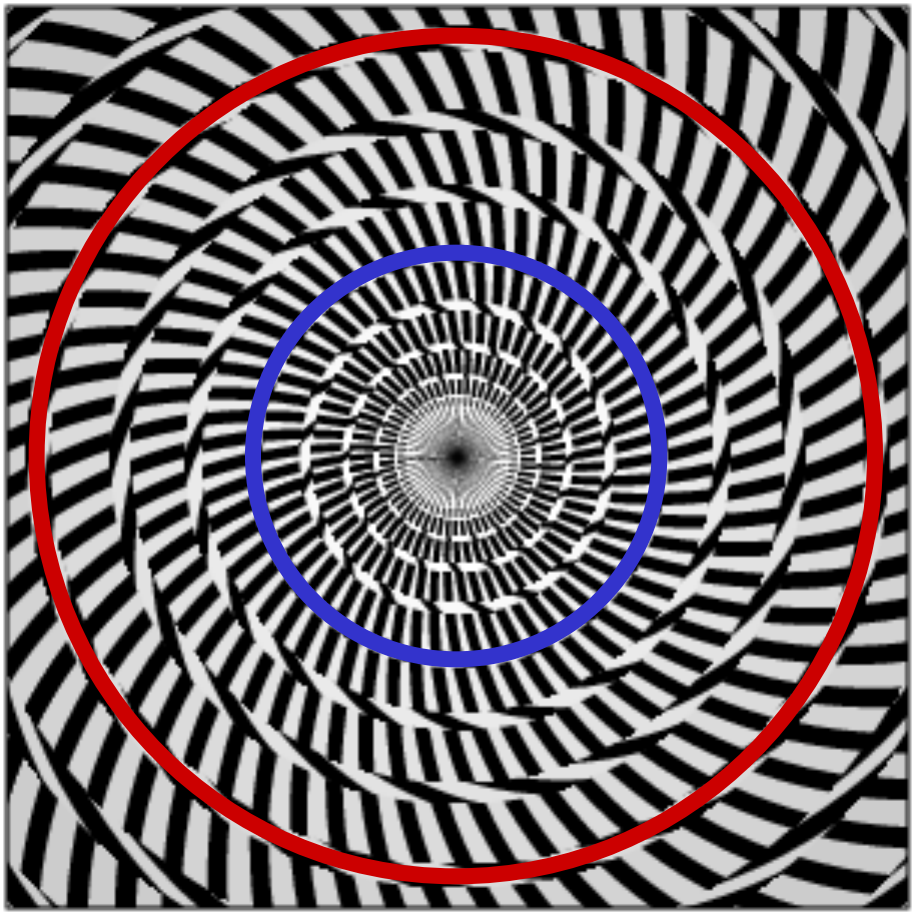
The perception of parallelism







The perception of curvatures



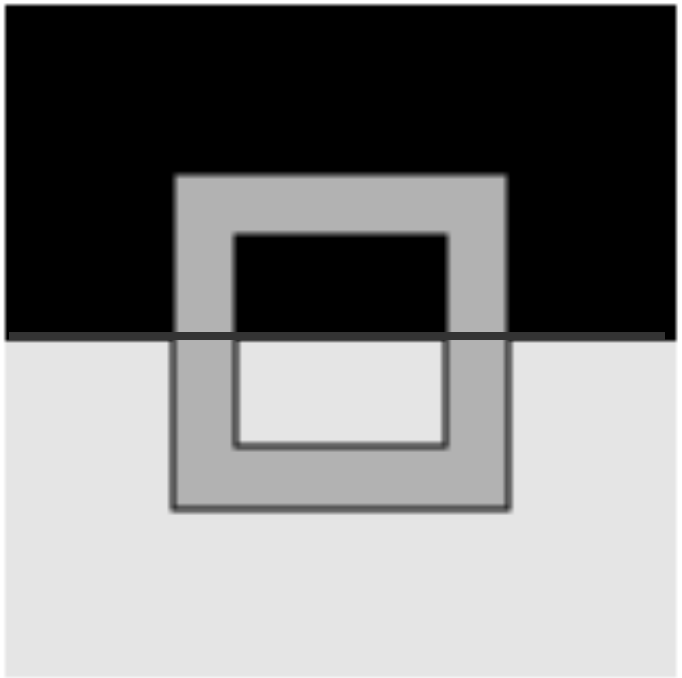
Illusions : interference of differently oriented patterns via adaptation

The perception of motion

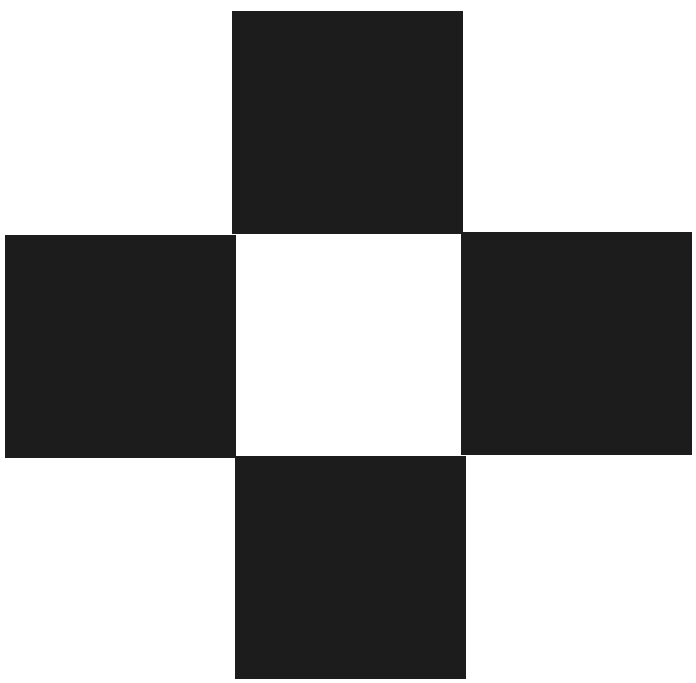
The `barber pole' rotates about the vertical, it does not translate vertically…

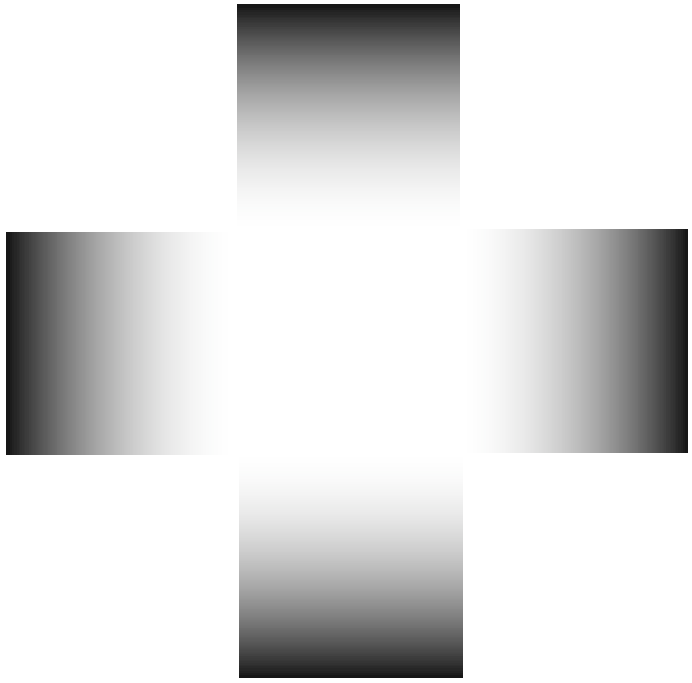
It's not that more context solves it all…

there is literally more than meets the eye,
i.c. a lot of massively parallel processing



The perception of intensity

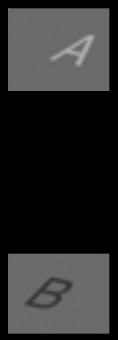




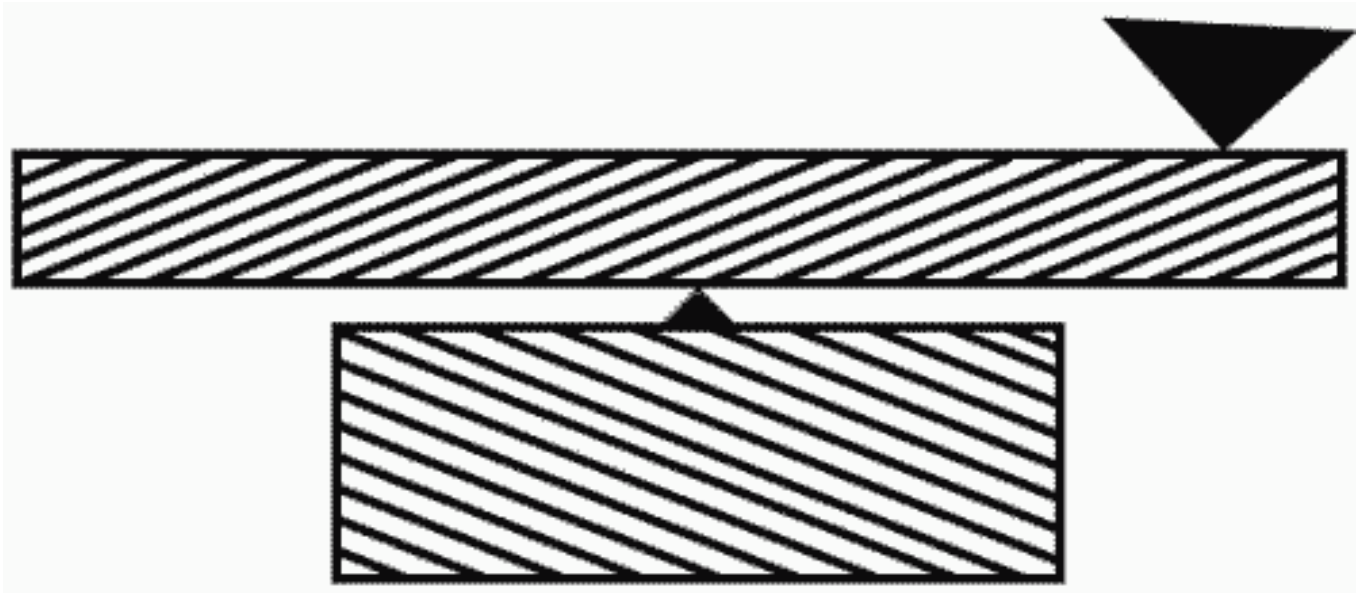
Computer Vision

INTRO

perception
applications
light



Parallelism again…

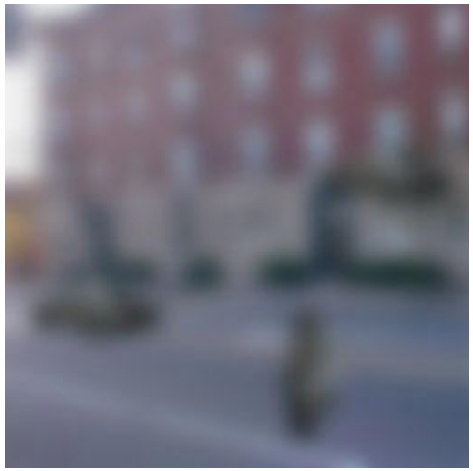


Kanisza illusion

Fill-in : averaging of perceived contrast at edges over regions possibly obtained via extrapolation of the edges… in any case *such illusion seems to help people to detect patterns in the world*.

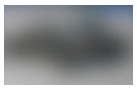
The role of context

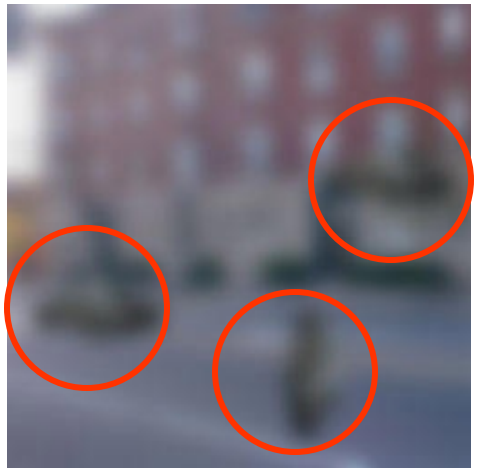
Human vision:
Biederman, Bar & Ullman, Palmer, …



The role of context

All encircled patterns are identical:





The role of context

Person?

The role of context

Person?

The role of context

Person?

The role of context

Person?

The role of context

human vision is much more than a bottom-up process of subsequent signal processing steps.

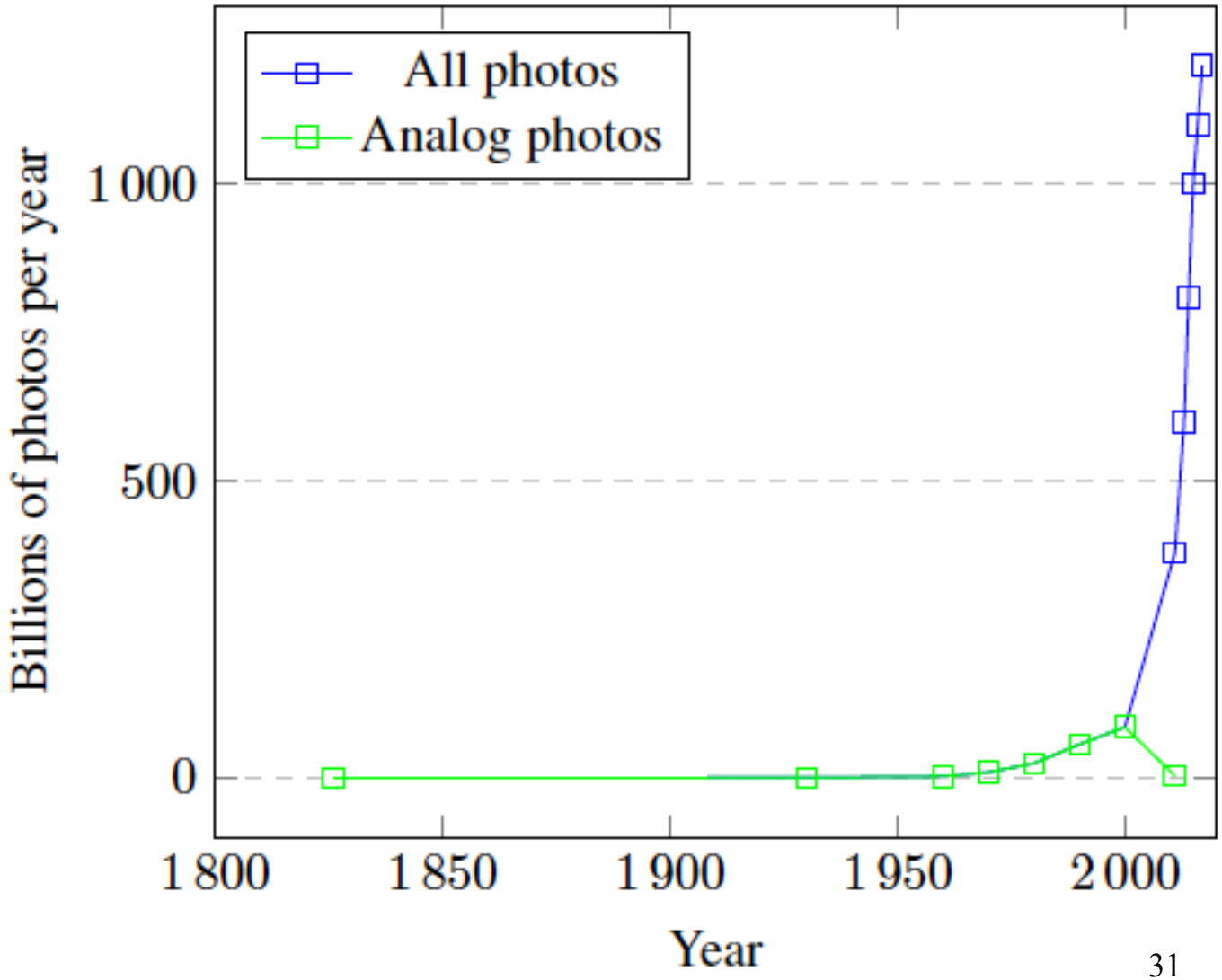
Car?

The central take-home message:

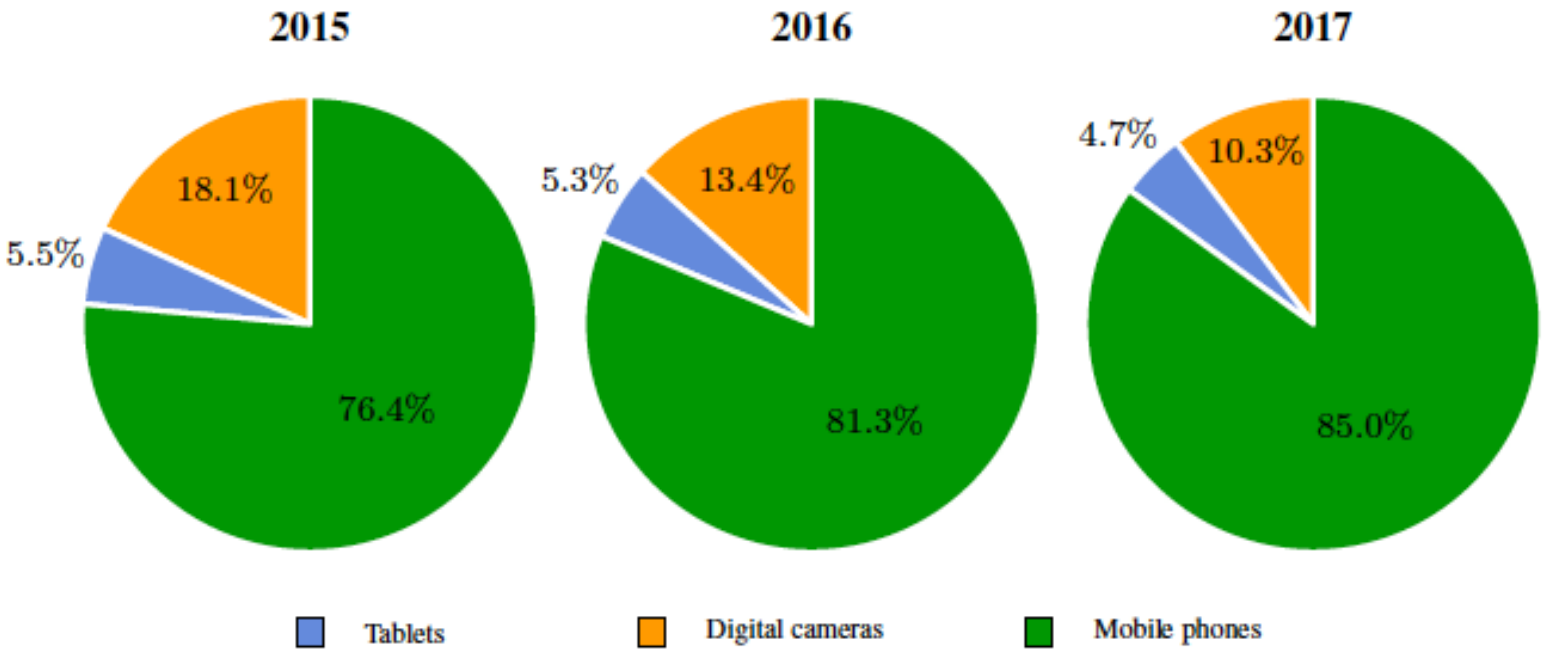
Effective vision needs more than sheer filtering and measuring

… it is hot …

The explosion of photography



The explosion of photography



Easier than ever to take a photo
The cost is extremely low (cheap memory)
Most people carry a camera most of the time

The development of computer vision apps

Most early applications where found in production environments, as these *allow for controlled conditions* and *have little uncertainty*

some areas do not allow for much control: medical IP, remote sensing, surveillance, etc.

currently CV is conquering the less controllable areas by storm

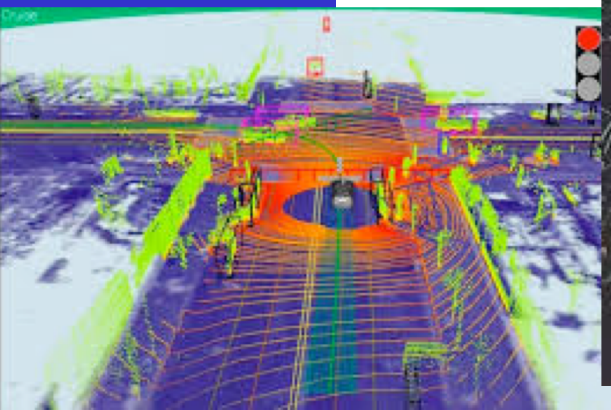
Ex App: image enhancement: mobile -> DSLR

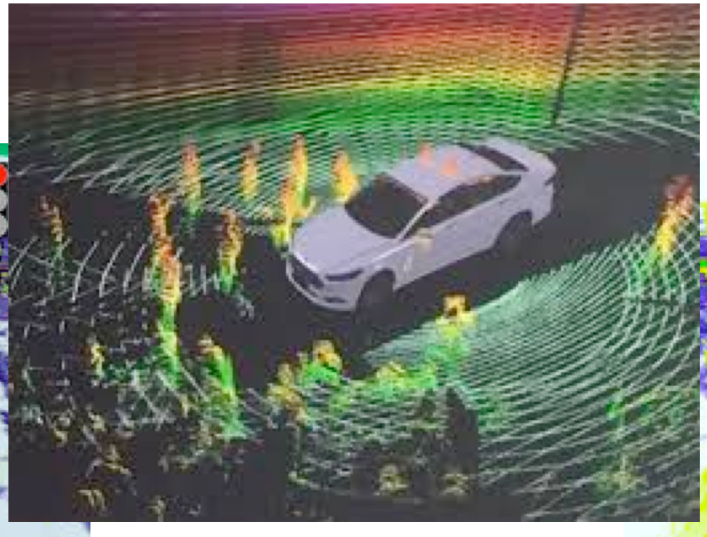
Ex App: synthetic face generation

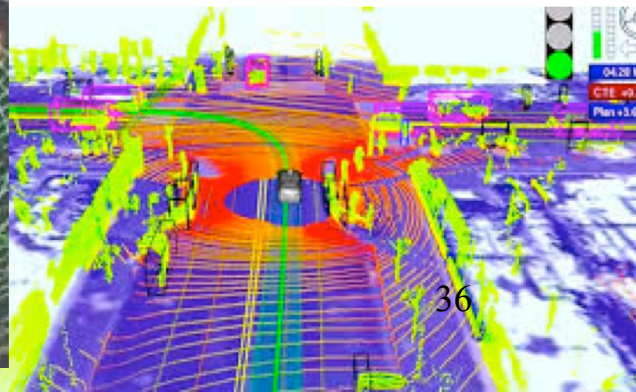
https://miro.medium.com/max/1176/1*LZp9nkzbSk8v6cpwp8CD8g.gif

Computer Vision

Ex App: autonomous vehicles





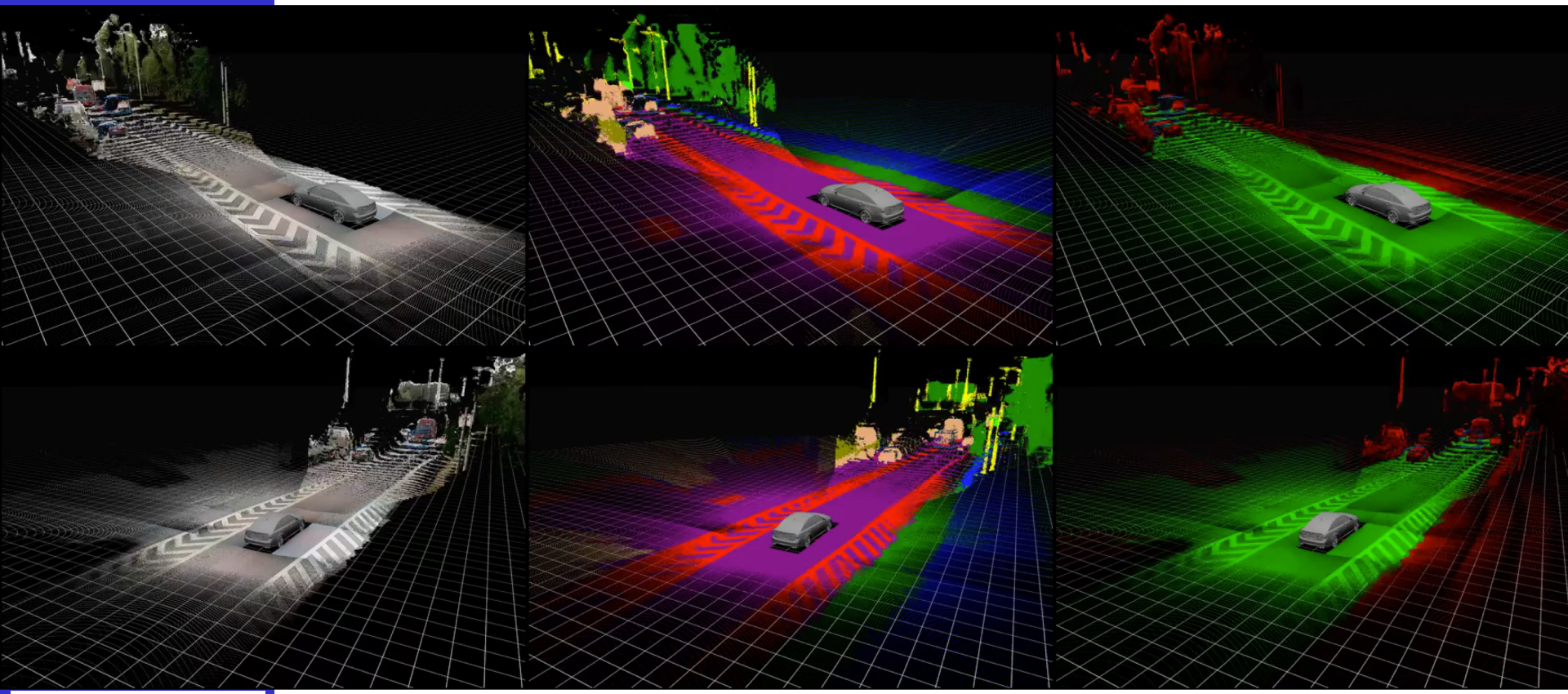


Ex App: autonomous vehicles

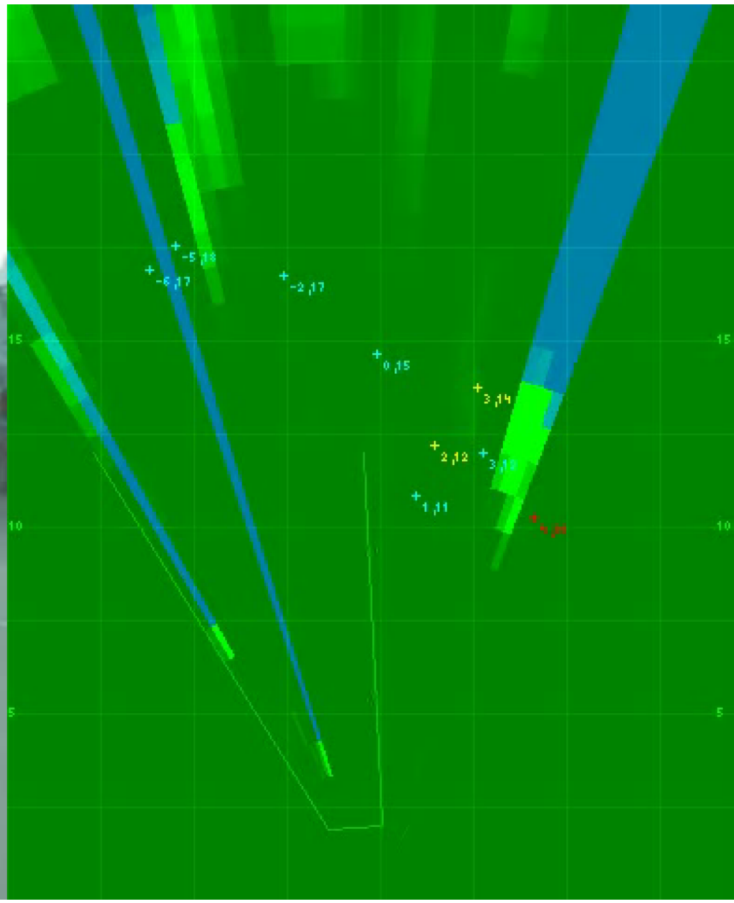
car detection:

Ex App: autonomous vehicles

putting vision modalities together:



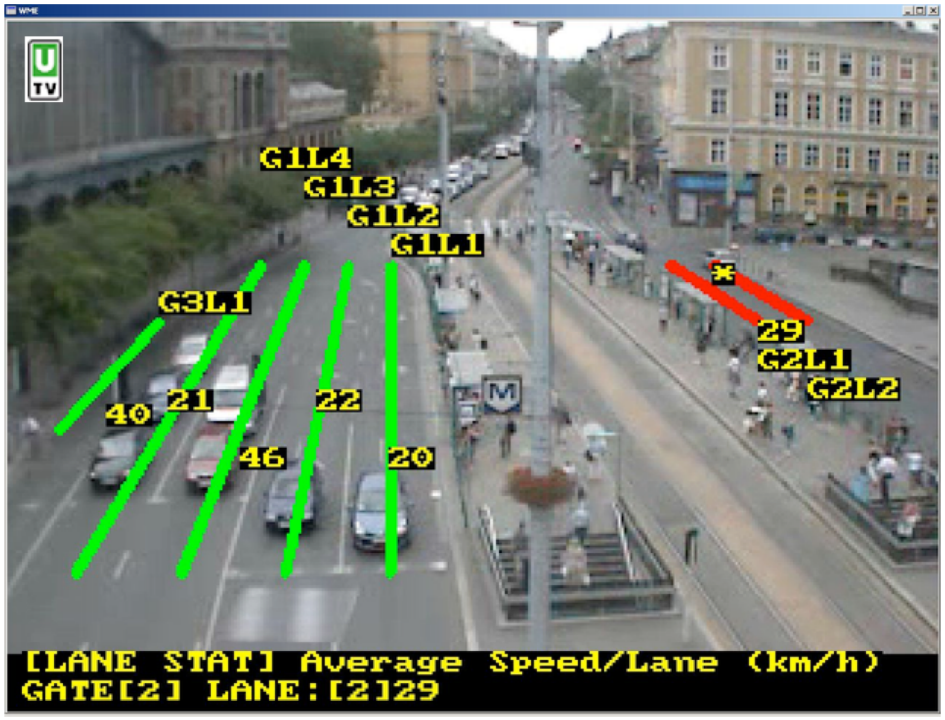
Ex: autonomous mobile platform



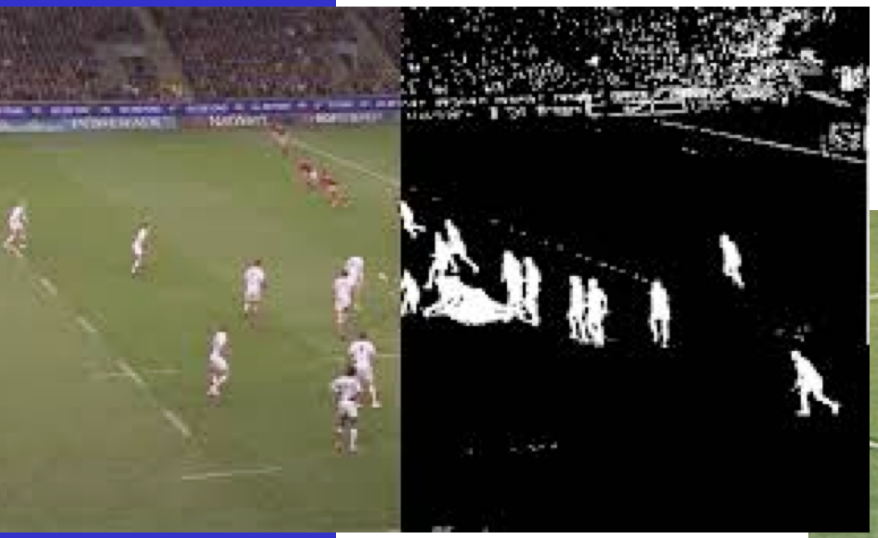
Ex App: image retrieval, captioning, …

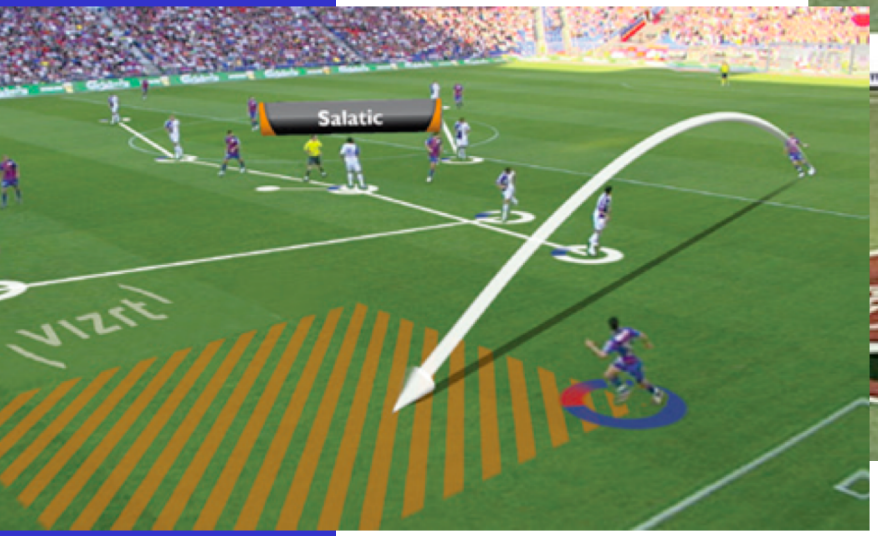
Describes without errors	Describes with minor errors	Somewhat related to the image	Unrelated to the image
 A person riding a motorcycle on a dirt road.	 Two dogs play in the grass.	 A skateboarder does a trick on a ramp.	 A dog is jumping to catch a frisbee.
 A group of young people playing a game of frisbee.	 Two hockey players are fighting over the puck.	 A little girl in a pink hat is blowing bubbles.	 A refrigerator filled with lots of food and drinks.
 A herd of elephants walking across a dry grass field.	 A close up of a cat laying on a couch.	 A red motorcorcycle parked on the side of the road.	 A yellow school bus parked in a parking lot.

Ex App: visual surveillance

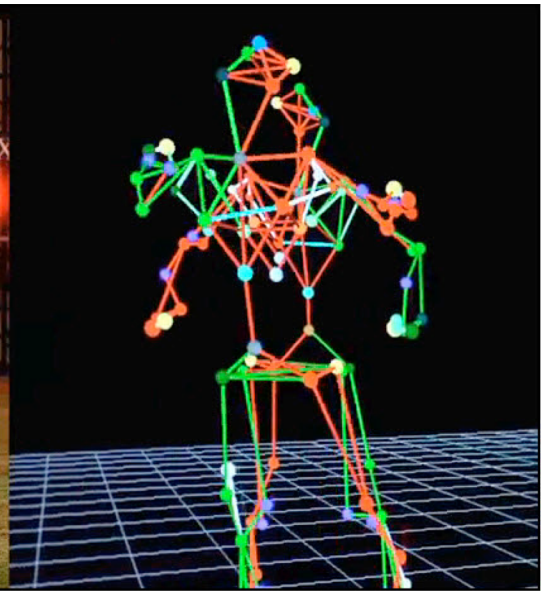


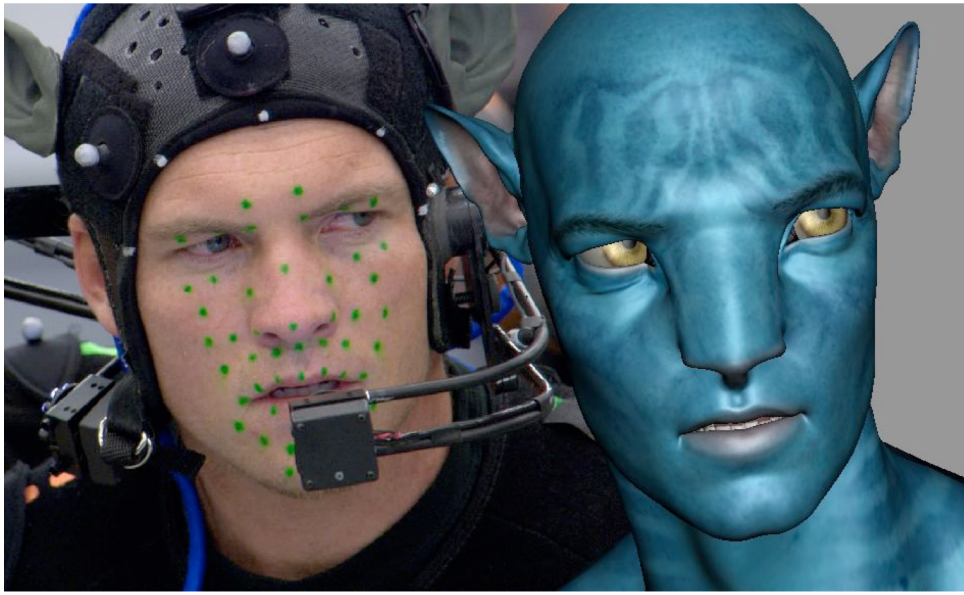
Ex App: Augm. Reality, eg sports





Ex App: motion capture for movies/games





Computer Vision

Ex App: computer-assisted surgery

Ex App: mobile mapping

The central take-home message:

It is feasible now to let most things see and interprete their environment

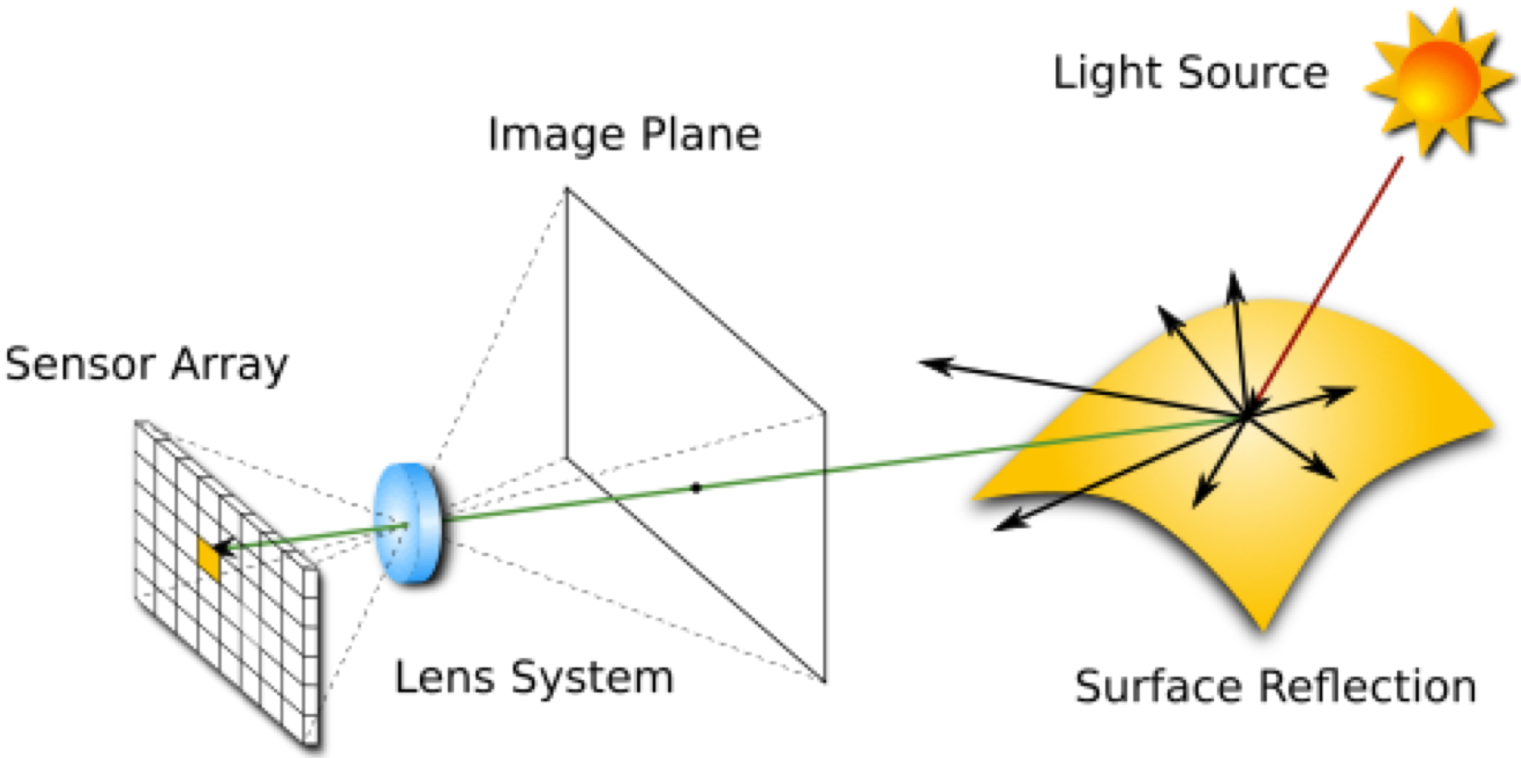
… it needs light …

And then there was Light…

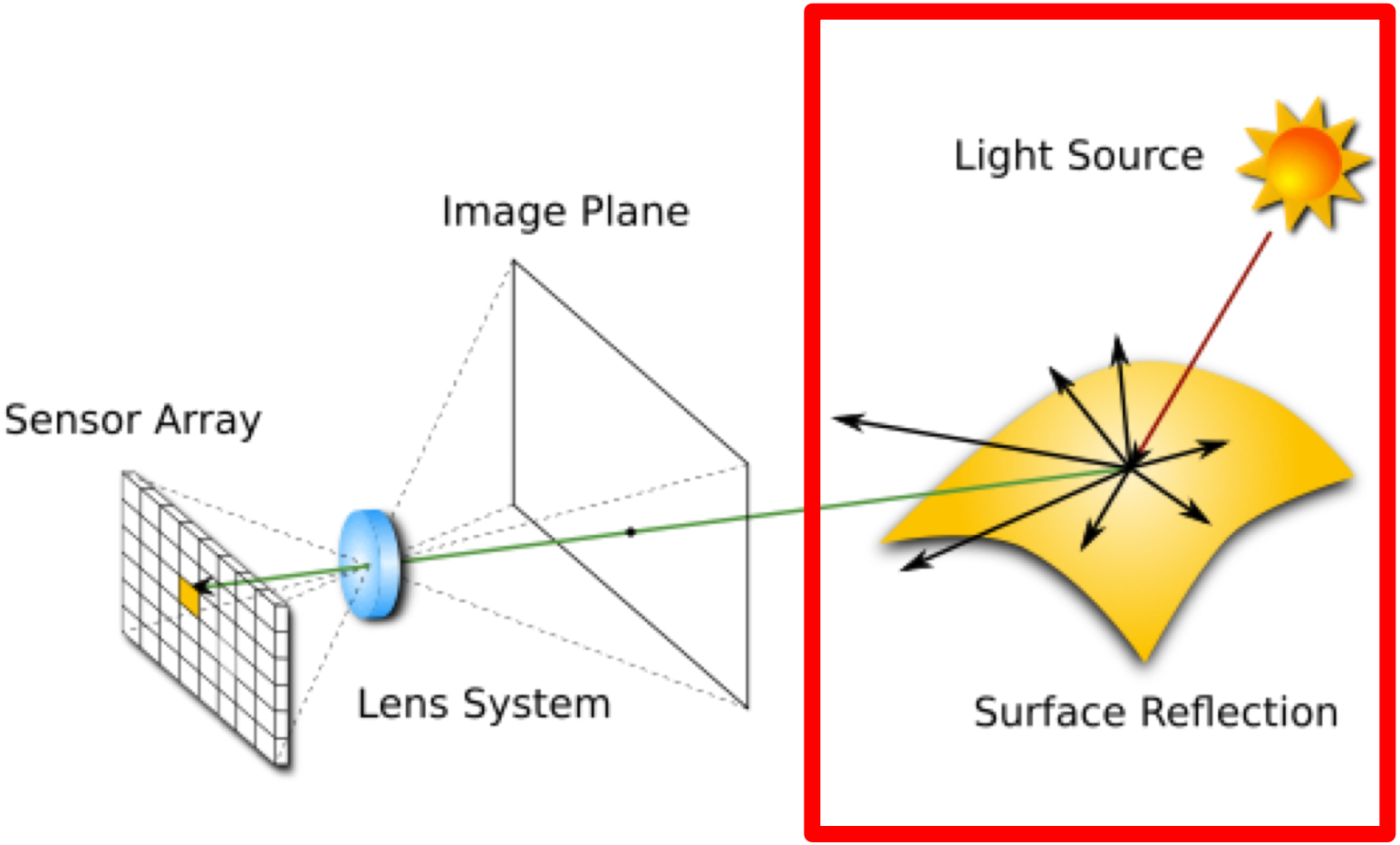
- no vision without light…
- … because it is influenced by objects

"What the...?"

Kickoff: the light, surface, lens & cam



Kickoff: the light, surface, lens & cam



topics

- the nature of light
- interactions with matter

An option on optics

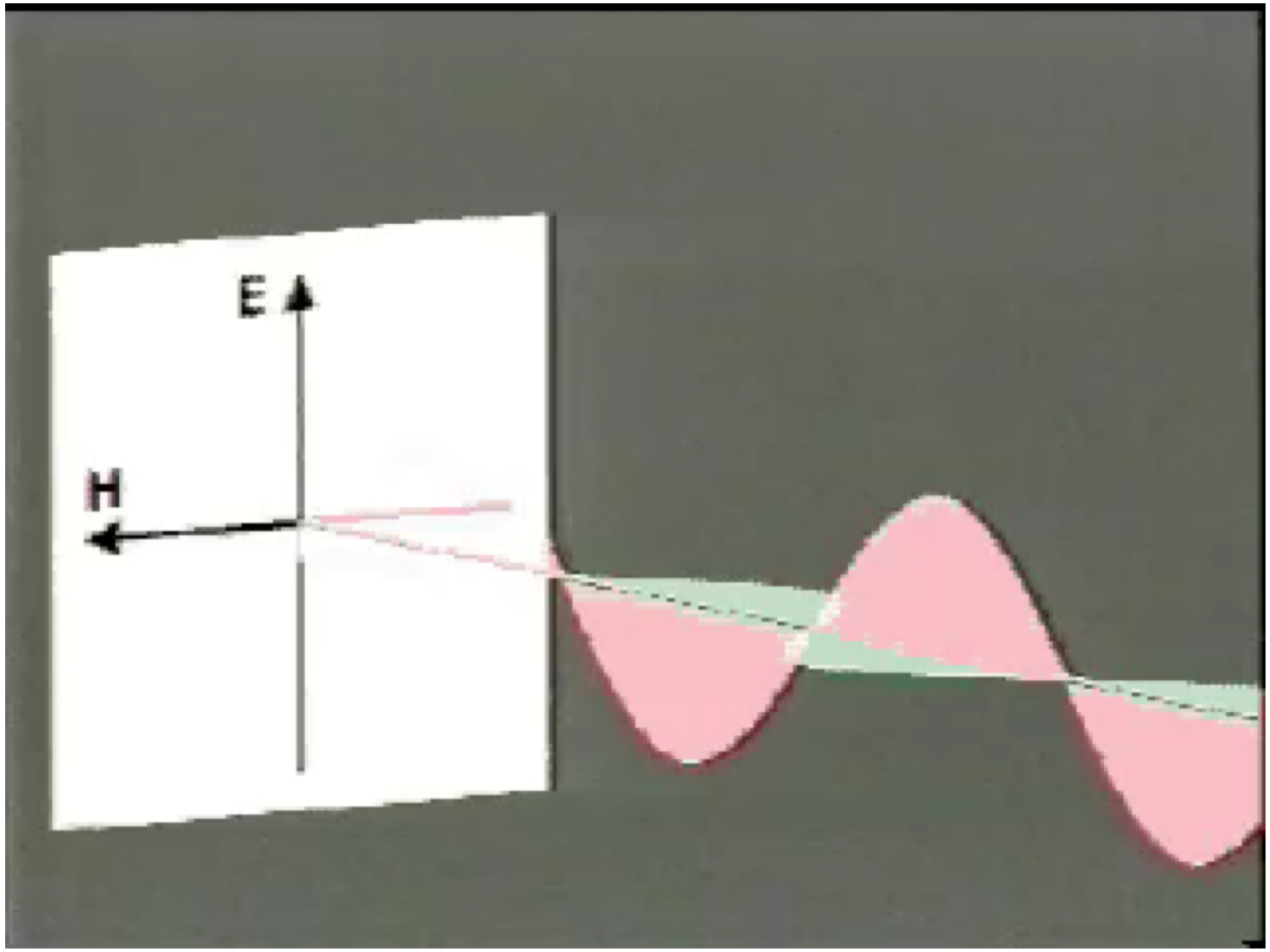
1. Geometrical optics

2. Physical optics, or

3. Quantum-mechanical optics

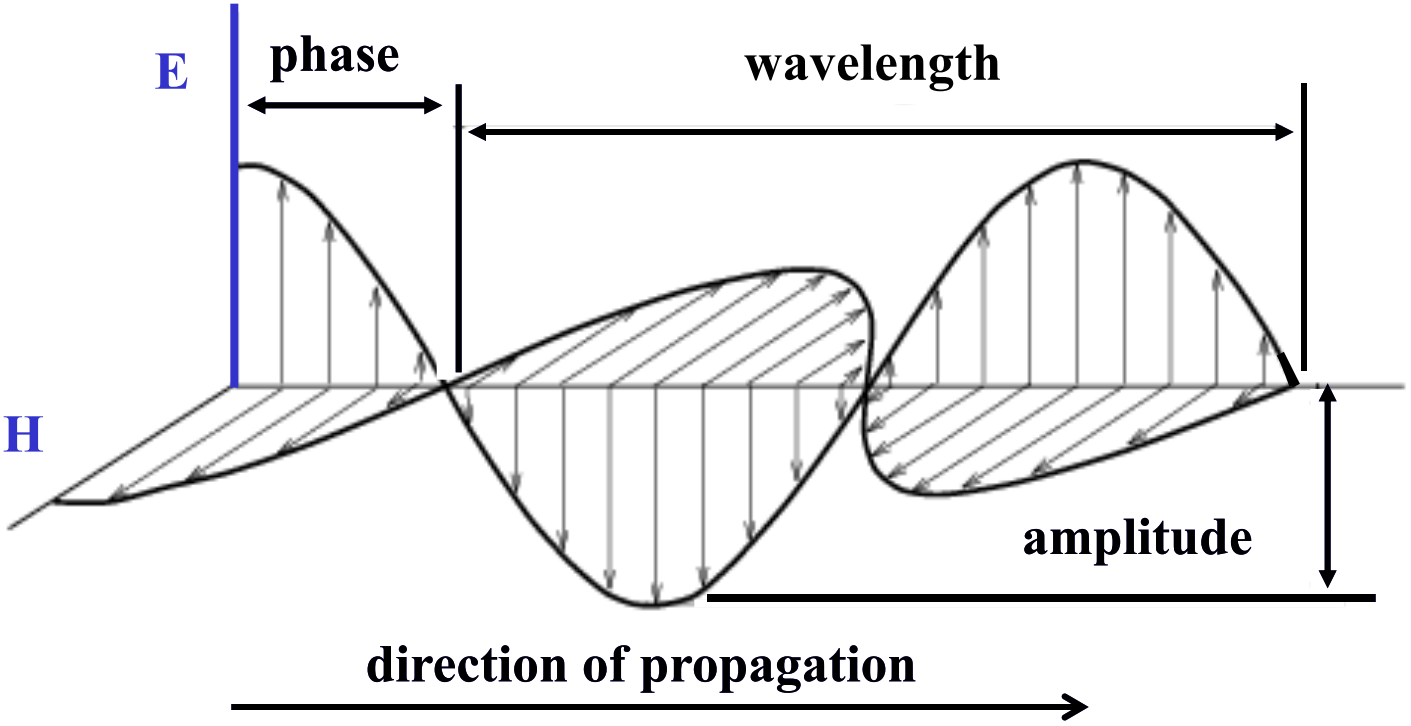
➔ **wave character**

Light as electromagnetic waves



Light as electromagnetic waves

Self-sustaining exchange of electric and magnetic fields



1. wavelength
2. direction
3. amplitude *E*
4. phase
5. direction of polarisation

The spectrum

Normal ambient light is a mixture of wavelengths, polarisation directions, and phases

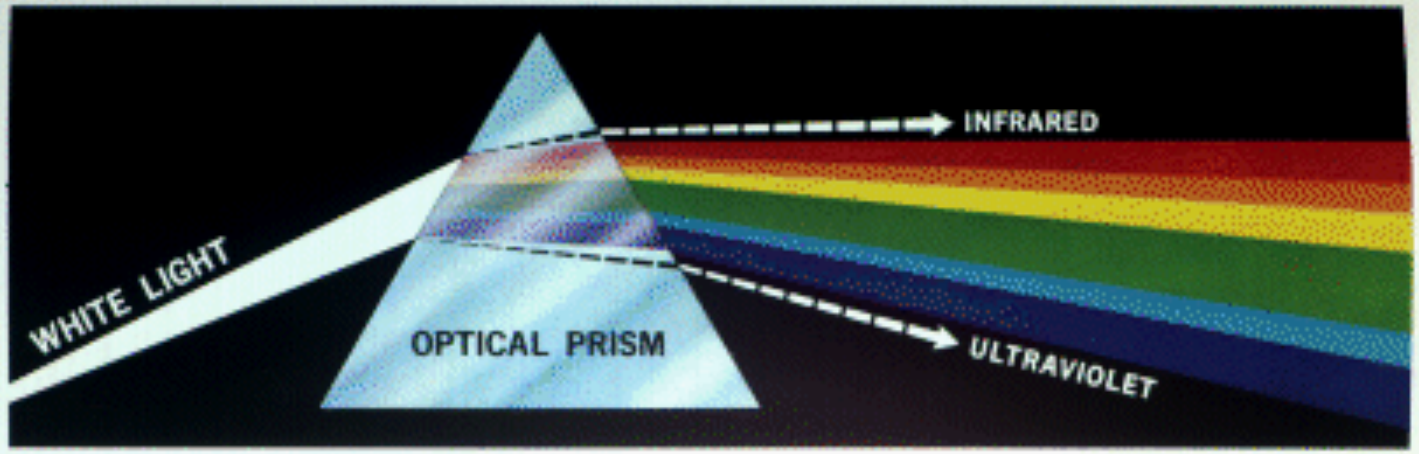
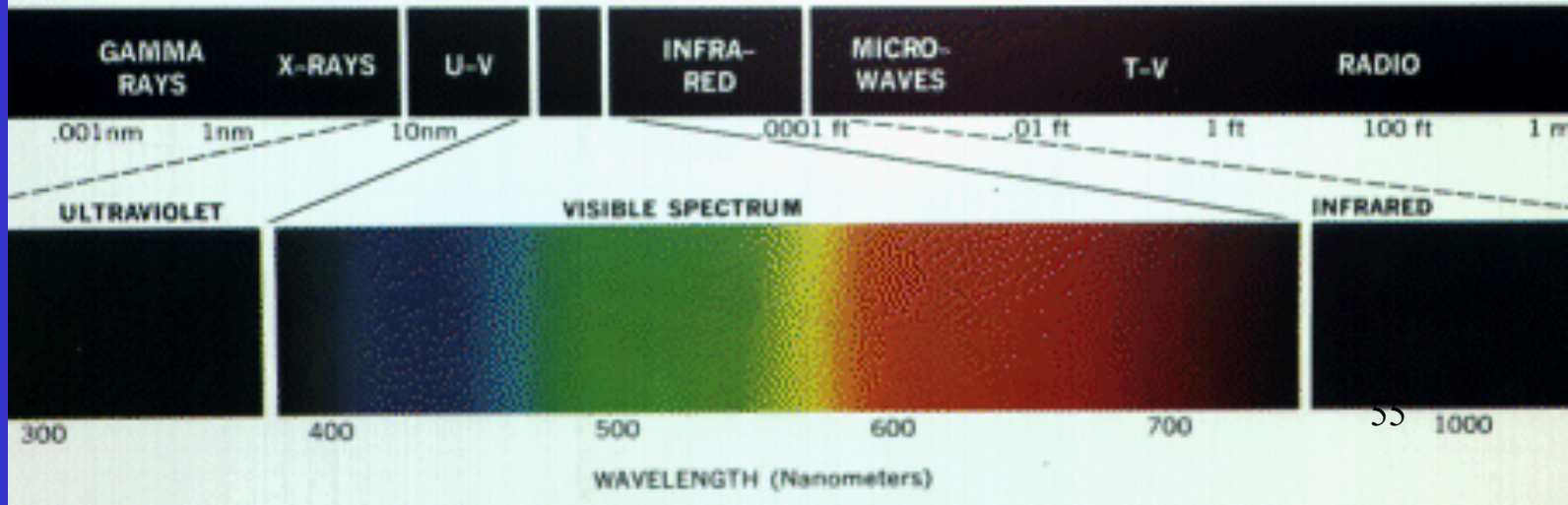


Plate I. Color spectrum seen by passing white light through a prism. (Courtesy of General Electric Co., Lamp Business Division.)

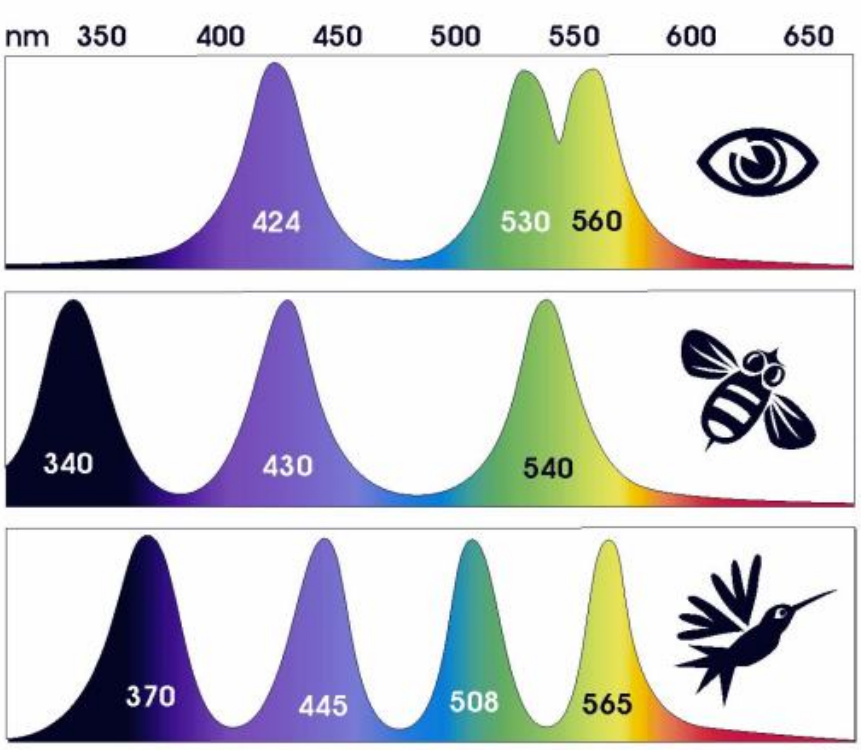


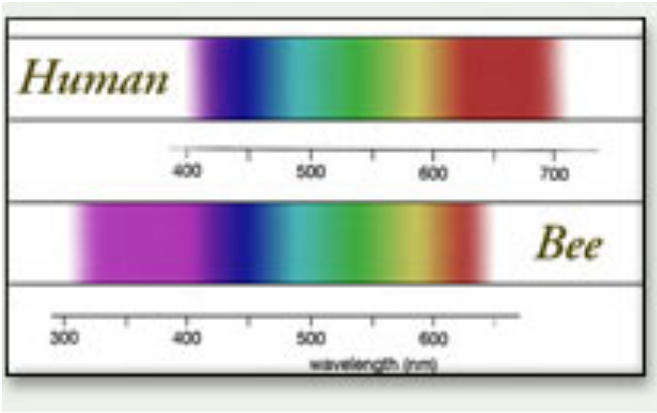
The visible range

Wavelength (in *nm*)	Colour
380 - 450	violet
450 - 490	blue
490 - 560	green
560 - 590	yellow
590 - 630	orange
630 - 760	red

NOTE : Cameras may have different spectral sensitivities (i.e. also different from human vision)

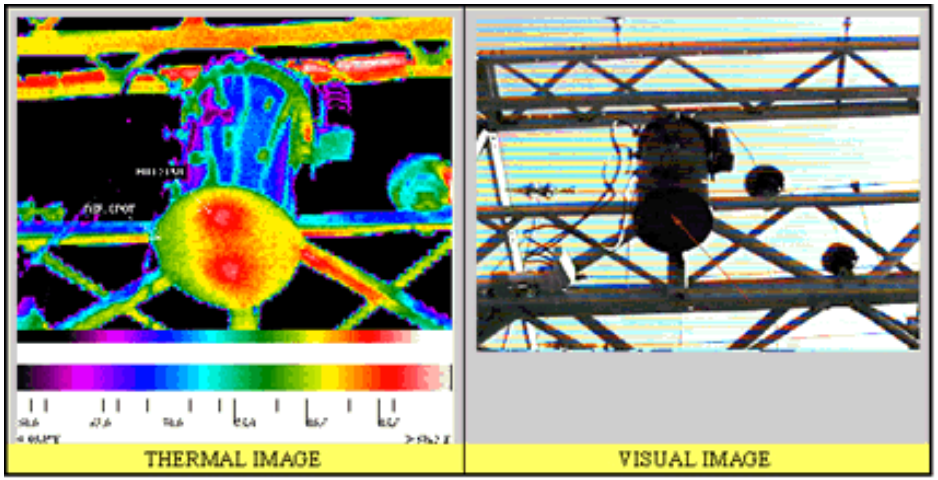
The visible range





NOTE : animals may have different spectral sensitivities (i.e. different from human vision), and may also have a Different number of cone types, like 4 in most birds.

Also cams for non-visible `light', e.g. infrared



Overheating of transformer coils, with far IR

Near infra-red (NIR) space image

NRG -> RGB for visualization (notice the strong reflection in the NIR for vegetation)

Interactions with matter

four types :

phenomenon	example
absorption	blue water
scattering	blue sky, red sunset
reflection	coloured ink
refraction	dispersion by a prism

+ diffraction

Interactions with matter

four types :

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Scattering

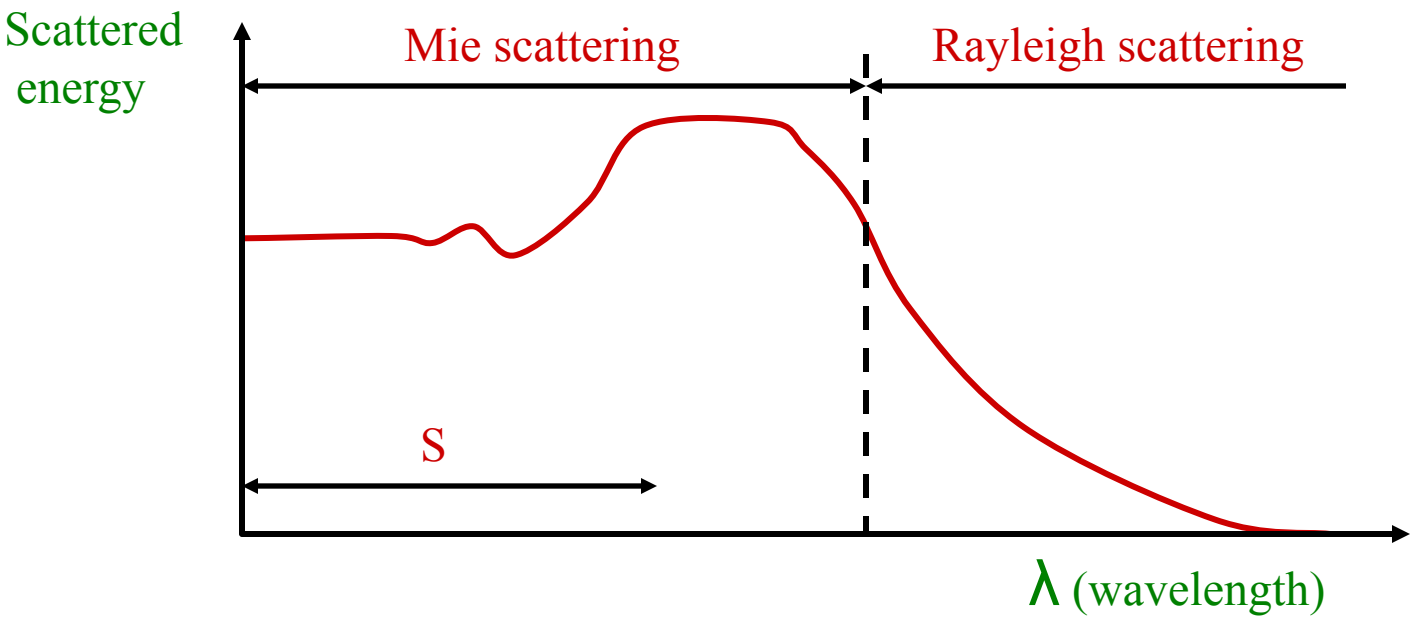
3 types depending on relative sizes of particles and wavelengths:

1. small particles: *Rayleigh* (strongly wavelength dependent)

2. comparable sizes: *Mie* (weakly wavelength dependent)

3. Large particles: *non-selective* (wavelength independent)

Wavelength dependence



Less haze in the infrared (long wavelengths -> little scatter)
Looking through clouds by radar (even longer wavelengths)
NOTE: without scatter we would wander mainly in the dark

Atmospheric showcase

Rayleigh:
Tyndall effect (blue sky)
Red, setting sun

Non-selective:
Grey clouds

Mie:
Coloured cloud from volcanic eruption

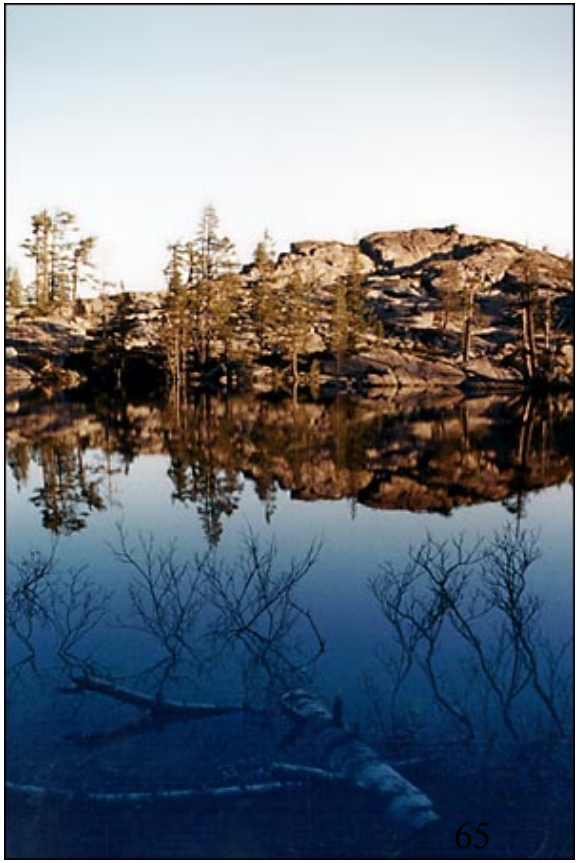
Interactions with matter

four types :

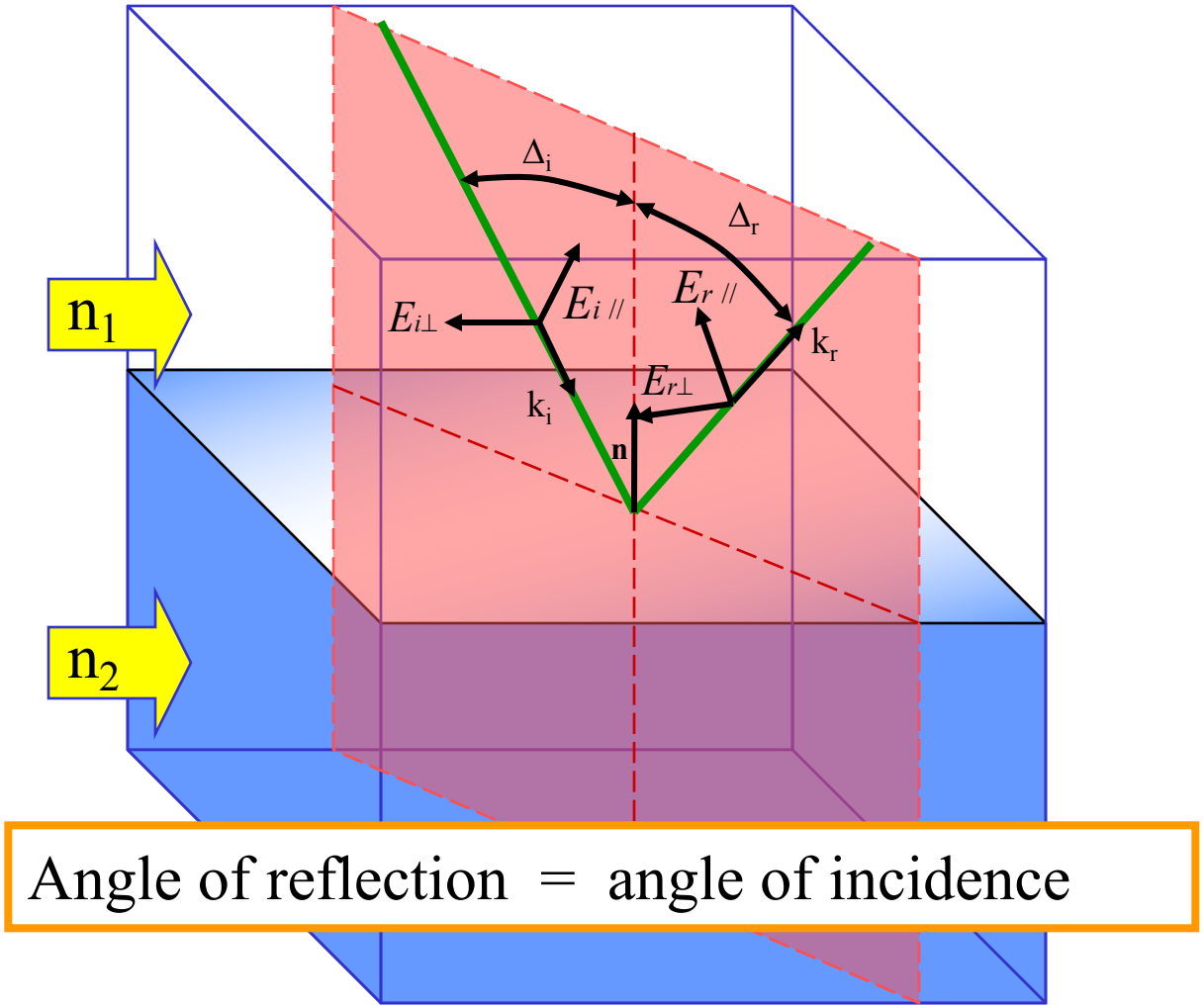
phenomenon	example
absorption	blue water
scattering	blue sky, red sunset
reflection	coloured ink
refraction	dispersion by a prism

+ diffraction

Mirror reflection

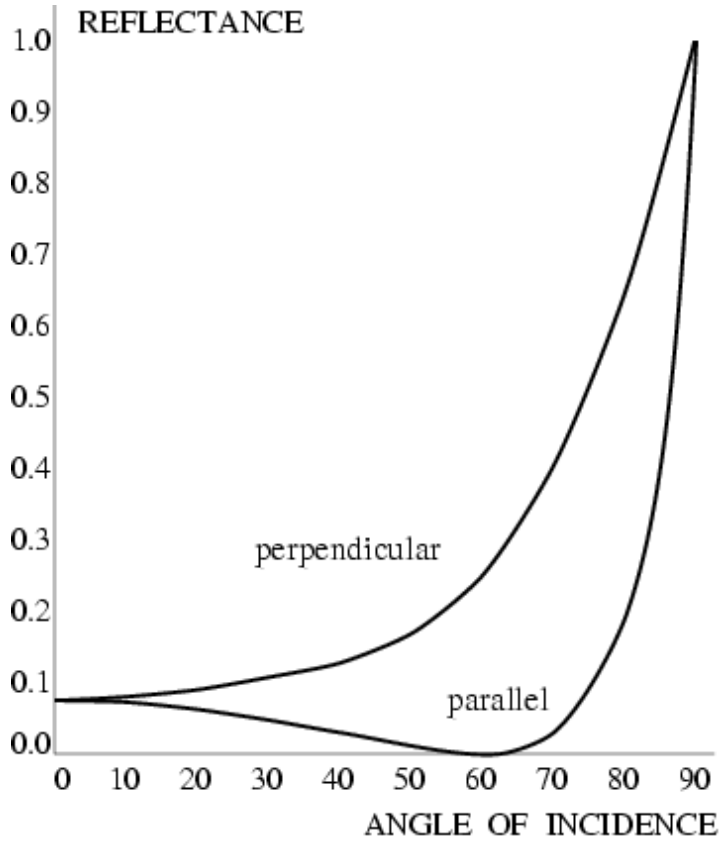


Mirror reflection



Angle of reflection = angle of incidence

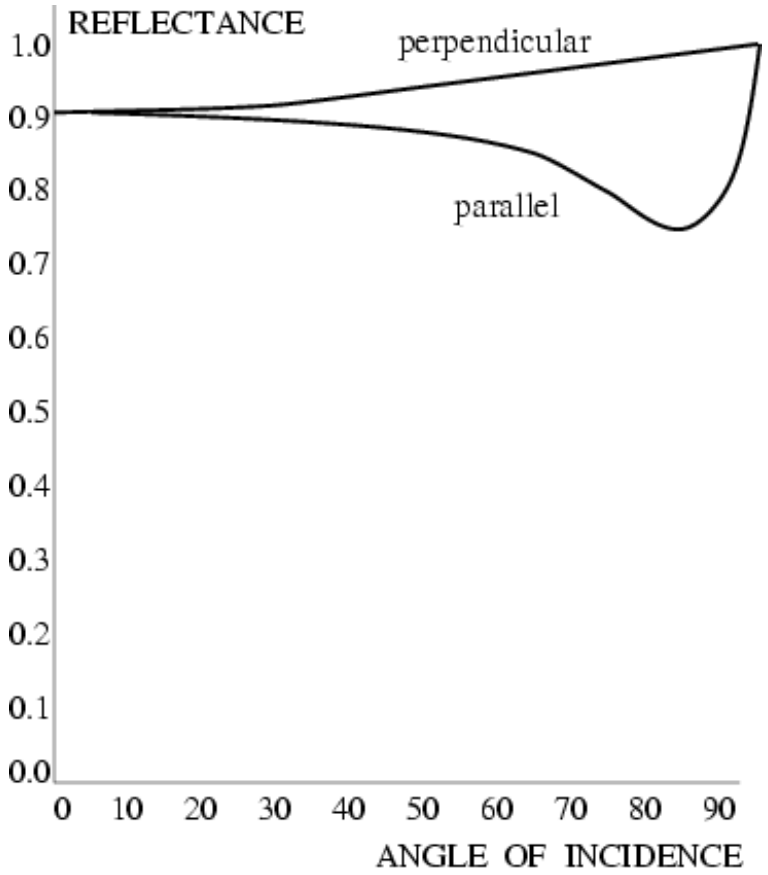
Mirror reflection : dielectric



Polarizer at *Brewster angle*

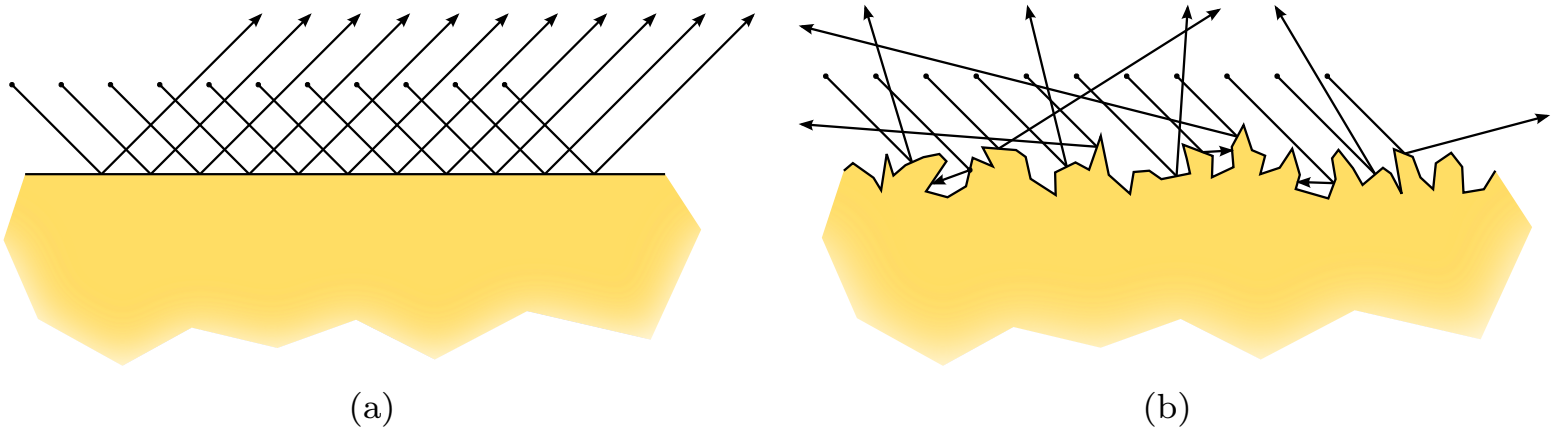
Full reflection at grazing angles

Mirror reflection : conductor



strong reflectors (under all angles)
more or less preserve polarization

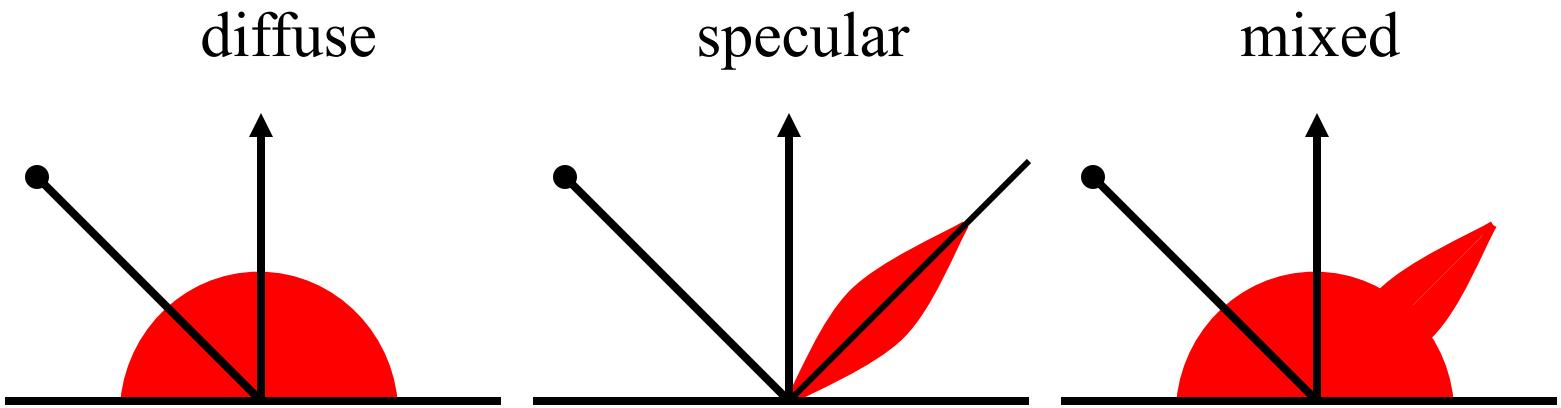
Roughness of surfaces leads to `diffuse' reflection



(a) Mirror or `specular' reflection, (b) diffuse reflection

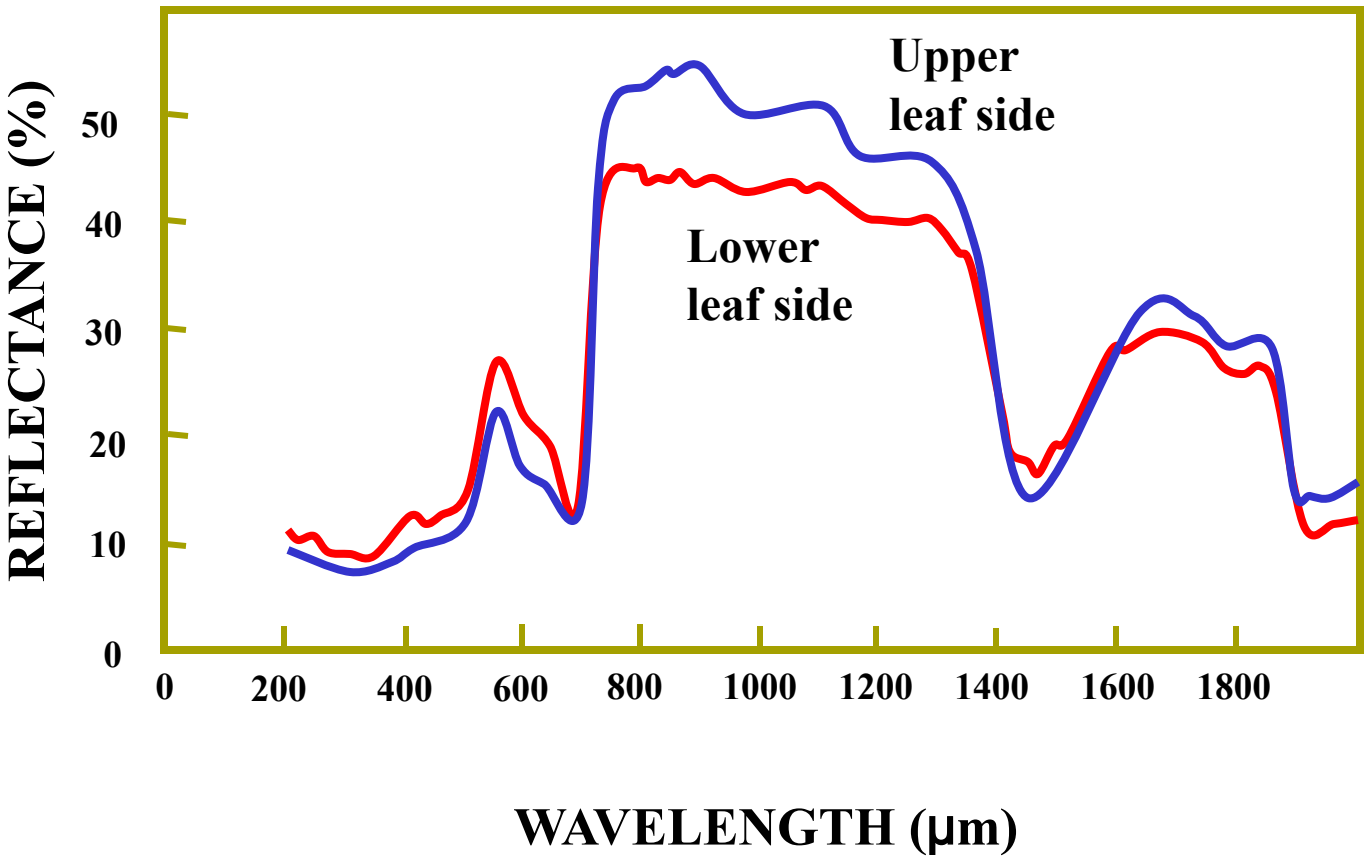
… and to mixed reflection for most real surfaces

three types of reflection :



Note : Lambertian example of diffuse reflection

Spectral reflectance
e.g. vegetation



Ideally: spectral BRDF at all points known

BRDF = bidirectional reflectance distribution function

Interactions with matter

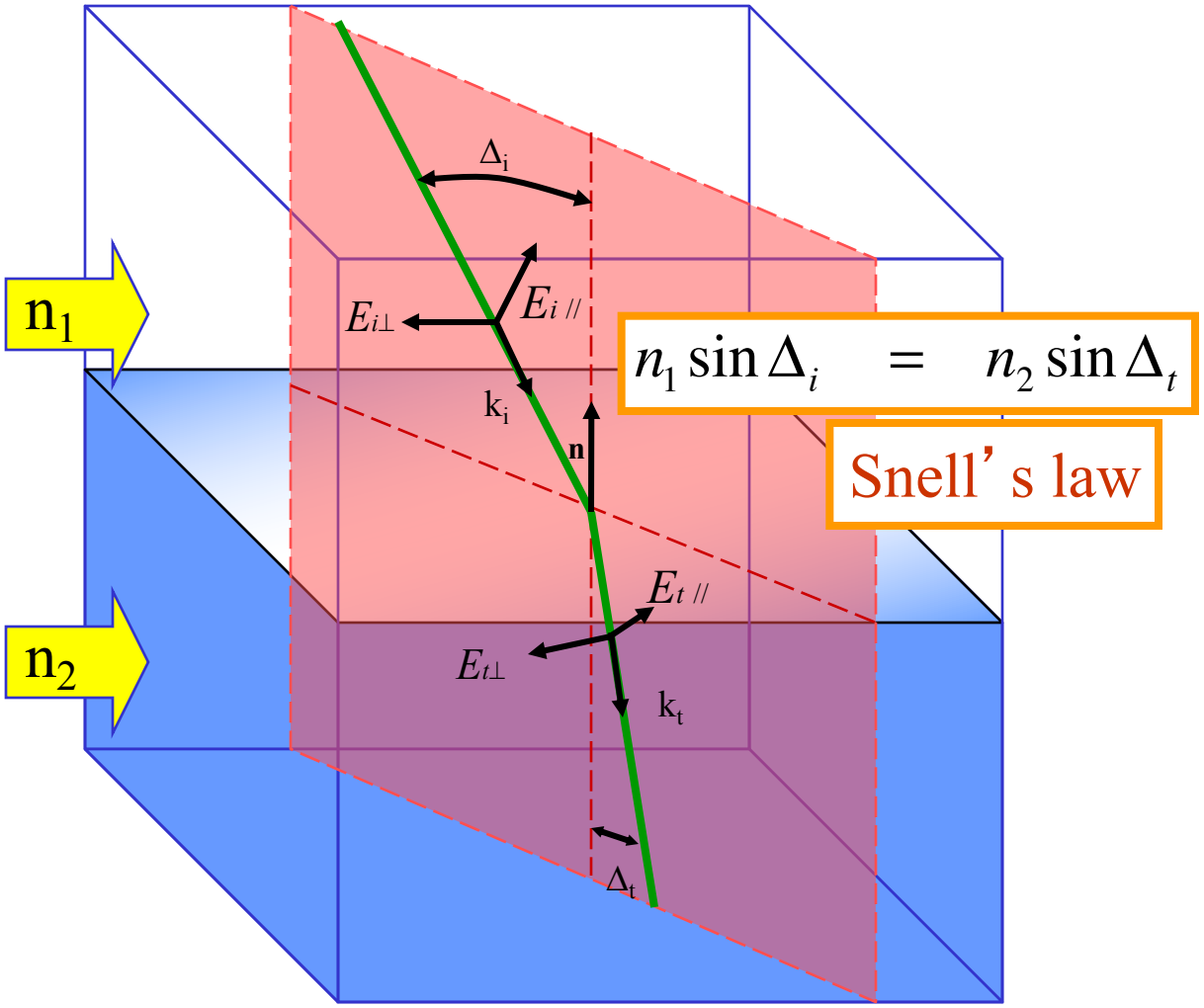
four types :

phenomenon	example
absorption	blue water
scattering	blue sky, red sunset
reflection	coloured ink
refraction	dispersion by a prism

+ diffraction

Refraction

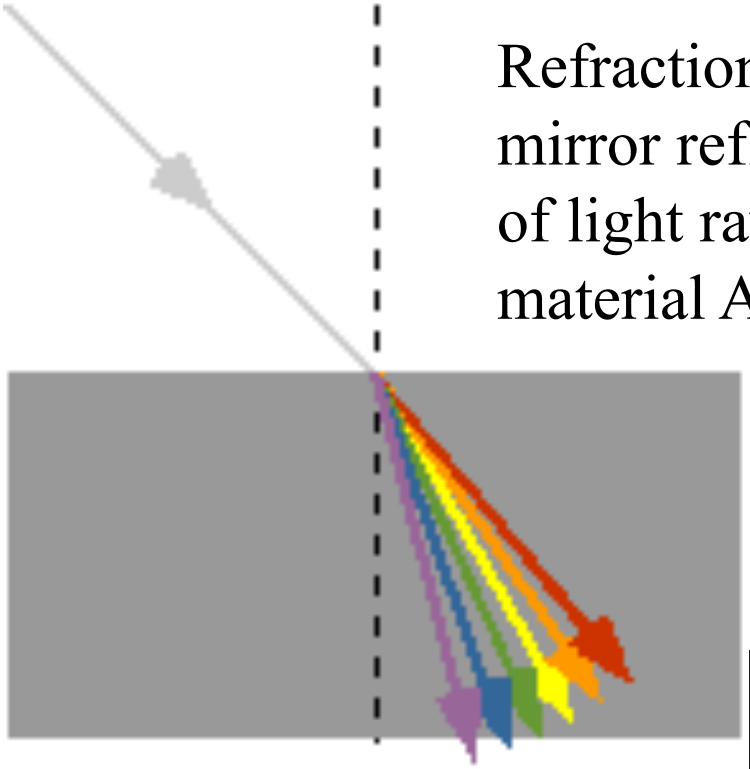
Refraction



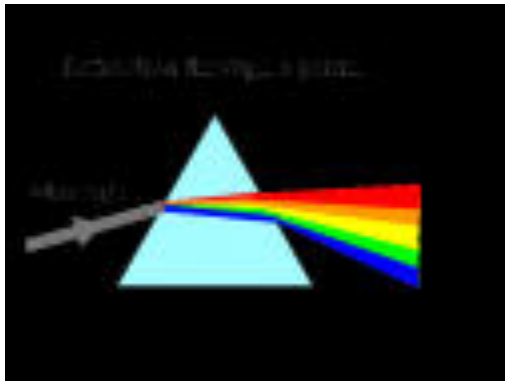
$$n_1 \sin \Delta_i = n_2 \sin \Delta_t$$

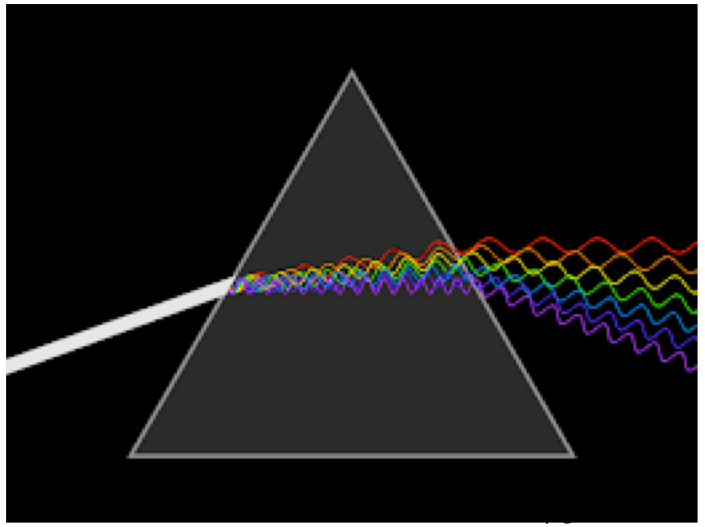
Snell's law

Dispersion



Refraction is more complicated than mirror reflection: the path orientation of light rays is changed depending on material AND wavelength !!!





Interactions with matter

four types :

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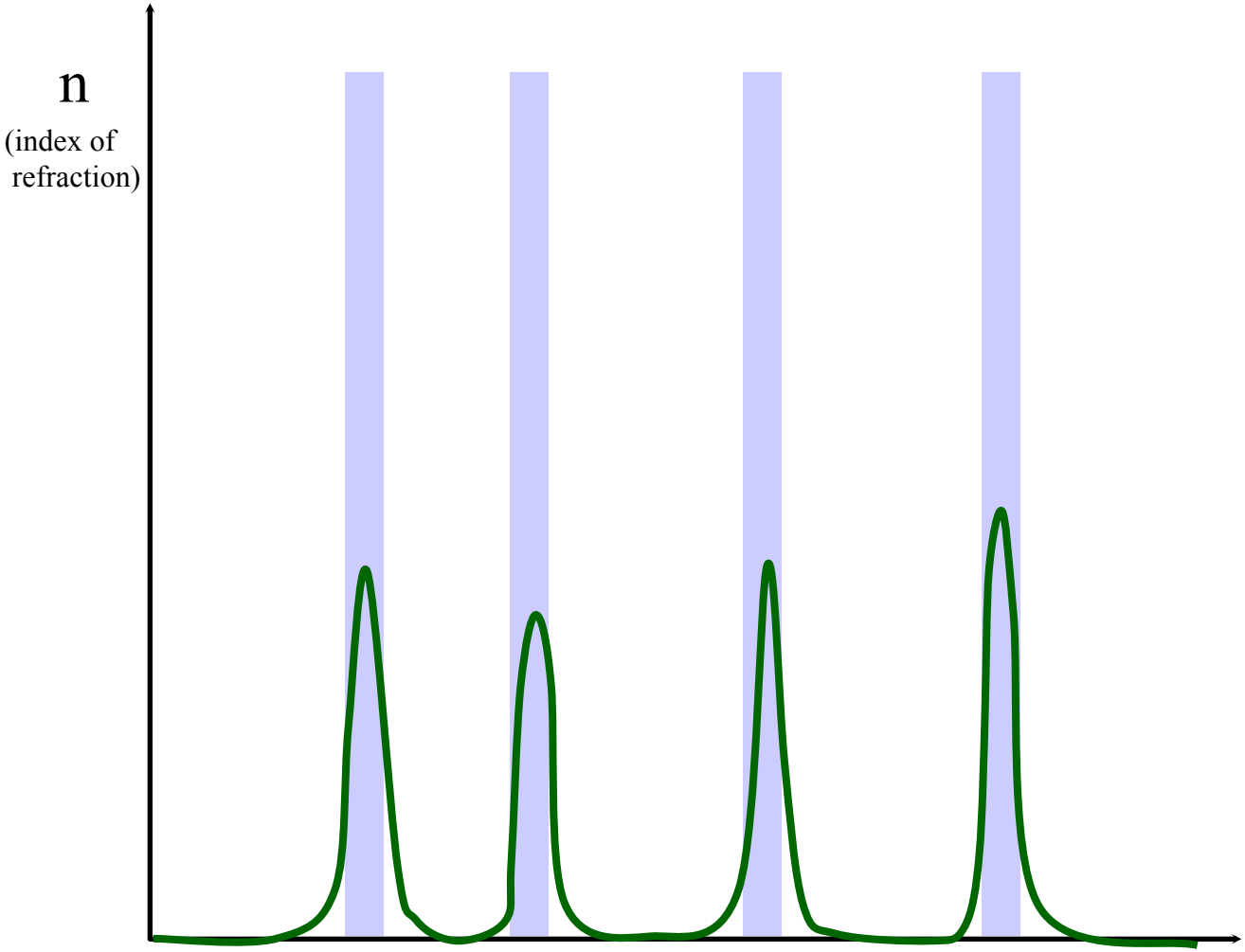
Absorption

Dissipation of wavelengths specific for the medium



Based on resonance frequencies of molecules -> peaks

Holes in sky light spectrum observed by Fraunhofer

The solar spectrum

Peaks around 500nm, hence human sensitivity for that part of the spectrum