Vision, Spiders & Time

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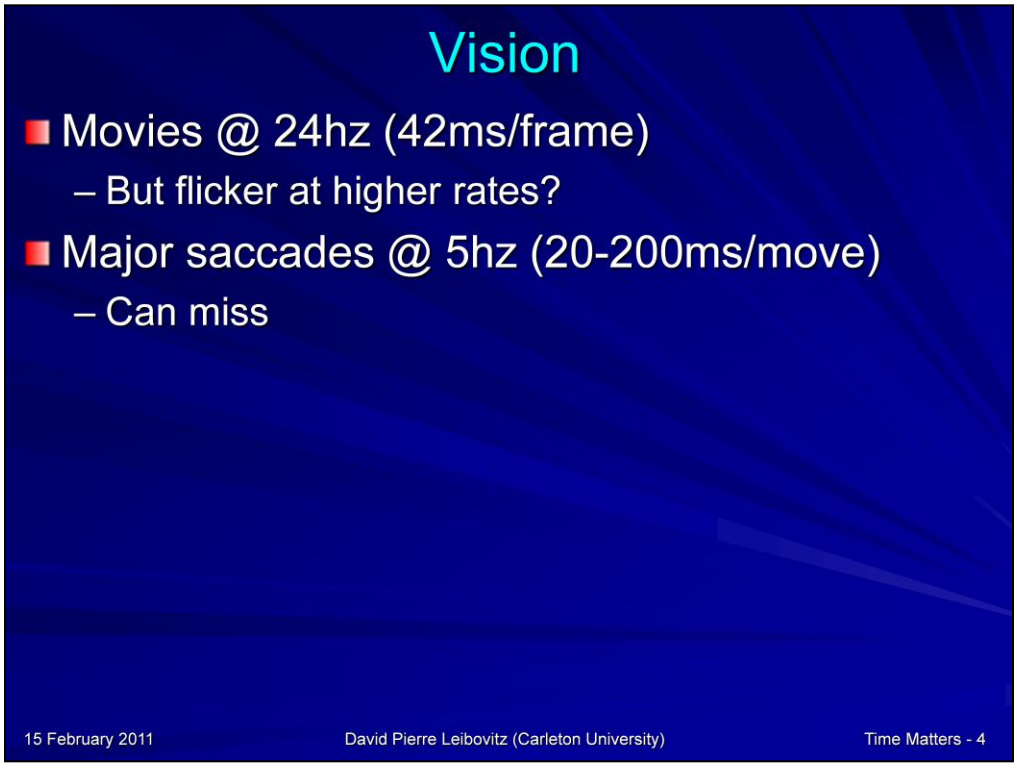
Summary

- How is vision perception related to imagination and planning
- What is the role of attention (saccades)
- Can smart spiders shed light on human cognition?
  - They have severe engineering restrictions
  - They they take a long time to think
  - How does that affect cognition
- I will relate spider time to practical matters
- Hopefully, you will also come to appreciate spiders as well ☺

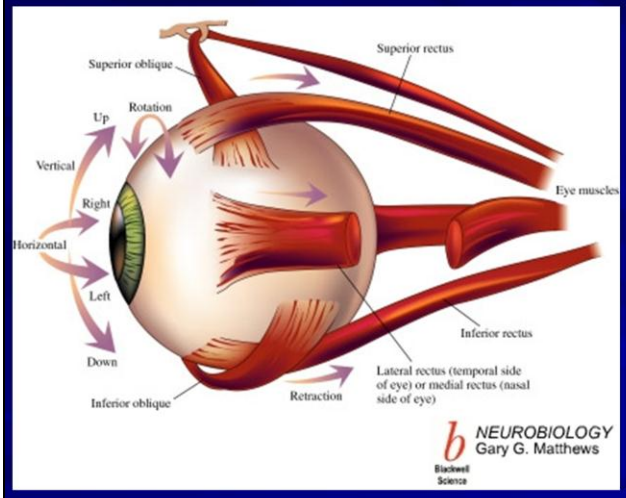
Human Vision Like a Camera?

- Static Camera vs. Video
  - Do we process changes?
- Process entire scene or saccade/attend to others
- Is it process-interpret-act or a top-down/bottom-up iterative thing
- What about imagination?



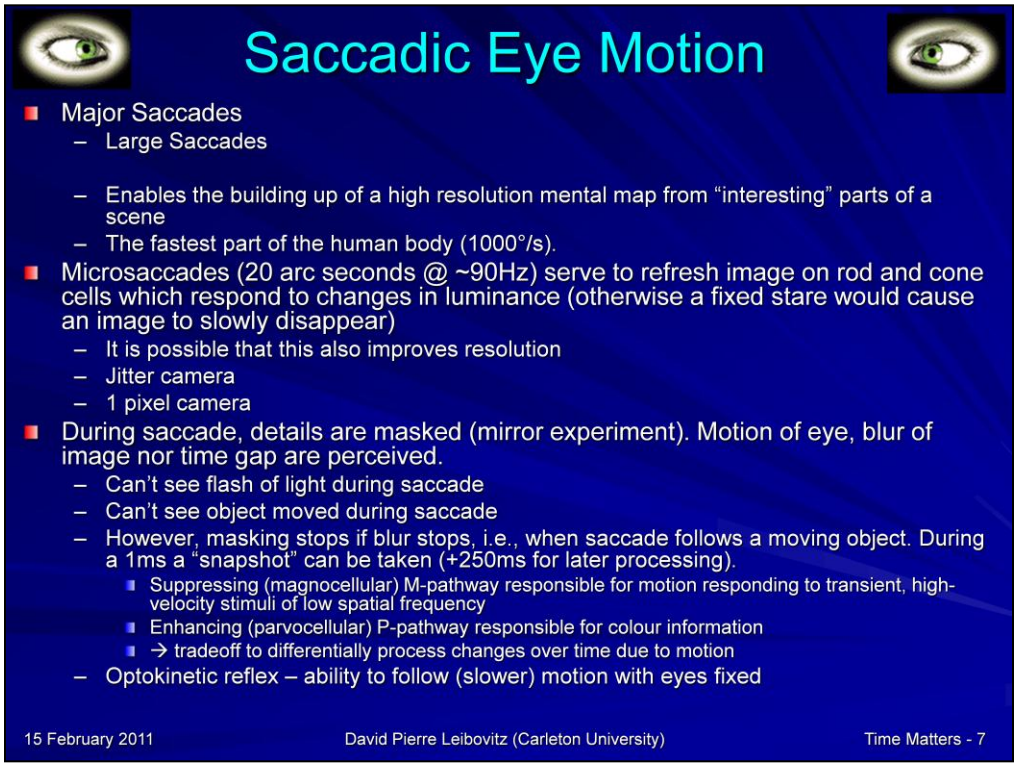
See: http://en.wikipedia.org/wiki/Flicker_fusion_threshold

Saccades


Superior oblique
Superior rectus
Rotation
Up
Vertical
Right
Horizontal
Left
Down
Eye muscles
Inferior rectus
Lateral rectus (temporal side of eye) or medial rectus (nasal side of eye)
Retraction
Inferior oblique
NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

Saccades	Major (Clinically observable)		Minor (Hard to observe)	
	Large	Small	Mini/Flick	Micro/Tremor
Angular Distance	>6.2°	6.2° - 1.2°	1.2° – 2’	40”
Occurrence	.05 - .3hz	Up to 5hz	40hz -	- 200hz
Time	200ms	20-200ms	10-20ms	<10ms
Reason	Head, Body Orientation Changes		View other features of object, next character grouping	Refresh Rod/Cone Signalling Extra Detail?

•The major/small saccades are the ones most people research or know about



•Selective suppression during saccades

•1994, David C. Burr, et al. Selective suppression of the magnocellular visual pathway during saccadic eye movements. Nature 371(6), 511 – 513

•Fulton, James T., Processes in Animal Vision {online} {Corona Del Mar, CA. USA} Vision Concepts, {published 2000-08-01}, {revised 2000-08-01},{cited 2000-08-01}. Available on the Internet: URL:http://www.4colorvision.com

•1 pixel camera

•From http://www.newscientisttech.com/article/dn10233-singlepixel-camera-could-simplify-imaging-.html

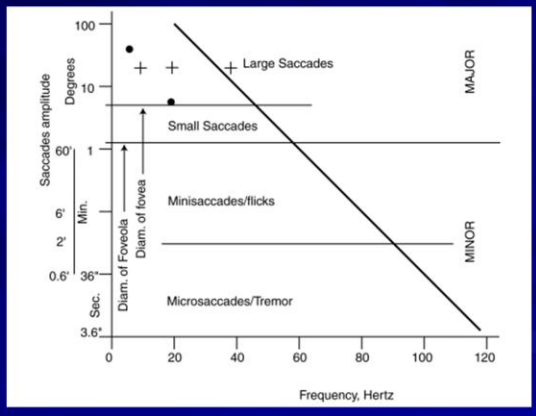
•One pixel over time

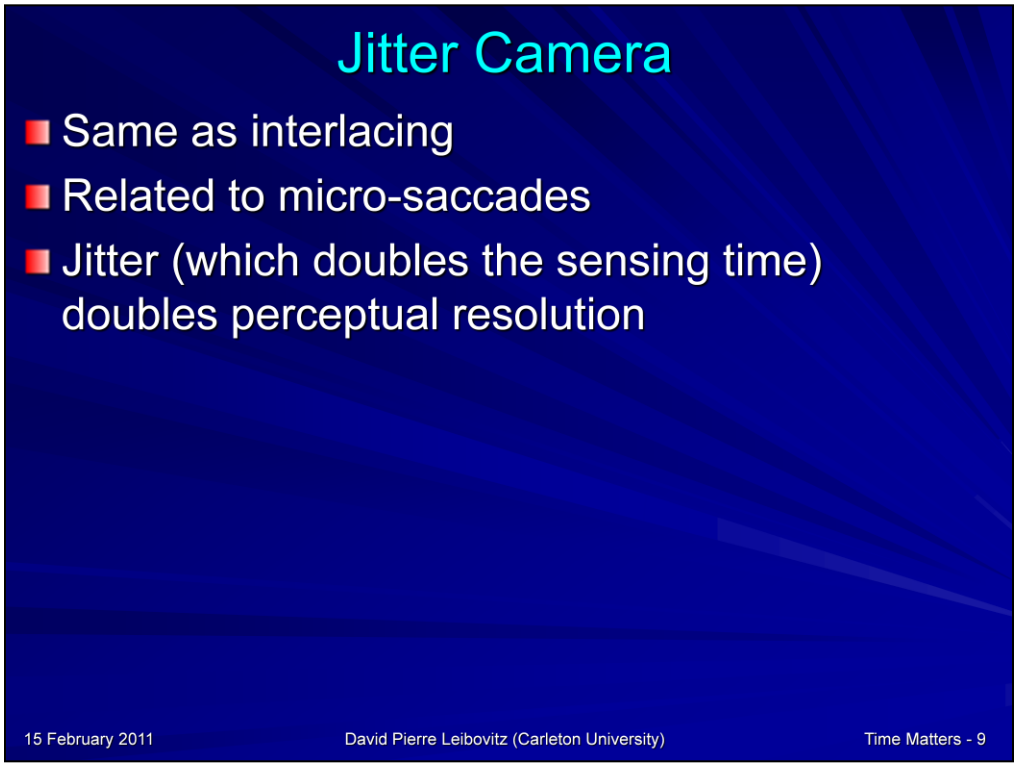
•Do not spend time throwing out (compressing) megapixel info, but just scan what is needed (compressed sensing – much like our periperal/focal vision)

•Less memory and power (on compute intensive compression)

•Ability to engineer for infrared, ultraviolet & terahertz

•From: http://www.dsp.ece.rice.edu/cscamera/

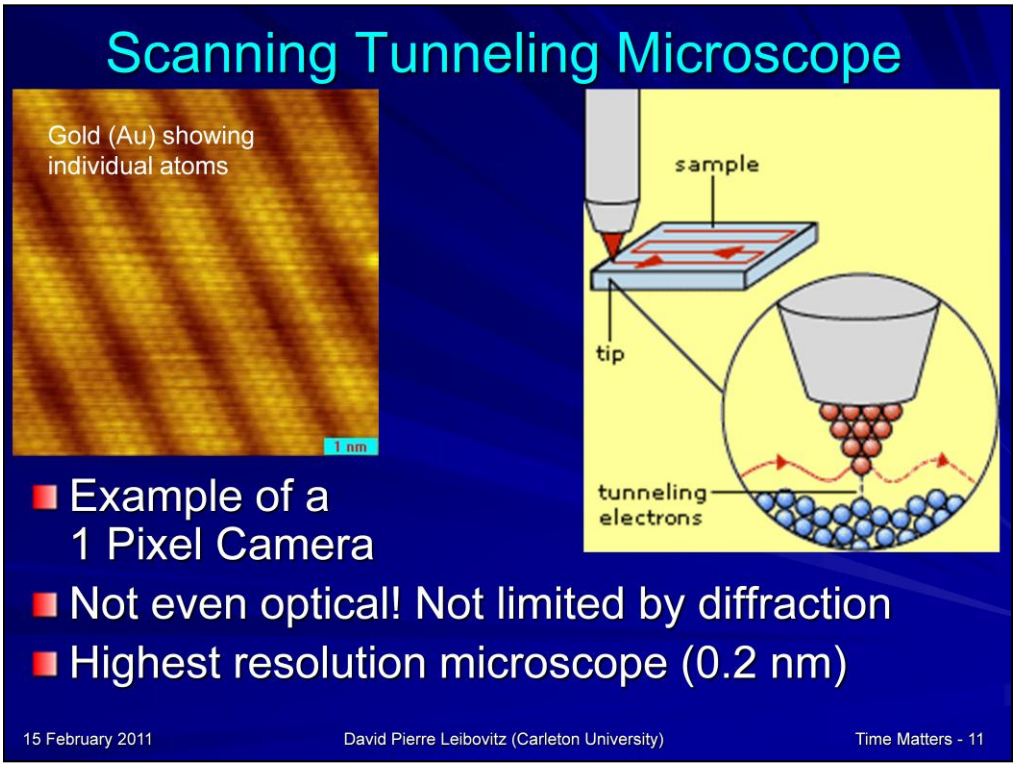

Saccades amplitude
Degrees
100
10
1
60'
6'
2'
0.6'
Min.
36"
Sec.
3.6"
Diam. of Foveola
Diam. of fovea
Large Saccades
Small Saccades
Minisaccades/flicks
Microsaccades/Tremor
MAJOR
MINOR
0
20
40
60
80
100
120
Frequency, Hertz



•Ben-Ezra, M., Zomet, A. & Nayar, S.K. (2004) Jitter Camera: High Resolution Video from a Low Resolution Detector. Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'04), Washington DC, II: 135-142, June 2004.

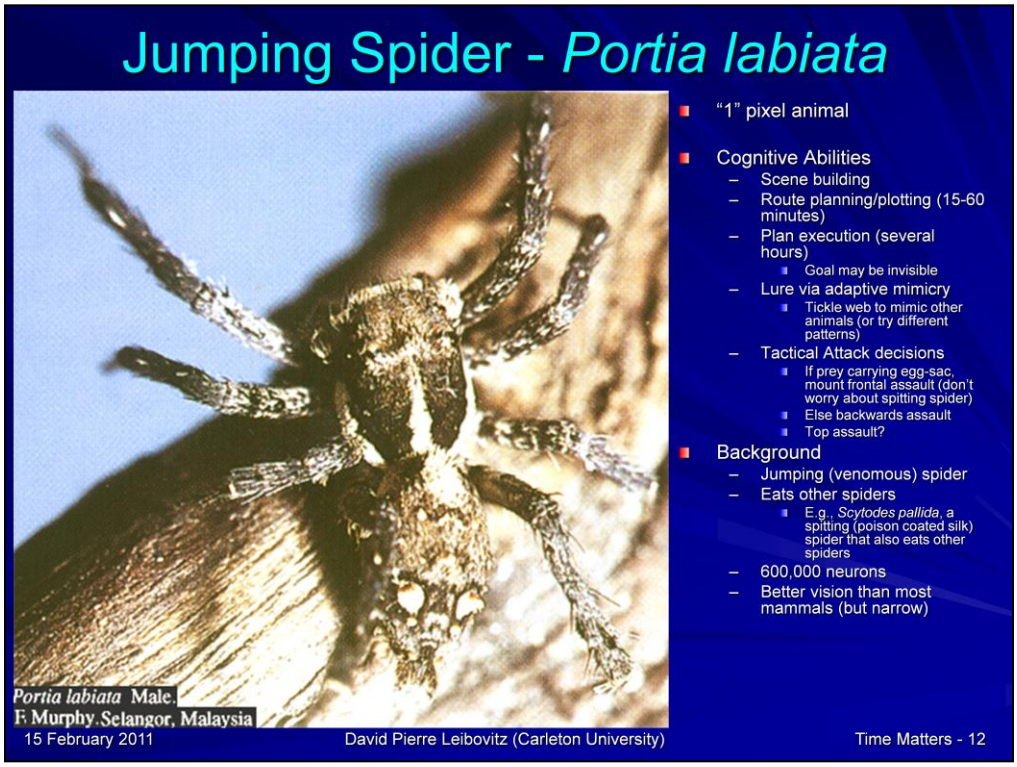
Visual Neglect

- In Visual Neglect, Patients can only see, or imagine half a scene.
- However, they can mentally rotate 180° and then imagine the other half (from the other perspective)
- This lends credence to the view that each side GENERATEs a view.



•Images from:

- •Gold: http://en.wikipedia.org/wiki/Scanning_tunneling_microscope
- •Tip: http://nobelprize.org/educational_games/physics/microscopes/scanning/index.html



- Tactics/Strategic Planning???
- Route executions
    - Several hours (at this time, portions of scanned route are not visible)
    - Good memory
- *Portia* genus
    - makes up 20 out of 5000 species of jumping spiders (*Salticidae* or *salticids*)
    - Found in Africa, Australia & Asia
- More than hard-wired reflexes
    - Thinking
    - Planning
    - Trial-and-error learning
    - Attention span
    - Flexible behaviour
- Luring/deceiving (mimicking) other spiders away from their webs
    - Pluck rhythms on web to mimic a trapped insect or a hostile one
    - If prey encountered before, it will know what rhythms to use, else
    - Try out various patterns by trial and error

- •Tickle lightly
- •Strum vigorously
- •Bob up and down

•Route Execution (great memory)

- •Avoid distraction
- •Avoid first wire (if wrong one)
- •Will give up on first wrong bend on wrong wire

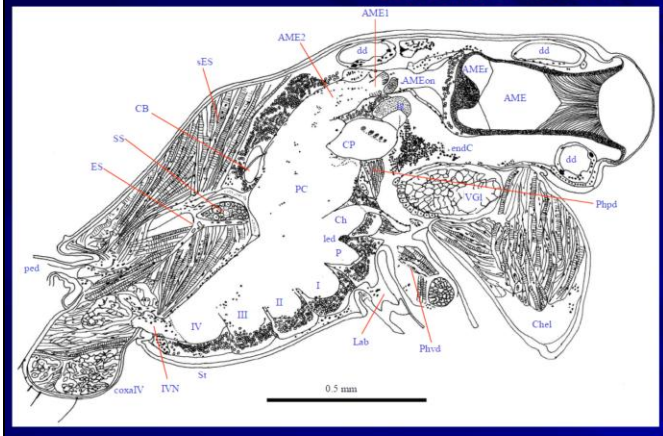
•Other memory

- •If jump then swim strategy (vs swim all the way) is favoured, it will try this next time, Switch if not succesfull.
- •Dynamic strategy (plasticity)
- •Once a given prey has been killed, similar prey is found easier, less attuned to others
- •→ Selective attention

•References for this “Spider” section are

- •Greenspan, R.J. & van Swinderen, B. (2004) Cognitive consonance: complex brain functions in the fruit fly and its relatives. Trends in Neurosciences, 27(12): 707-711
- •McCrone, J. (2006) Smarter than the average bug. New Scientist, 2553(27May).
- •Tarsitano, M.S. & Jackson, R.R. (1997) Araneophagic jumping spiders discriminate between detour routes that do and do not lead to prey. Animal Behaviour, 53, 257-266.
- •Tarsitano, M.S. & Andrew R. (1999) Scanning and route selection in the jumping spider *Portia labiata*. Animal Behaviour, 58, 255-265.
- •Harland, D.P. & Jackson, R.R. (2000) 'Eight-legged cats' and how they see - a review of recent research on jumping spiders (Araneae: Salticidae). Cimbebasia, 16,: 231-240
- •Hill, D.E. (1975, 2006) The structure of the central nervous system of jumping spiders of the genus *Phidippus* (Araneae: Salticidae)

Brain Size



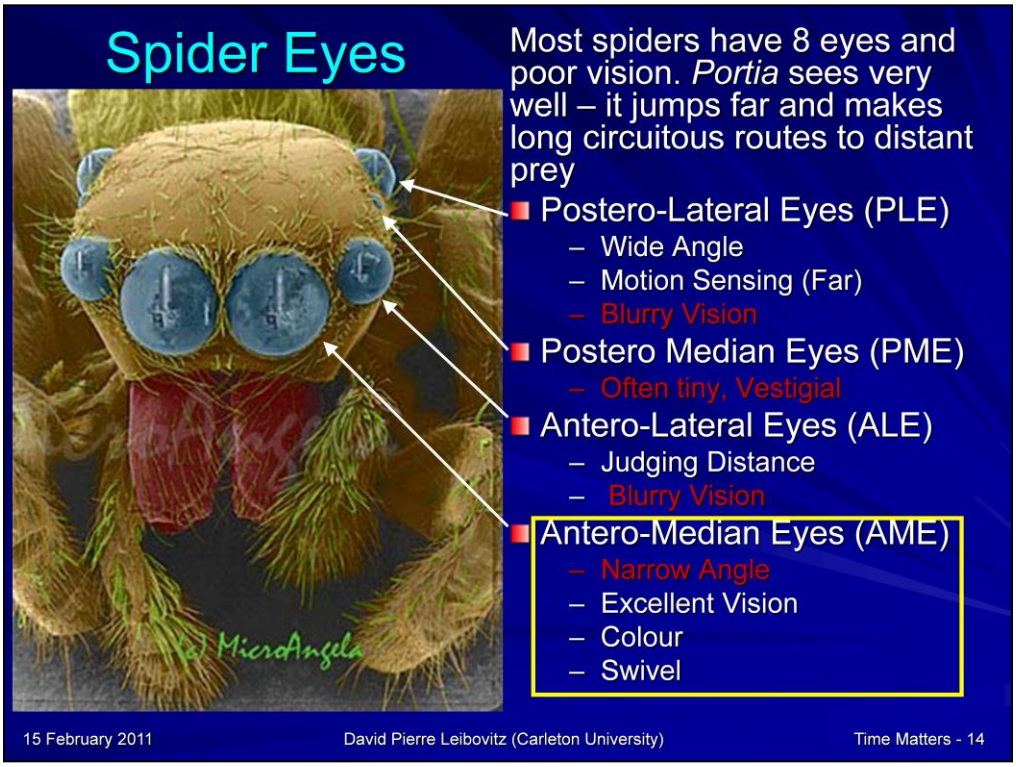
Neurons (not connectivity)

- Humans: 100 billion
- Mouse: 70 million
- Honeybee: 1 million
- Portia: ½ million
- Housefly: ¼ million

- In Portia, limited size will force a lengthy and complex (algorithmic) visual scan to convert scene into a more compact (plan oriented?) representation.
- There just isn't enough neurons to rebuild a visual scene

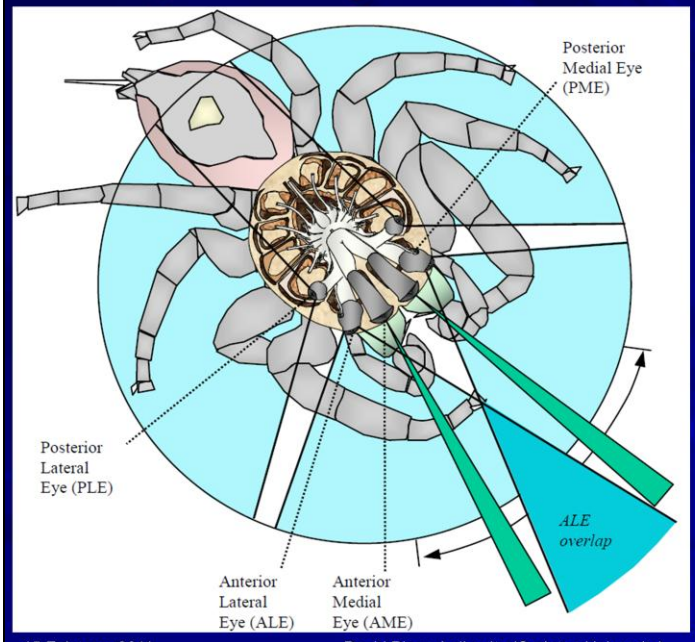
•Portia has ~600K neurons

•Image from Hill(1975,2006)



- Image from: http://www.pbrc.hawaii.edu/microangela/jspider.htm
- PME
  - Sometimes is larger and covers off missing fields of view (and detects motion)
- "Focus" of presentation, will be on the front eyes only.

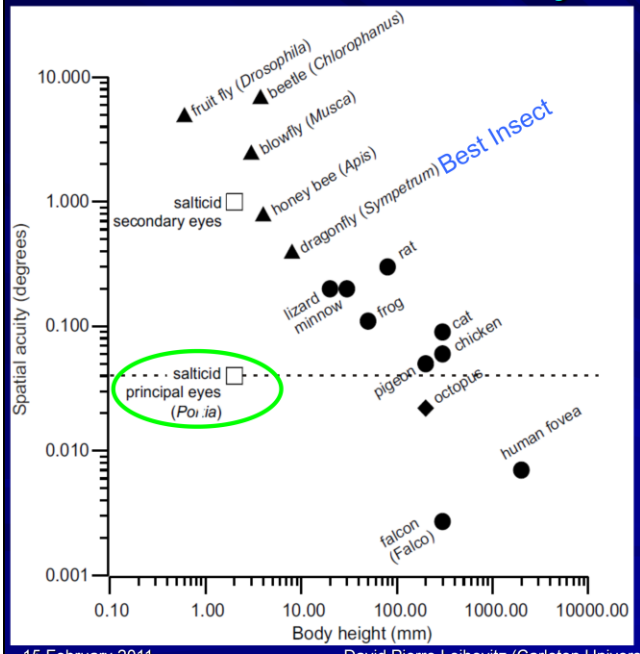
Spider Eyes – Fields of View



- ALE overlap enables accurate judgement of distance (binocular vision)
- AME do not overlap
  - Narrow telephoto systems

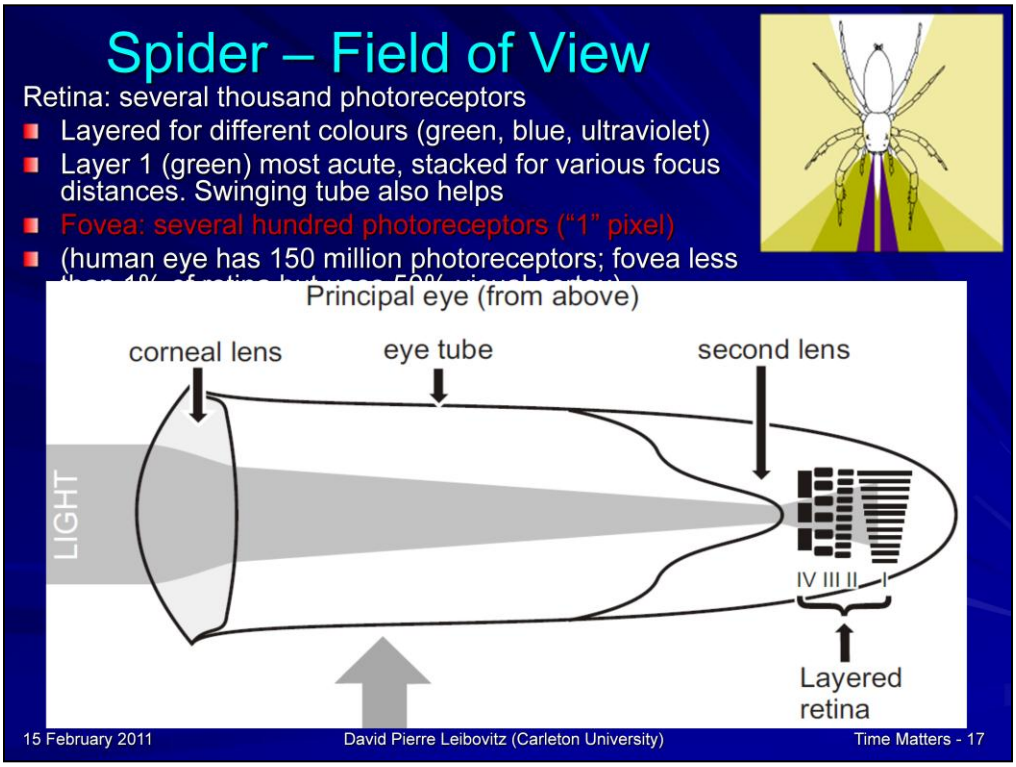
•Image from Hill (1975,2006)

Acuity



- *Portia* visual acuity is better than cats and pigeons
  - Measured in angular resolution, not via light sensitivity
- But slow…

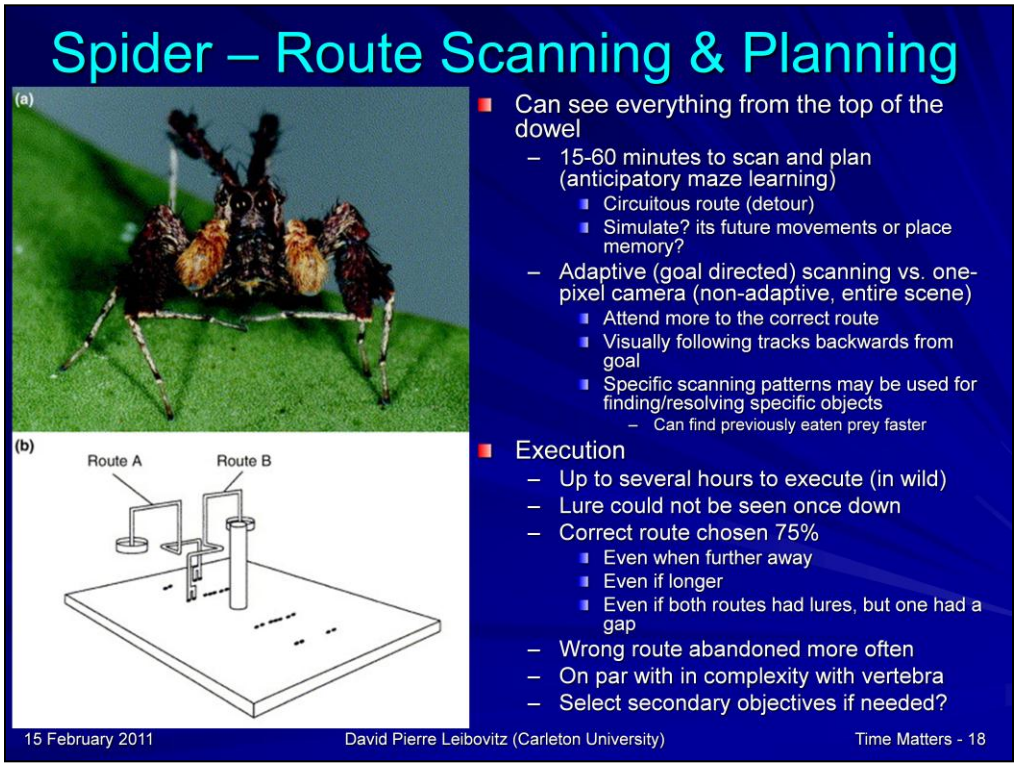
•Image from: Harland & Jackson (2000)



•Images from

- •Spider: http://www.amonline.net.au/spiders/toolkit/hairy/see.htm
- •Eye: Harland & Jackson (2000)

•With such a narrow field of view, Portia must scan its environment



•Image from: Greenspan & Swinderen (2004)

•Many different setups used

•Eyes:

- •4 pairs of simple (camera like) eyes
  - •1 pair of large principle eyes for acute vision & object detection
    - •2° field of view (humans have 140°/eye horizontally, 90° vertically, 180° with both; fovea 2°-4°)
    - •30° (around and above) movement (humans have 190° of fovea with movement)
    - •Fovea: 0.6°
  - •3 pairs of smaller secondary eyes for motion detection
    - •360° (around and above) field of view

•Seeing

- •Area Examining
  - •Continuous back/forth, up/down sweeps
  - •"Spontaneous activity" even in absence of visual stimuli
- •Object Scanning
  - •Restricts movement to object
  - •"Extended Retina"
- •Body orientation also changed.

•Multiple routes in experimental design

•If it tried, difficulty did not affect correct choice

•"Confidence" used to discern if an attempt should be made

•Scanning is not just the building up of a (compressed) image. There simply aren't enough neurons to hold a single snapshot of the environment

Principles

- Time can be used to accumulate smaller bits of information into larger bits (scanning)
  - Scanning may be algorithmic
- However, to reduce scanning time (as compared to an actual 1 pixel camera) it must be adaptive, i.e. selective attention based on goals affected by memory
- Moreover, to reduce representation size, scanning must be done in conjunction with planning
  - It is possible that the "plan" is the representation of perception
  - We "see" and attend to affordances
- Perception and decision making (goal system) are part of a dynamic system and cannot be divorced
  - It is only when the timescales of both are similar that this is made apparent
  - Seeing the "big picture" is a more human example. Information needs to be synthesized in order to make good plans
- Even in humans, visual neglect shows that perception is goal oriented – a visuomotor system

•Marotta + (2003) Hemispatial neglect- its effects on visual perception and visually guided grasping

•Rafal + (2002) Visual detection is gated by attending for action Evidence from hemispatial neglect

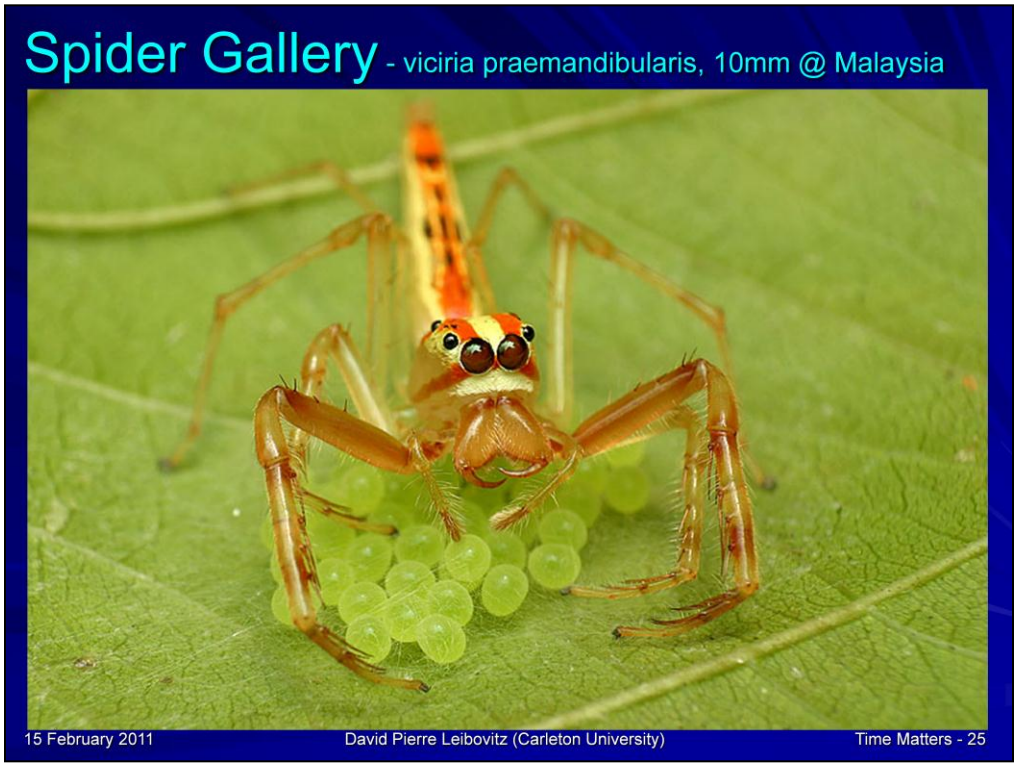
Image from: http://www.apbworks.co.nz/ft_02.htm

•Image from: http://www.apbworks.co.nz/ft_10.htm

•Image from: http://www.apbworks.co.nz/ft_12.htm

•Image from: http://www.apbworks.co.nz/ft_11.htm

•Image from: http://www.apbworks.co.nz/ft_07.htm



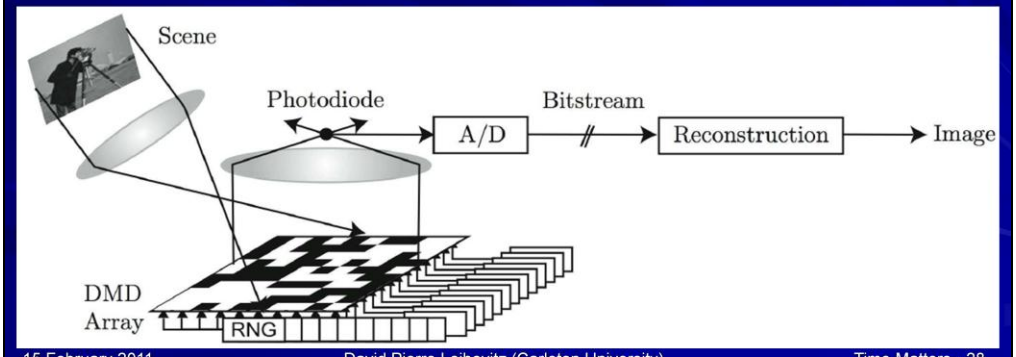
•Image from: http://www.apbworks.co.nz/ft_04.htm

•Image from: http://www.apbworks.co.nz/ft_06.htm

•Image from: http://channel.nationalgeographic.com/channel/photogallery/spiderpower/photo9.html

One Pixel Camera

- Compressive Imaging/Sensing
  - Rather than take mega-pixel images and then compress (which is extremely resource intensive), build up your image smartly
  - Like our saccadic system?
  - Compressive classification
    - What we know (possible classifications) can influence what we are looking for, i.e., look quicklyfor distinctive salient features, look more at discriminants
    - Scanning is
    - Goal directed perception
  - Single pixel can be extremely specialized (sensitive, terahertz)
- Initial designs are not adaptive (no memory).
  - Quick scans of slowly (temporal & spatial) changing areas, more detailed elsewhere



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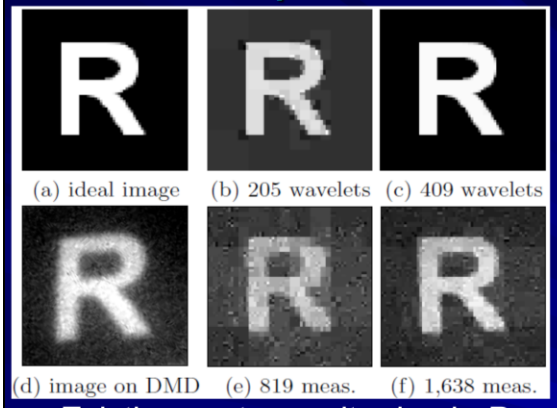
•DMD - **Digital micromirror device**

•RNG – random number generator

•References

•Davenport, M.A, et al (2007) The Smashed Filter for Compressive Classification and Target Recognition. Proc. SPIE Computational Imaging V, San Jose, California, January 2007

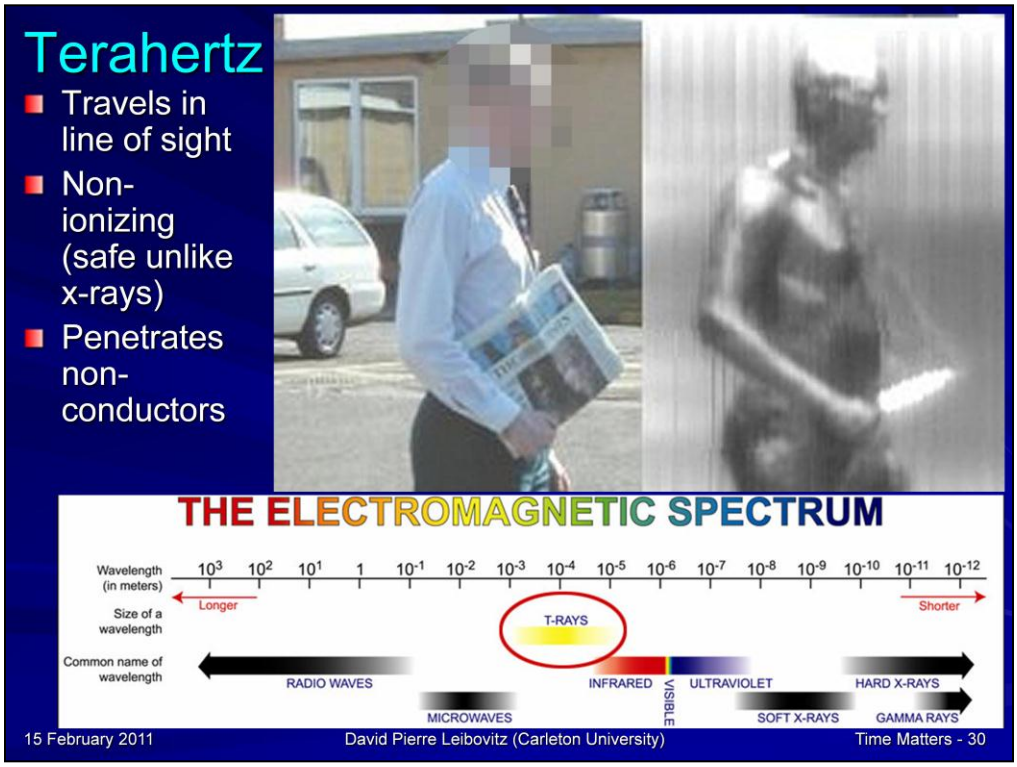
Compression vs. Integration



- Top Row
  - 64x64 bit image with various wavlet compressions (throwing data out)
- Bottom Row
  - 320x240 DMD with various random samplings

- Existing system quite dumb. Previous sample (pixel) does not direct next one.
- → Leads to cognitive/dynamic systems
- Does it take longer to reduce a mega pixel image to an internal representation than to build one up pixel by pixel?

•Waken, M.B et al (????) Compressive Imaging for Video Representation Coding

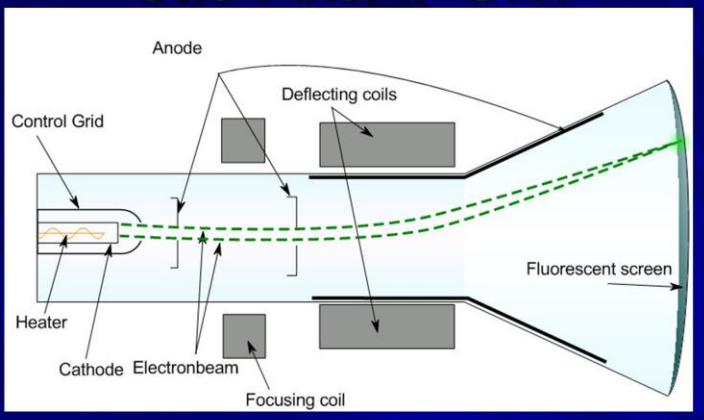


•Spectrum from: www.advancedphotonix.com

•Terrorist: http://www.compadre.org/informal/features/FeatureArchive.cfm?Type=PhysicsResearch&Skip=10

•Privacy concern about seeing “naked” bodies.

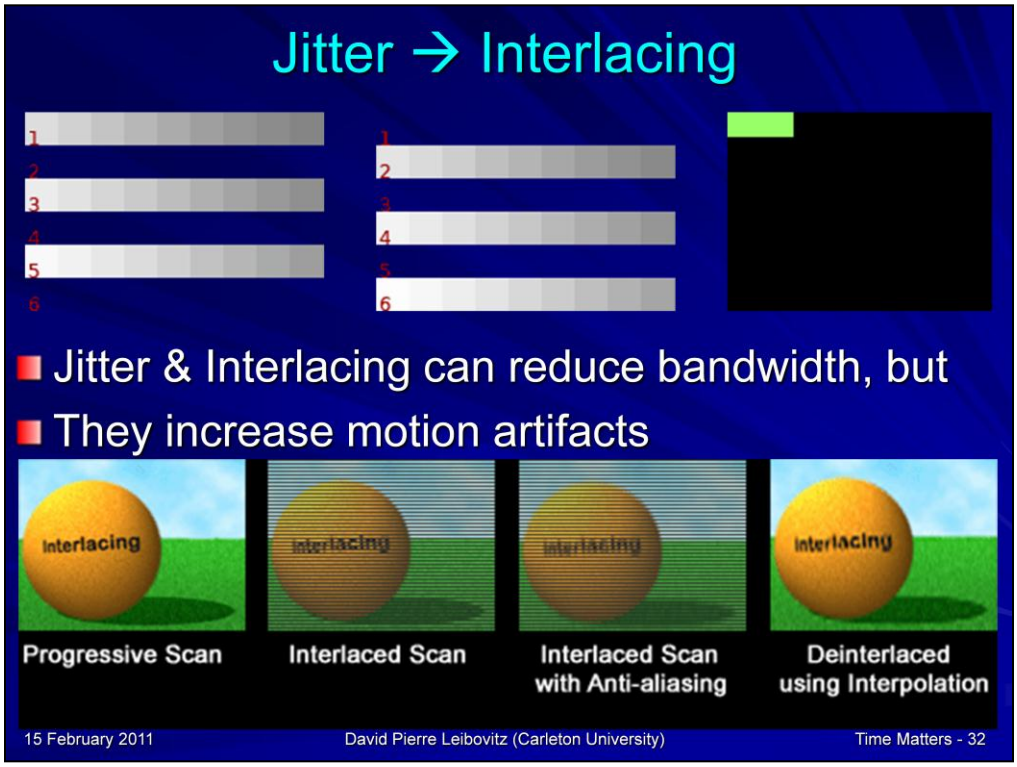
One-Pixel → CRT



- Although One-Pixel Cameras (perception) is not common (what about saccades?), what about generation (imagination)

Images

- http://en.wikipedia.org/wiki/Cathode_ray_tube



Images

- http://en.wikipedia.org/wiki/Interlacing

How do Artists Draw?

- Is it similar to how they eye-track?