Interactive System
インタラクティブシス
テム特論(2)

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Hash tag #itsys

Outline

1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 小テスト／Mini Test
6. 聴覚、聴覚インタフェース／Auditory Interface
7. 触覚、触覚インタフェース／Tactile Interface
8. 力覚、力覚インタフェース／Haptic Interface
9. 移動感覚インタフェース／Locomotion Interface
10. 小テスト／Mini Test

TODO's TOPIC

- 目の構造／Eye structure
- 目のセンサ／ Eye sensors
- 奥行き知覚／Depth perception
- 眼球運動／Eye movement

眼の構造／Eye Structure

- 角膜／Cornea: surface lens
  – LASIK: Laser in Situ Keratomileusis
- 水晶体／Lens: Internal lens.
  – Focal length is adjustable by deformation.
- 虹彩／Iris: Adjust amount of light.
- 網膜／Retina: Light sensor

カメラとの比較／Comparison with Camera

- レンズ／Lens
  Camera: 1
  Eye: 2
- 虹彩／Iris: same
- センサ／Sensor
  Camera: Film or CCD
  Eye: Retina

- Difference = Focal length adjustment(焦点調節)
  – Camera: Shift lens
 – Eye: Deform lens

網膜／Retina = Optical Sensor

•中心窩／Fovea: Center of vision. Very high spatial resolution.

• Optic nerve: Nerve from retina to brain.

  Optic nerve is in front of the retina. (transparent)

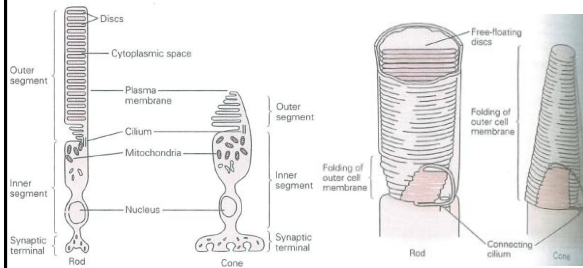•盲点／Optic disc (blind spot): Hole that optic nerve axons exit.

盲点／Blind Spot

•Close your right eye, and gaze '+' with your left eye.

•Move the paper back and force, and find '●' disappears.

•You also find the line connected.

TODAY's TOPIC
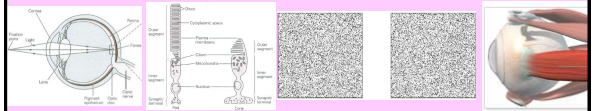
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## 網膜の視細胞／Optic cells in the retina

- Rod Cell (桿体細胞) and Cone Cell (錐体細胞)
  - Light to electric conversion is done at outer segment.
  - Channels composed of protein is opened by the light.
  - Rod cell has longer outer segment.
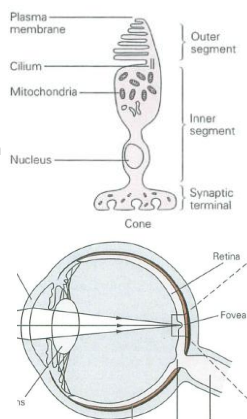
桿体細胞／Rod cell

- Black and White sensor.
- Plays major role when dark
- High sensitivity (x100 cone cell)
  - Can capture single photon
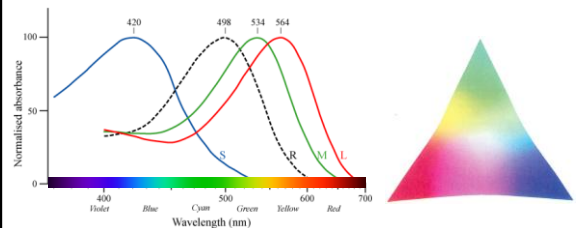- One eye has 130,000,000 cells.
- Slow response.
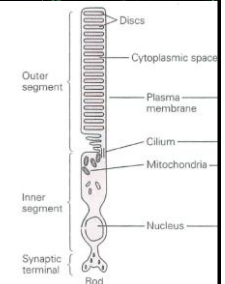
錐体細胞／Cone cell

- Color sensing
  - Three types (L,M,S)
  - Caused by different proteins in the channel.
- Play major role when bright.
- Has lower sensitivity.
- One eye has 7,000,000.
- Clustered at fovea (中心窩).
- Fast Response.

桿体細胞・錐体細胞／Rod cell & Cone cell

- Rod cell: black & white sensor. center = 498nm.
  Green Laser Pointer is the best for presentation.
- Cone cell:Three types
  S：420nm, M：534nm, L：564nm
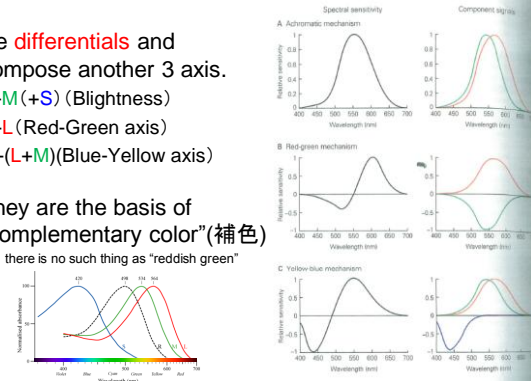 Color perception is based on the combination of the three.

色知覚メカニズム／Brain color perception ≠ R,G,B
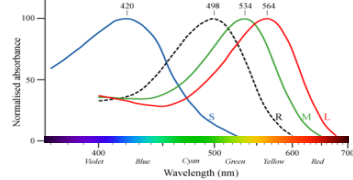
Take differentials and
  compose another 3 axis.
- L+M(+S)（Blightness）
- M-L（Red-Green axis）
- S -(L+M)(Blue-Yellow axis)

- They are the basis of
 "complementary color"(補色)
  – there is no such thing as "reddish green"

紫色とは何か？／What is purple?

- 3types of cone cells: R,G,B
  – The longest wave light = very reddish red.
  – So, why the shortest wave light is not "bluish blue", but purple?
  – And why, the purple can be composed of red+blue?

- Due to the small peak of red cell.
  – The red cell perceives very short wave as well.
    - Physical purple=shortest wavelength.
    - Composed purple=red + blue

桿体・錐体の分布／Distribution of the cells.
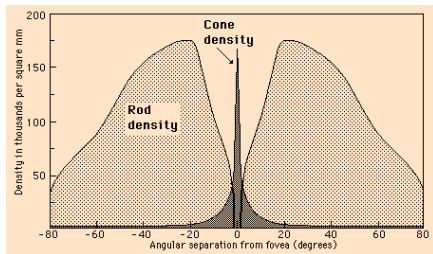
- Cone cell = central vision (中心視)
  ✓Peripheral vision is almost color blind
- Rod cell = peripheral vision (周辺視)
  ✓You can see stars better by peripheral vision

色知覚は空間解像度が低い
Color process has very low resolution

Flowers

Black & white

Color only

RGB and YCbCr(YUV)

RGB: corresponds to 3 cone cells.

Mathematics tells us...
ANY 3 independent vectors can be "basis vectors"
(orthogonality not required)

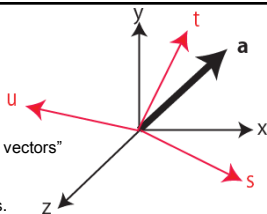RGB = One type of 3 independent vectors.
There are infinite ways.

YCbCr (YUV): Y(blightness), Cb(color axis 1), Cr(color axis 2)
Similar to brain's color perception.
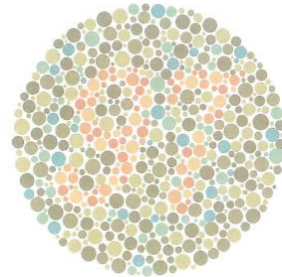
$Y = 0.257R + 0.504G + 0.098B + 16$
$Cb = -0.148R - 0.291G + 0.439B + 128$
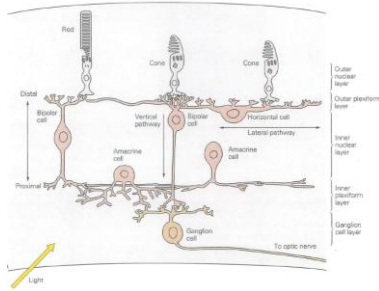$Cr = 0.439R - 0.368G - 0.071B + 128$
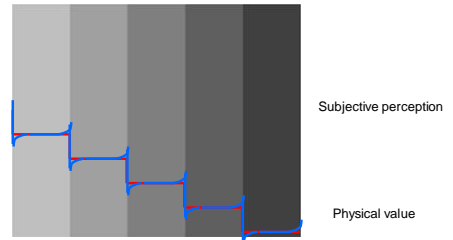
Used in JPEG image compression

色盲／Color blindness

- One to three types of cone cells lacks.
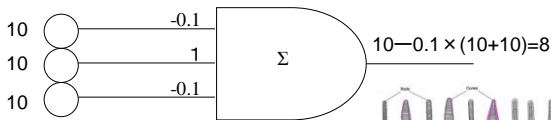
網膜での情報処理／Retinal image processing

- Sensors: About 200,000,000 / eye
- Nerve axons to the brain: about 1,000,000 / eye
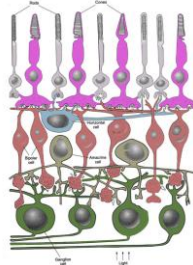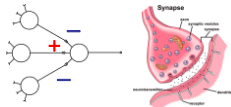- Retinal image process: 200 cells⇒1 output
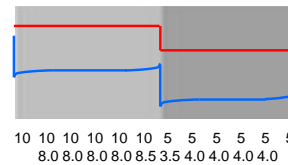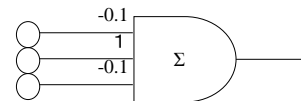
Key to the retinal process: "Mach belt" illusion

Subjective perception

Physical value

側抑制／Lateral inhibition（1/3）

$$10 - 0.1 \times (10+10) = 8$$

- Synaptic calculation
- Central input: +(plus)
- Surrouinding input: -(minus)

側抑制／ Lateral inhibition （2/3）

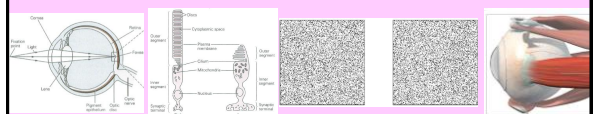10 10 10 10 10 10 5 5 5 5 5 5
8.0 8.0 8.0 8.0 8.5 3.5 4.0 4.0 4.0 4.0

側抑制／ Lateral inhibition(3/3)：
Harman grid illusion
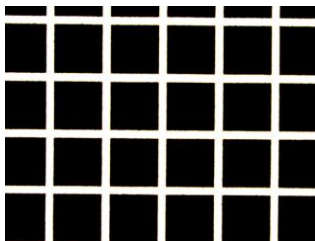
(1) 周辺視／peripheral vision: the cross point
becomes dark, due to lateral inhibition
（2）中心視／central vision: No such effect
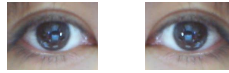⇒The peripheral vision "compress" larger field.

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- 奥行き知覚／Depth perception
- 眼球運動／Eye movement

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奥行き知覚の鍵／Depth perception cues

- 単眼性／With single eye
  - 経験／Experience
  - 焦点調節／Accommodation
  - 運動視差／Motion Parallax

- 両眼性／With two eyes
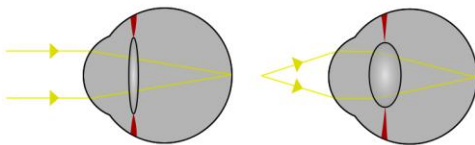 - 輻輳角／Vergence eye movement
 - 両眼視差／Binocular disparity

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Depth cue(1) 経験／Experience

- 重なり（遮蔽）／Occlusion
  - Occluded (shielded) objects are more distant than occluding (shielding) objects.
- 遠近法／Perspective
  - Near= Large, Bottom, Clear
  - Far = Small, Top, Blur
- 記憶／Memory
  - Knows the physical size

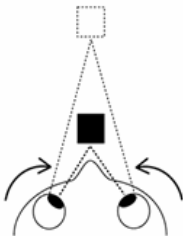## Depth cue(2) 焦点調節／Accommodation: Changing the power of the lens

- Automatic focus adjustment by lens deformation
- The adjustment itself works as depth cue.
  - works at close range.

Depth cue(3) 運動視差／Motion Parallax
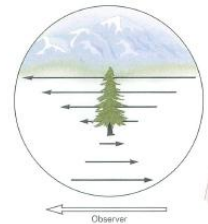
- When the head moves...
  - Near: Moves in the opposite direction.
  - Far: Does not move, or moves in the same direction.

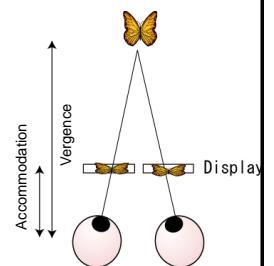## Depth cue(4)輻輳／Vergence eye movement

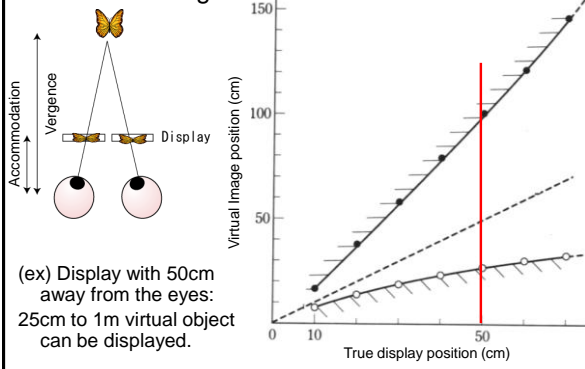- The eyes converge (move inward) and diverge (move outward) by distance.

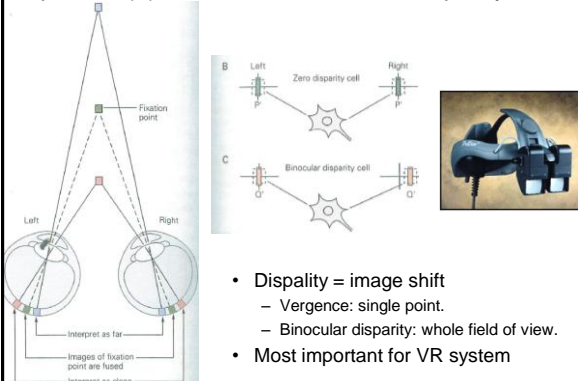## 輻輳 - 調節矛盾の問題
Vergence-accomodation conflicts

- Accommodation & vergence are slightly coupled.

- Stereo display problem:
  - Accomodation=constant
  - Vergence = variable
  ⇒Severe Fatigue

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輻輳‐調節矛盾の許容範囲
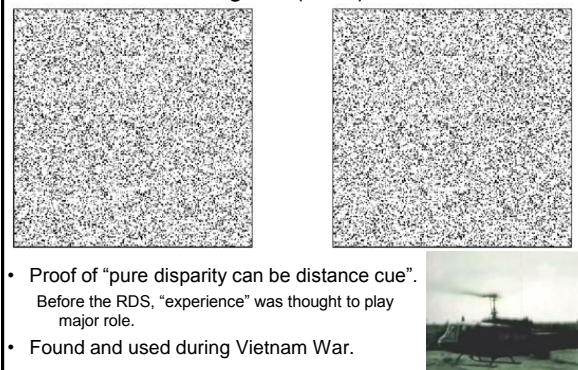## Tolerance of vergence-accomodation conflicts

Accommodation
Vergence
Display

Virtual Image position (cm)

True display position (cm)

(ex) Display with 50cm away from the eyes:
25cm to 1m virtual object can be displayed.

Depth cue(5) 両眼視差／Binocular disparity

- Dispality = image shift
  - Vergence: single point.
  - Binocular disparity: whole field of view.
- Most important for VR system

Stereogram

ランダムドット・ステレオグラム
Random dot stereogram (RDS)

- Proof of "pure disparity can be distance cue".
  Before the RDS, "experience" was thought to play major role.
- Found and used during Vietnam War.

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Eye movement

Eye muscle

- 6 muscles (3 pairs) rotate eyes.
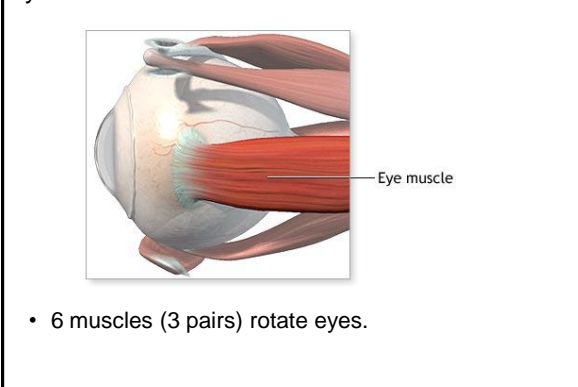
Eye movement: 入力手段として／As an Interface

先を読む頭脳
羽生善治
伊藤毅志
松原 仁

新潮社

初級者の視線の動き

中級者の視線の動き

羽生さんの視線の動き

Measurement of Eye movement (review)

① サーチコイル法／Search Coil
② 眼底電位／Electrooculography, EOG
③ 強膜反射／Limbus Tracking Method
④ 画像処理／Computer Vision
⑤ 角膜反射／Reflection at Horny Coat

コイル2　コイル2　コイル1
コイル1
コイル2の電界効果域
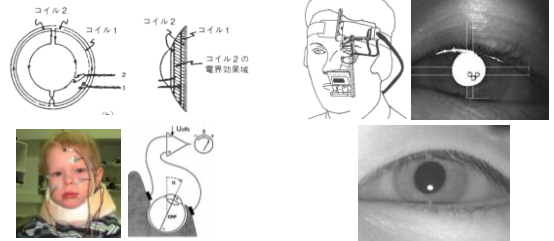
## 眼球運動の種類／Eye movements

- スムーズパースート（滑動性眼球運動）／Smooth Persuit
  - Follow slow movement of small dots. Voluntary (conscious)

- サッケード（跳躍性眼球運動）／Saccade
  - Stepwise movement
  - Motion start is voluntary and involuntary.
  - During motion,
    - You cannot stop (involuntary)
    - Visual acuity drops.

- 固視微動／Miniature eye movement
  - Very small vibration. 30～100Hz.
  - Reflesh the image on the retina.
    - Anesthetisation of muscles⇒No visual image.

（対象物の動き）
（眼球運動）
0
時間(sec)

（対象物の動き）
随従運動
跳躍運動
（眼球運動）
0
時間(sec)
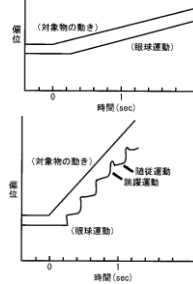
安定化のための反射としての眼球運動
Eye movement for stabilization

- 前庭動眼反射／Vestibulo-ocular reflex(VOR)
  - Cancel head rotation.
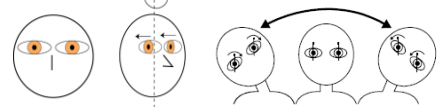
- 視運動性眼球運動／Optokinetic Response(OKR)
  - When the whole visual field moves, the eye follows.

Railroad ties

TODAY's SUMMARY

- 眼の構造／Eye structure
  - conea, retina, fovia, blind spot
- 眼のセンサ／Eye sensors
  - rod cell, cone cell, color vision
  - peripheral & central vision
  - image processing
- 奥行き知覚／Depth perception
  - accommodation, vergence
  - binocular disparity
- 眼球運動／Eye movement
  - smooth persuit, saccade,
  - VOR, OKR