# 健康数据可视化

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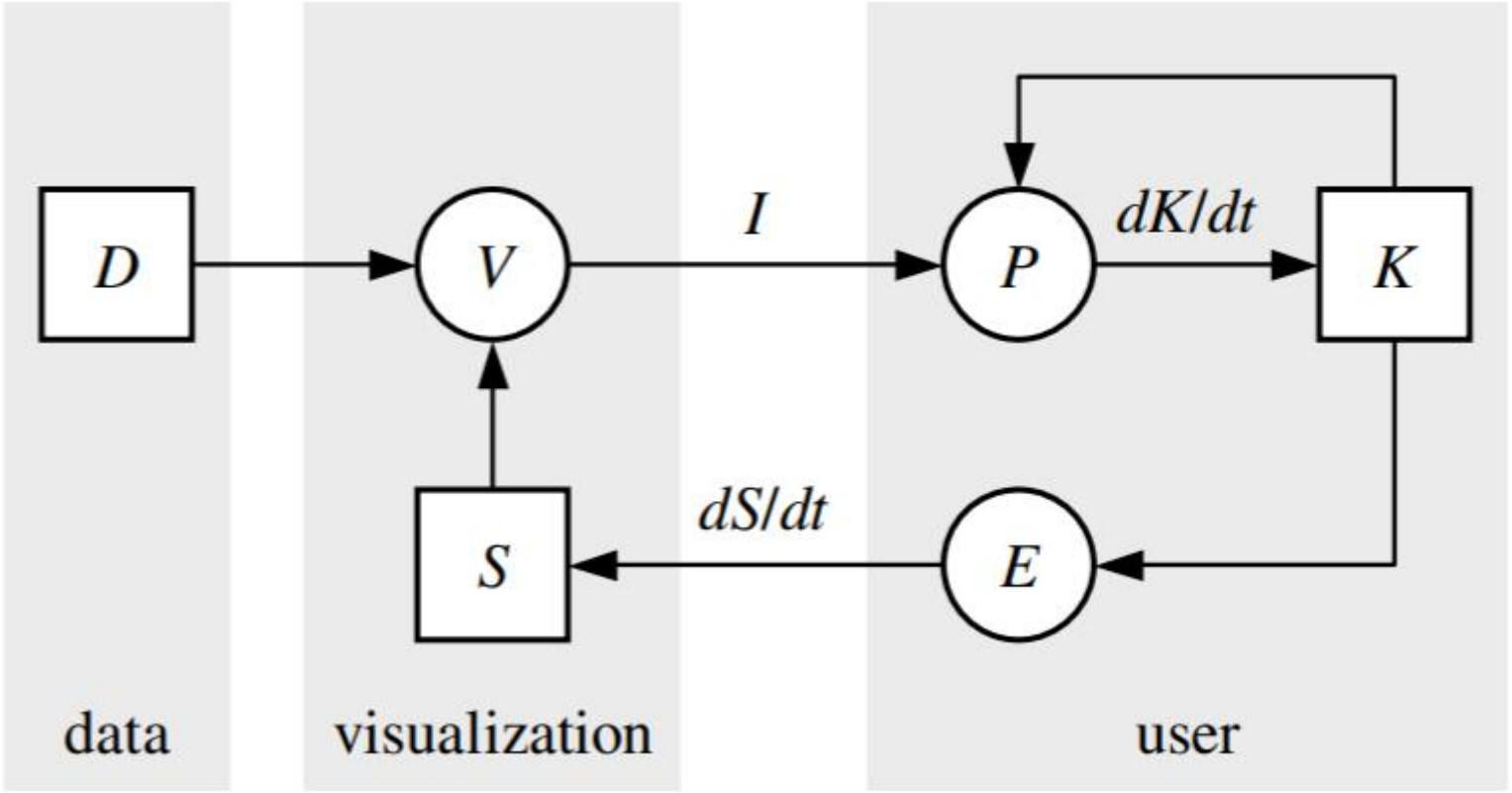
# 2.从数据到（可视化）图形

# 可视化流水线

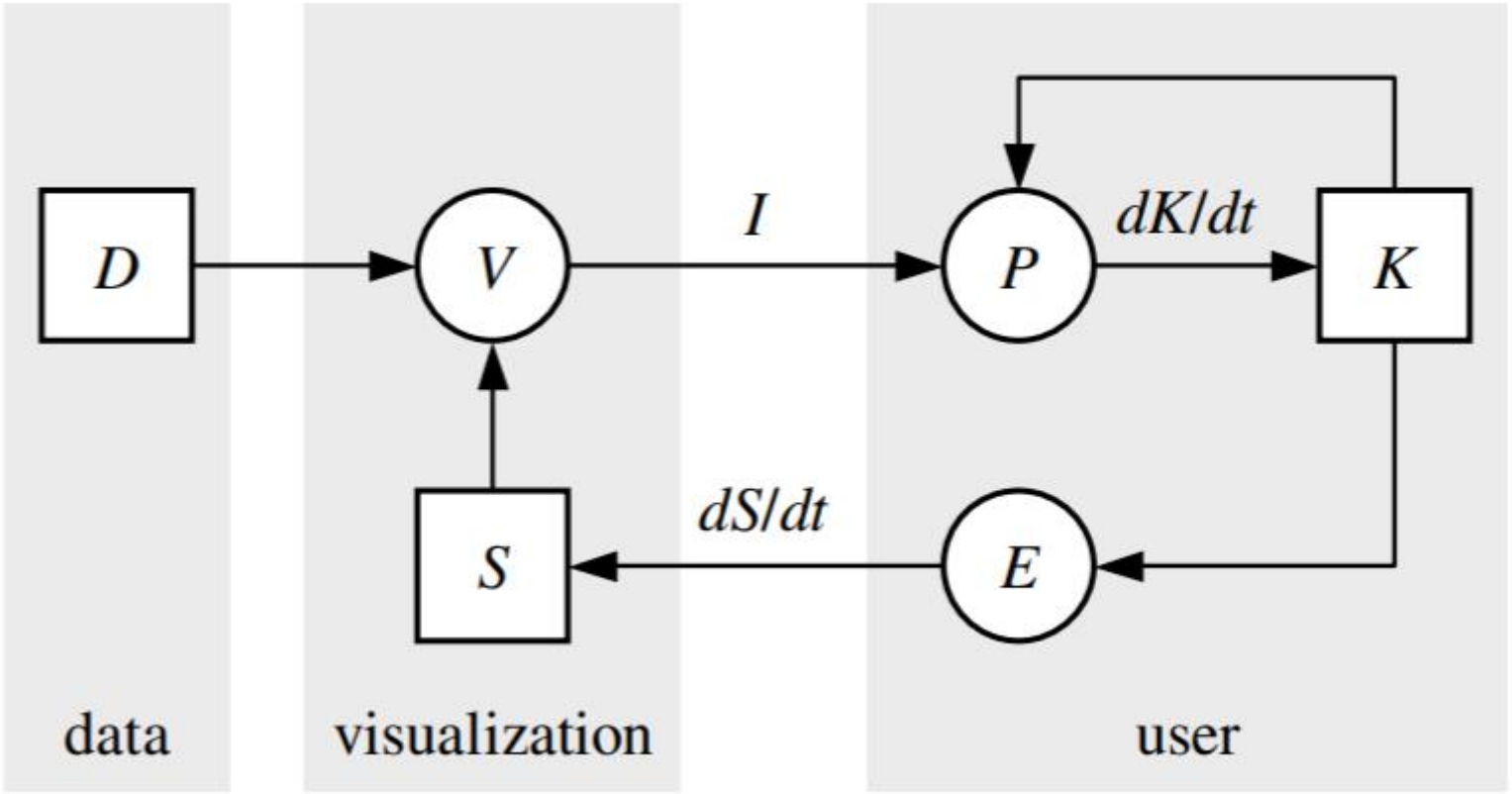
- 如何从数据产生可视化?




$$I(t) = V(D,S,t) \qquad \frac{dK}{dt} = P(I,K) \qquad K(t) = K_0 + \int_0^t P(I,K,t)\,dt$$

[Jarke van Wijk. The Value of Visualization. Proceedings of the IEEE Visualization Conference, pp. 79-86, 2005.]

# 可视化流水线




$$\frac{dS}{dt} = E(K) \qquad S(t) = S_0 + \int_0^t E(K)\,dt$$

[Jarke van Wijk. The Value of Visualization. Proceedings of the IEEE Visualization Conference, pp. 79-86, 2005.]

# 可视化+感知流水线


可视化流水线

视觉感知流水线

# 结构数据与非结构数据

- 结构数据 Structured data
  - 已知数据类型，语义
- 非结构数据 Unstructured data
  - 没有预先定义好的数据模型
  - 通过文字描述
  - 为丰富描述，可能还有图像、录像
- 非结构数据转换成结构数据
  - 自然语言处理：文字→结构数据从视频提取物体，转换成坐标
- 结构和非结构数据举例？

# 结构或非结构数据?

- 眼动跟踪数据

**Video stimulus:** With the exception of stimulus 7 (Kite), all videos were captured with a Panasonic HDC-SD5 camcorder. Stimulus 7 was captured with an Apple iPhone 4S at 30 frames per second (fps) since the camcorder was not available at this point in time. The other videos were recorded at 25 fps and with a tripod for stabilization. Except for stimulus 3 (Dialog), the audio track was removed from the videos since it was negligible for the tasks. Stimulus 3 has a stereo MP3-coded audio track at 128 kBit/s. All videos were converted to Xvid-coded AVI files with a frame rate of 25 fps and a maximum data rate of 12MBit/s. The videos have a resolution of 1920x1080 pixels and were displayed centered on the screen with their native resolution. These technical parameters were chosen to ensure the compatibility with the eye tracking software.

**Eye tracking data:** The data was recorded with a Tobii T60 XL eye tracker, with a sampling rate of 60Hz and a 24" screen with a resolution of 1920x1200 pixels. We provide the complete data from the recordings (except for the absolute timestamps due to privacy) in separated TSV files, exported from the Tobii software. The data files include raw gaze data with timestamps and coordinates, as well as fixation indices extracted by the Tobii fixation filter with standard settings (velocity threshold = 35 pixels/samples; distance threshold = 35 pixels). We recommend using the raw gaze data for best accuracy and reliability of the data; this is especially true for videos with smooth pursuit because this type of eye movement is not supported by the fixation filter. A complete description of the extracted file format is available in the Tobii T60 XL manual.

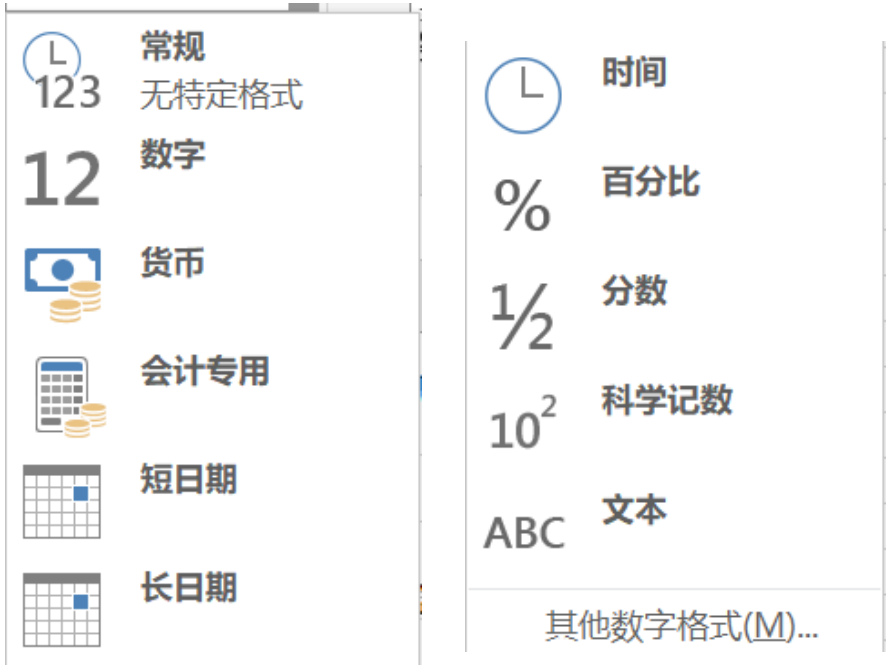
**Dynamic AOIs:** To support the application of advanced analysis methods based on AOIs, we included sets of manually annotated, dynamic AOIs for every video in the dataset. With this additional information, various AOI-based eye tracking metrics can be applied to the data. AOIs are annotated by dynamic and axis-aligned bounding boxes. We provide the data in an XML format that is compatible to the well documented ViPER file format. Hence, an import to other visualization or analysis systems can be performed by simple XML parsing.

## Benchmark Data

| ID | Images | Stimulus | Setting | Task | Induced Patterns |
|---|---|---|---|---|---|
| S1 |  | Car Pursuit | Panning camera follows a red car while it was going through a roundabout. | Follow the red car. | Potential smooth pursuit with long time spans of attentional synchrony on the red car. |
| S2 |  | Turning Car | Camera follows turning car. The movement of the car describes the shape of an eight. | Recognize the shape that is described by the movement of the car. | Attentional synchrony on the car with potential smooth pursuit eye movement. |
| S3 |  | Dialog | Two persons talk to each other in front of the camera. | Follow the dialog attentively. | Switching focus between the faces of both persons. Label on |

# 数据抽象与分类

- 如何描述数据（Data）的数值类型?
- 如何描述数据集（Dataset）的类型?
- 同样的数字在不同数值类型中的含义?




图片授权：creative commons

# 如何对数据的值进行分类？

- **定性数据（Qualitative）：**表示事物性质、规定事物类别的文字表述型数据，不能将其量化，只能将其定性。

- **定量数据（Quantitative）：**其特征在于它们都是以数值的形式出现的，有些数值型数据只可以计算数据之间的绝对差，而有些数值型数据不仅可以计算数据之间的绝对差，还可以计算数据之间的相对差。

作者：SPSSAU
链接：
https://www.zhihu.com/question/377458608/answer/2025393594
来源：知乎

# 数据的值分类

- 定类数据（名义数据）nominal
- 定序数据 ordinal
- 定距数据 interval
- 定比数据 ratio

# 数据的值分类

- **定类数据 nominal**：名义级数据，数据的最低级，表示个体在属性上的特征或类别上的不同变量，仅仅是一种标志，没有序次关系。例如，“性别”，“女”编码为1，“男”编码为2。

作者：SPSSAU
链接：
https://www.zhihu.com/question/377458608/answer/2025393594
来源：知乎


1 2 3 4 5

# 数据的值分类

- **定序数据 ordinal:** 数据的中间级，用数字表示个体在某个有序状态中所处的位置，不能做四则运算。例如，Likert scale，1=很不赞同，2=不太赞同，3=中立，4=比较赞同，5=很赞同。

作者：SPSSAU
链接：
https://www.zhihu.com/question/377458608/answer/2025393594
来源：知乎

2　　1　　3

# 数据的值分类

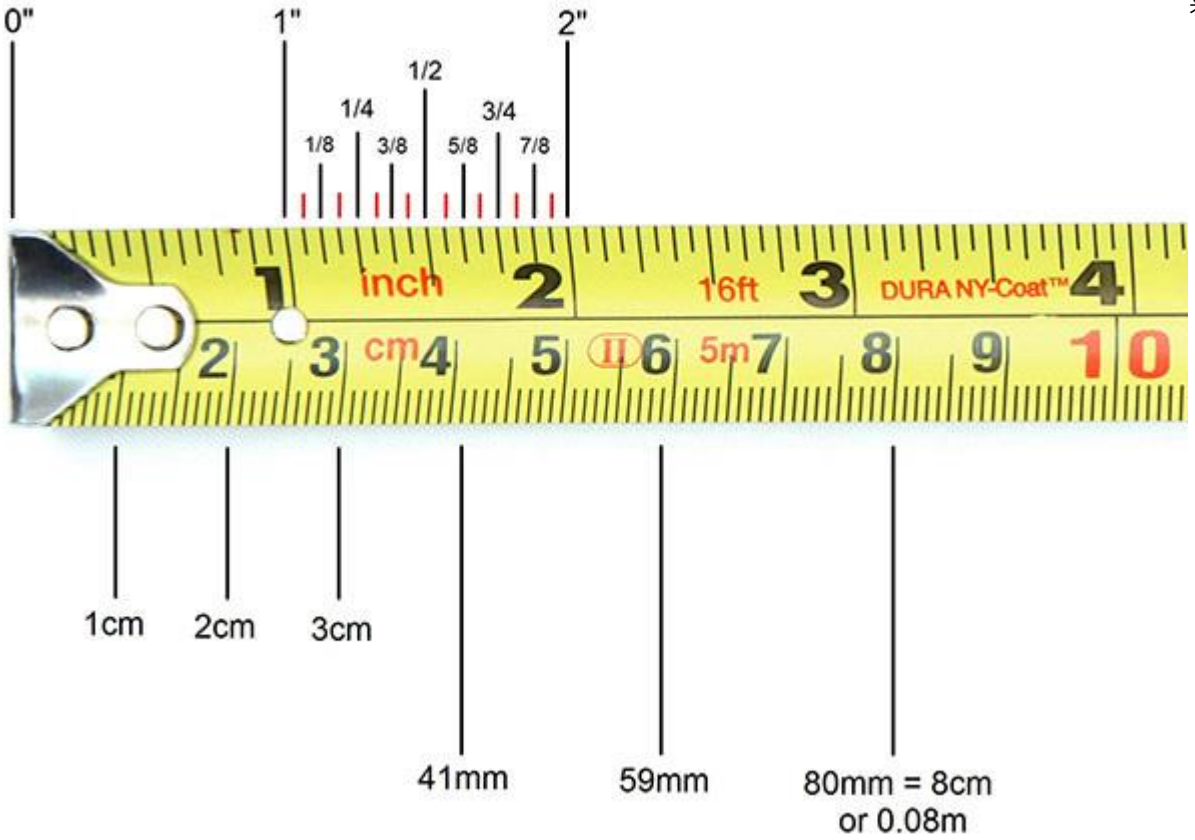
- **定距数据 interval：**具有间距特征的变量，有单位，**没有绝对零点**，可以做加减运算，不能做乘除运算。例如，温度。
- 温度为0代表什么？摄氏温度，华氏温度
- 还有哪些定距数据？

作者：SPSSAU
链接：
https://www.zhihu.com/question/377458608/answer/2025393594
来源：知乎

# 数据的值分类

- **定比数据 ratio:** 数据的最高级，既有测量单位，也有绝对零点，增加一个确定的基准值或标准，能够进行比对。例如速度，长度，身高。

作者：SPSSAU
链接：
https://www.zhihu.com/question/377458608/answer/2025393594
来源：知乎



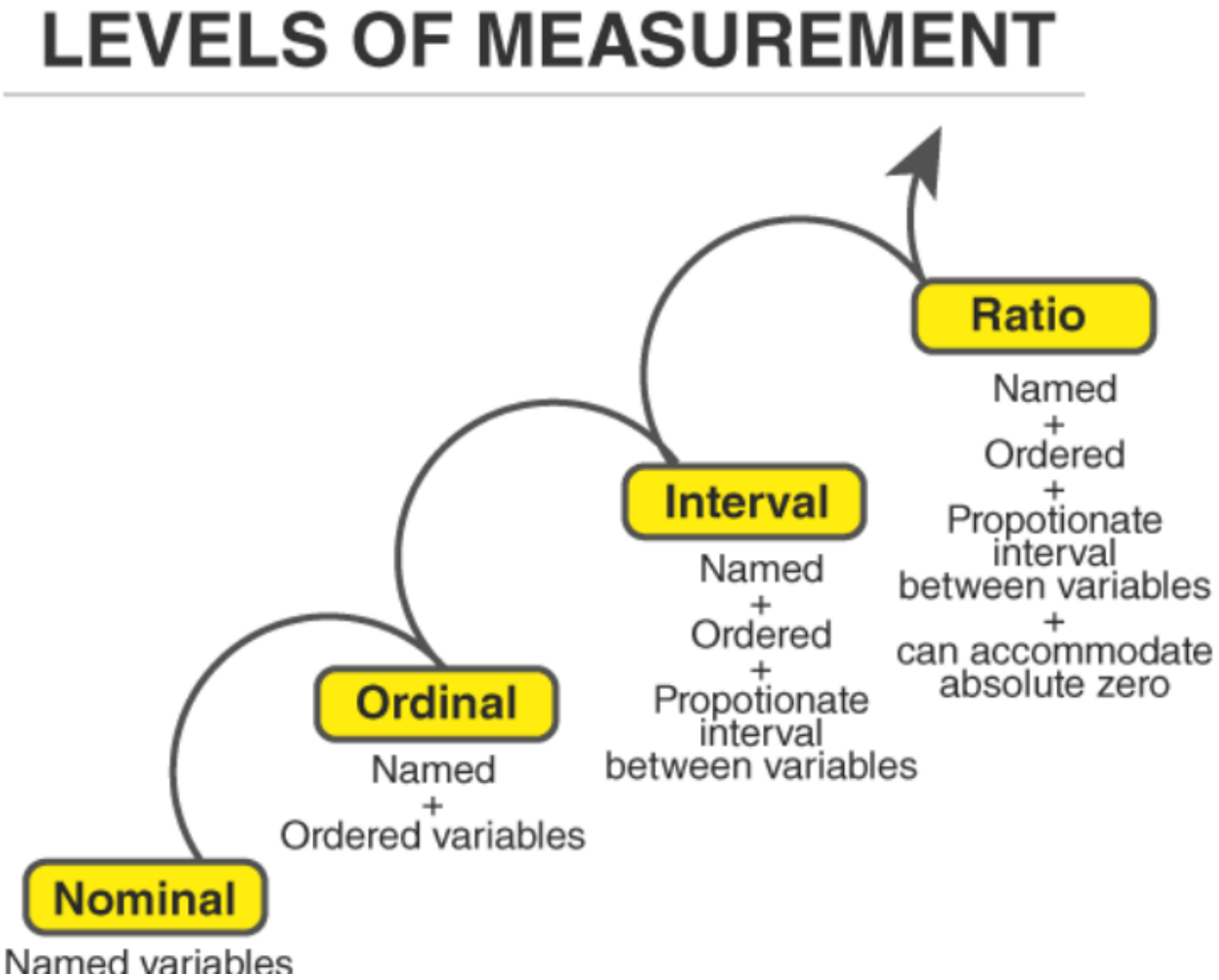

许可证: creative commons

# 不同类别数据的值上可进行的运算

- 定类数据 Nominal (categories, labels)
  - 运算: =, ≠
- 定序数据 Ordinal (ordered)
  - 运算: =, ≠, >, <
- 定距数据 Interval (location of zero arbitrary)
  - 运算: =, ≠, >, <, +, - (距离)
- 定比数据 Ratio (fixed zero)
  - 运算: =, ≠, >, <, +, −, ×, ÷ (比例)

[Stevens SS. On the Theory of Scales of Measurement. Science. 1946 Jun 7;103(2684):677-80. doi: 10.1126/science.103.2684.677]

# 数据的值分类总结

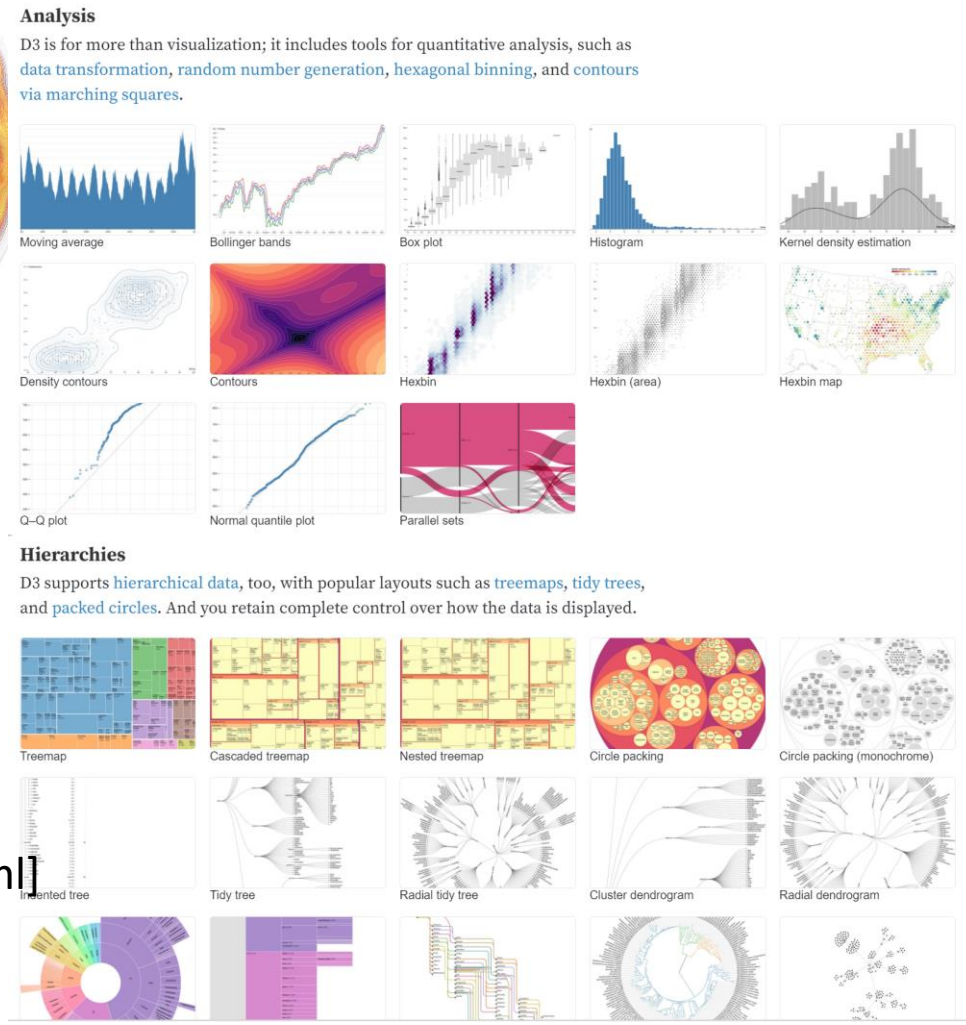



https://byjus.com/maths/scales-of-measurement/

# 数据集的分类 Type of datasets

- 科学可视化的数据集
  - 标量场
  - 向量场
  - 张量场
- 信息可视化的数据集
  - 表格
  - 集合
  - 关系
  - 地理位置

[https://www.sci.utah.edu/sci-media.html]




[https://d3js.org]

# 表格数据

- 每行是一项（item）
- 每列是一个属性（attribute）
- 每行有独特的键（key）
- 每行应是独特的

Attributes

Keys　　Values

| ID | Name | Age | Shirt Size | Favorite Fruit |
|---|---|---|---|---|
| 1 | Amy | 8 | S | Apple |
| 2 | Basil | 7 | S | Pear |
| 3 | Clara | 9 | M | Durian |
| 4 | Desmond | 13 | L | Elderberry |
| 5 | Ernest | 12 | L | Peach |
| 6 | Fanny | 10 | S | Lychee |
| 7 | George | 9 | M | Orange |
| 8 | Hector | 8 | L | Loquat |
| 9 | Ida | 10 | M | Pear |
| 10 | Amy | 12 | M | Orange |

Item

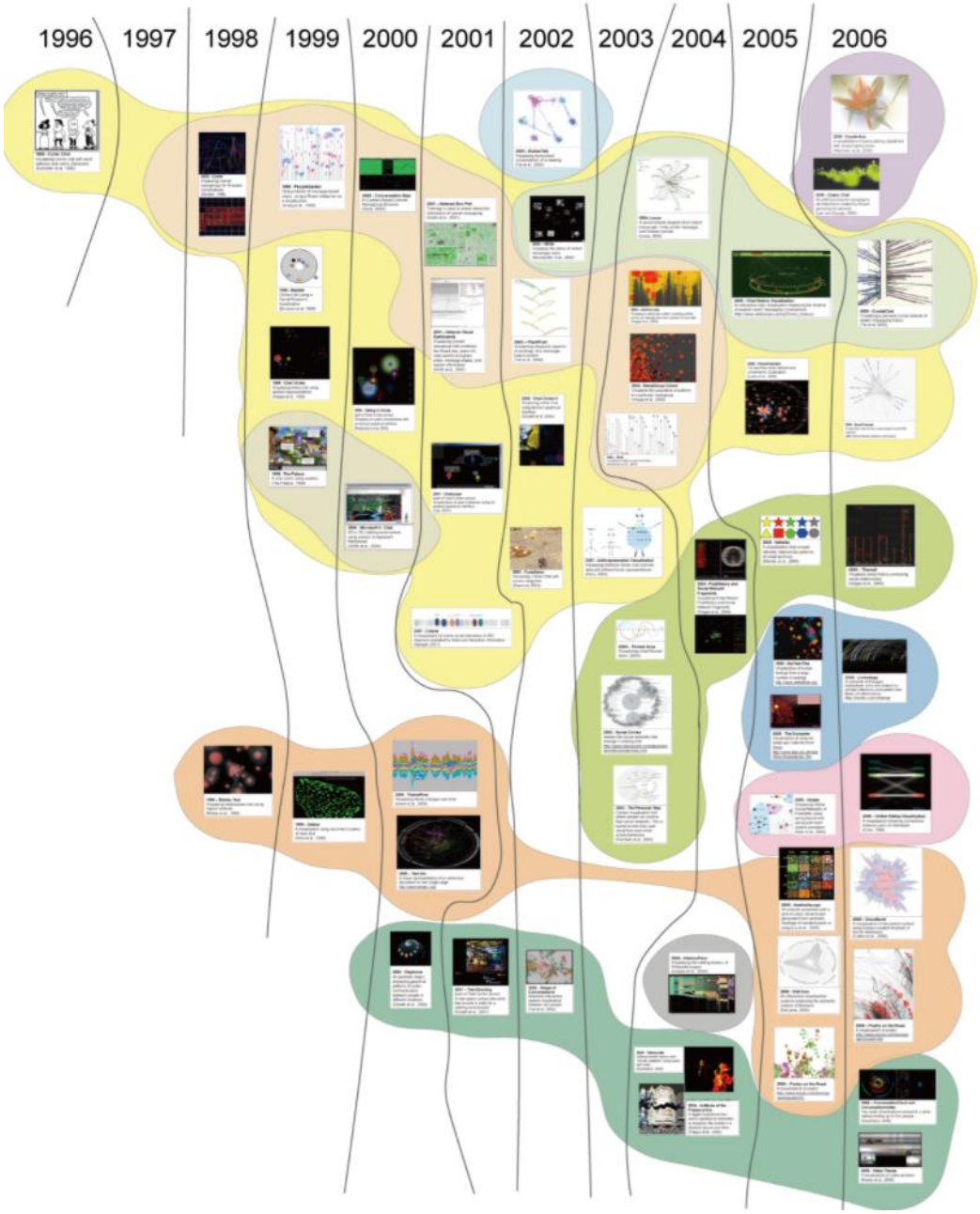
[https://www.dataviscourse.net/2020]

# 表格数据

- 多维表格
  - 需要通过多个键进行索引的表格
  - 往往由多个表格构成
  - 例如，多个患者的体检表格数据
- 非多维表格和多维数据是什么关系？

# 集合数据

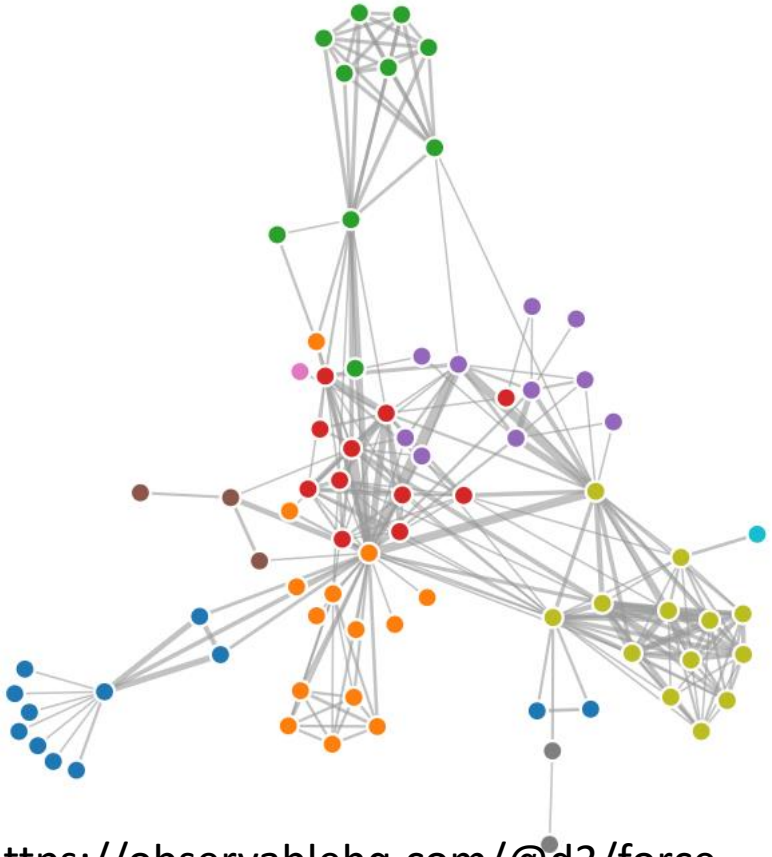
- 集合（sets）
  - 独特元素
  - 无序
- 列表（lists）
  - 可有重复元素
  - 有序
- 聚类（clusters）
  - 相似的元素




[F2-Bubbles: Faithful Bubble Set Construction and Flexible Editing]

# 关系数据

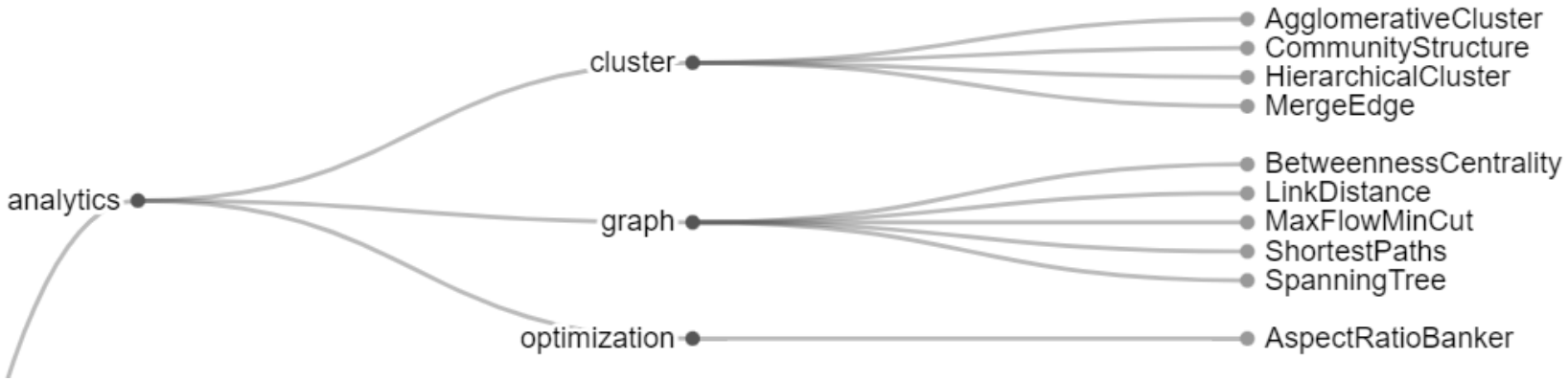
- 图（graph）和网络（network）
- 通过节点（node）和边（edge）表示
- 有向图（directed graph），无向图（undirected graph）
- 例如，社交网络，文章之间引用网络，转账网络



https://observablehq.com/@d3/force-directed-graph

# 关系数据

- 树
  - 没有环的图
  - 表示层次：根节点→叶节点；双亲节点→子节点
- 一个单位的组织结构，软件项目的类继承结构

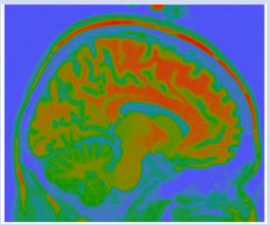
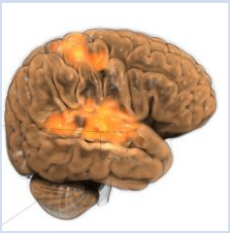
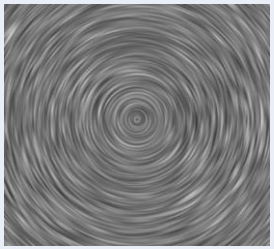
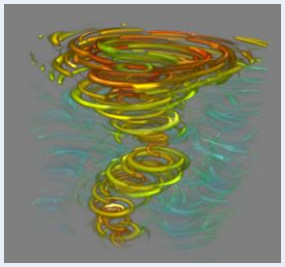
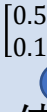
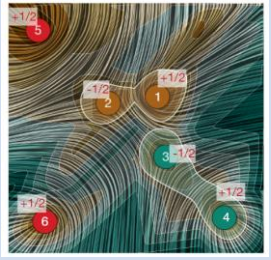
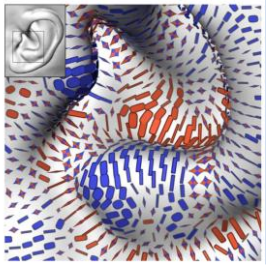



https://observablehq.com/@d3/tidy-tree

# 场数据 Field Data

- 在空间中是连续的
- 数据存储再采样(sampling)得来的单元格里，通过插值(interpolation)重建成连续数据

定义域 domain

| 值域 range ＼ $\mathbb{R}^d$ | $d=2$  | $d=3$  |
|---|---|---|
| $\mathbb{R}$<br>标量 scalar<br>空间上任意一点的值是一个标量<br>0.5  |  |  <br>[D. Jönsson and A. Ynnerman (2017), Correlated Photon Mapping for Interactive Global Illumination of Time-Varying Volumetric Data. doi:10.1109/TVCG.2016.2598430.] |
| $\mathbb{R}^m, m=2,3$<br>向量 vector<br>空间上任意一点的值是一个向量<br>[0.5, 0.5]  |  <br>[Source: D. Weiskopf] |  <br>[M. Falk, D. Weiskopf (2008): Output-Sensitive 3D Line Integral Convolution, doi:10.1109/TVCG.2008.25] |
| $\mathbb{R}^{m\times b}$<br>张量 tensor<br>空间上任意一点的值是一个矩阵<br>$\begin{bmatrix}0.5 & 0.1\\ 0.1 & 0.2\end{bmatrix}$  |  <br>[J. Jankowai et al. (2019), Robust Extraction and Simplification of 2D Symmetric Tensor Field Topology. doi:10.1111/cgf.13693] |  <br>[T. Schultz and G. L. Kindlmann (2010), "Superquadric Glyphs for Symmetric Second-Order Tensors," doi: 10.1109/TVCG.2010.199.] |

# 场数据的网格类型

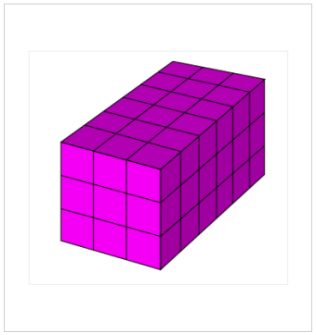
A **Cartesian grid** is a special case where the elements are unit squares or unit cubes, and the vertices are points on the integer lattice.

A **rectilinear grid** is a tessellation by rectangles or rectangular cuboids (also known as rectangular parallelepipeds) that are not, in general, all congruent to each other. The cells may still be indexed by integers as above, but the mapping from indexes to vertex coordinates is less uniform than in a regular grid. An example of a rectilinear grid that is not regular appears on logarithmic scale graph paper.

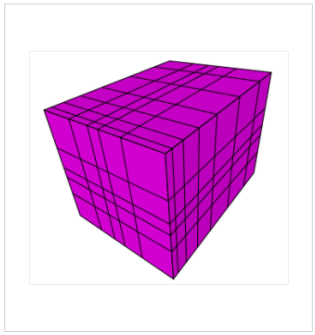
A **skewed grid** is a tessellation of parallelograms or parallelepipeds. (If the unit lengths are all equal, it is a tessellation of rhombi or rhombohedra.)

A **curvilinear grid** or **structured grid** is a grid with the same combinatorial structure as a regular grid, in which the cells are quadrilaterals or [general] cuboids, rather than rectangles or rectangular cuboids.

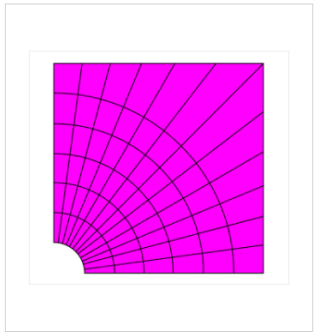
**Examples of various grids**



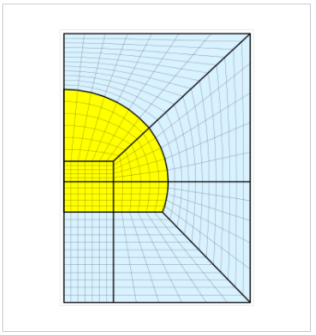
3-D Cartesian grid



3-D rectilinear grid



2-D curvilinear grid



Non-curvilinear combination of different 2-D curvilinear grids

[https://en.wikipedia.org/wiki/Regular_grid]

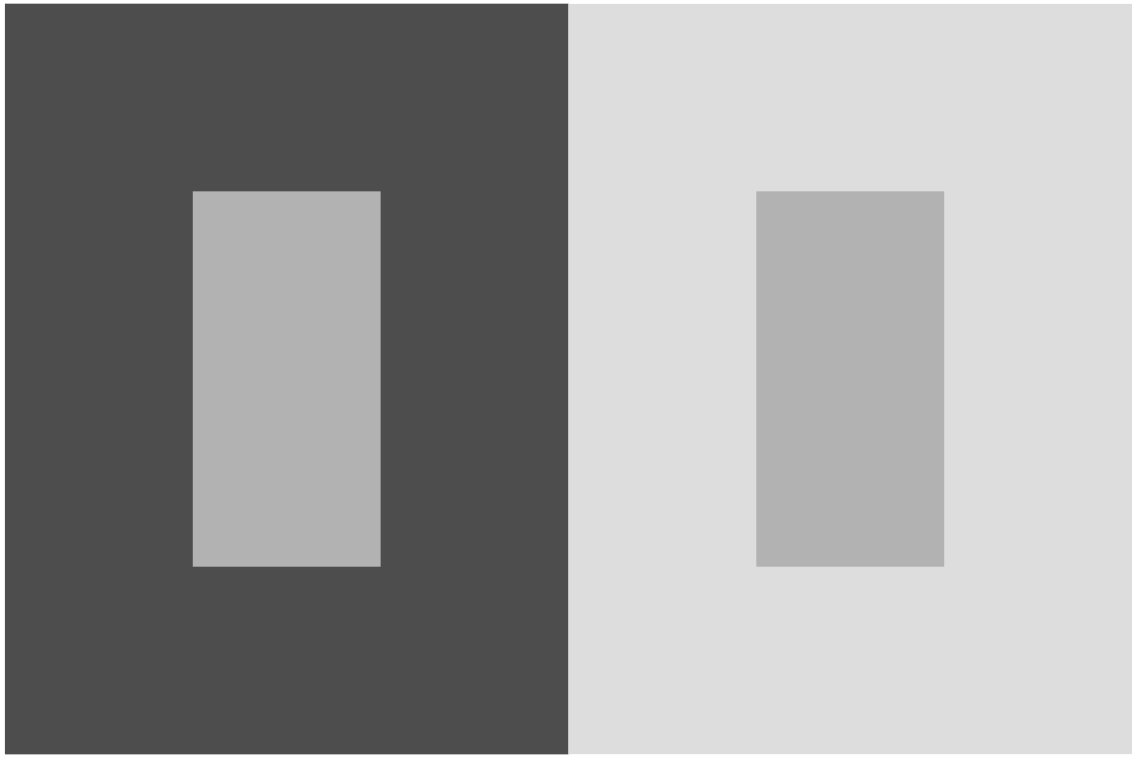
# 视觉感知


可视化流水线

视觉感知流水线

# 先来做几个小测验-1

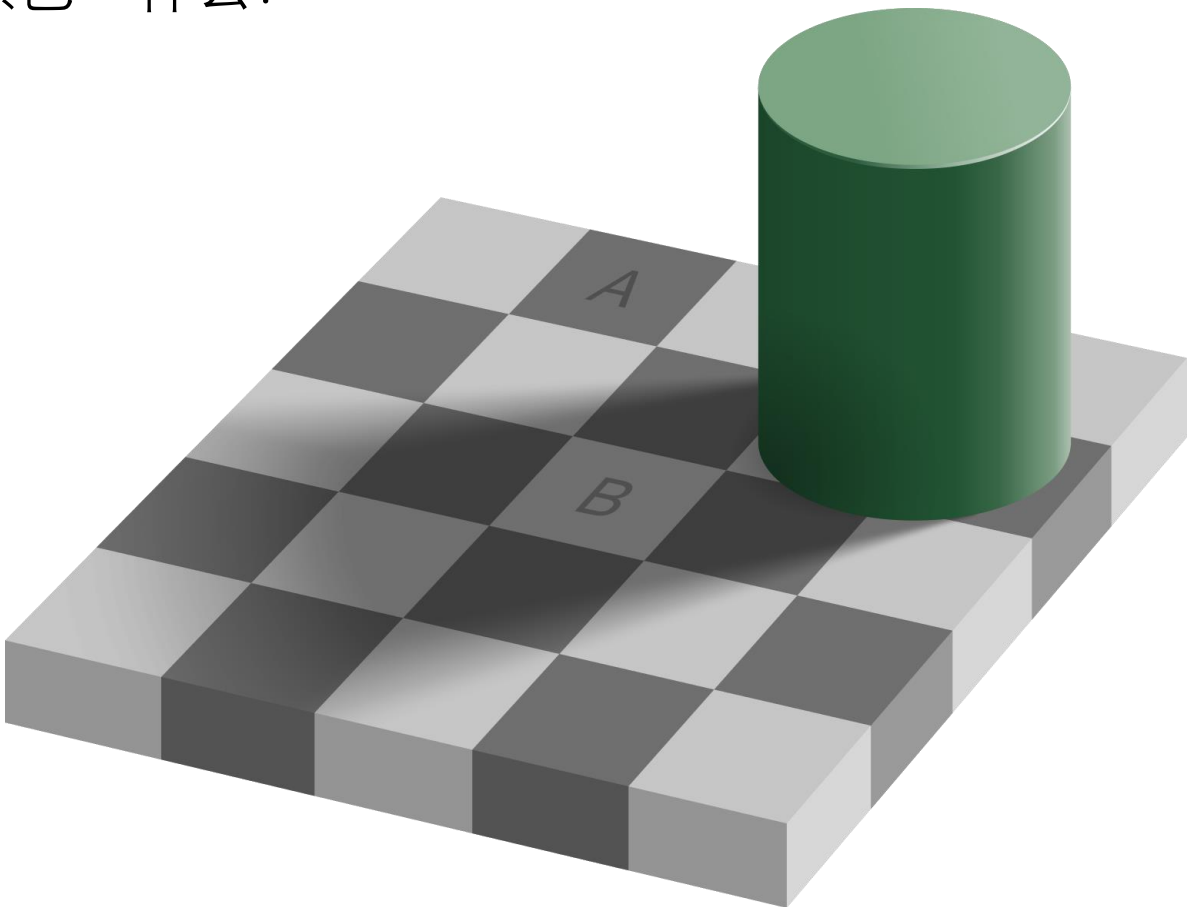
- 两个小灰色矩形的颜色一样么?



Public Domain, https://commons.wikimedia.org/w/index.php?curid=4338395

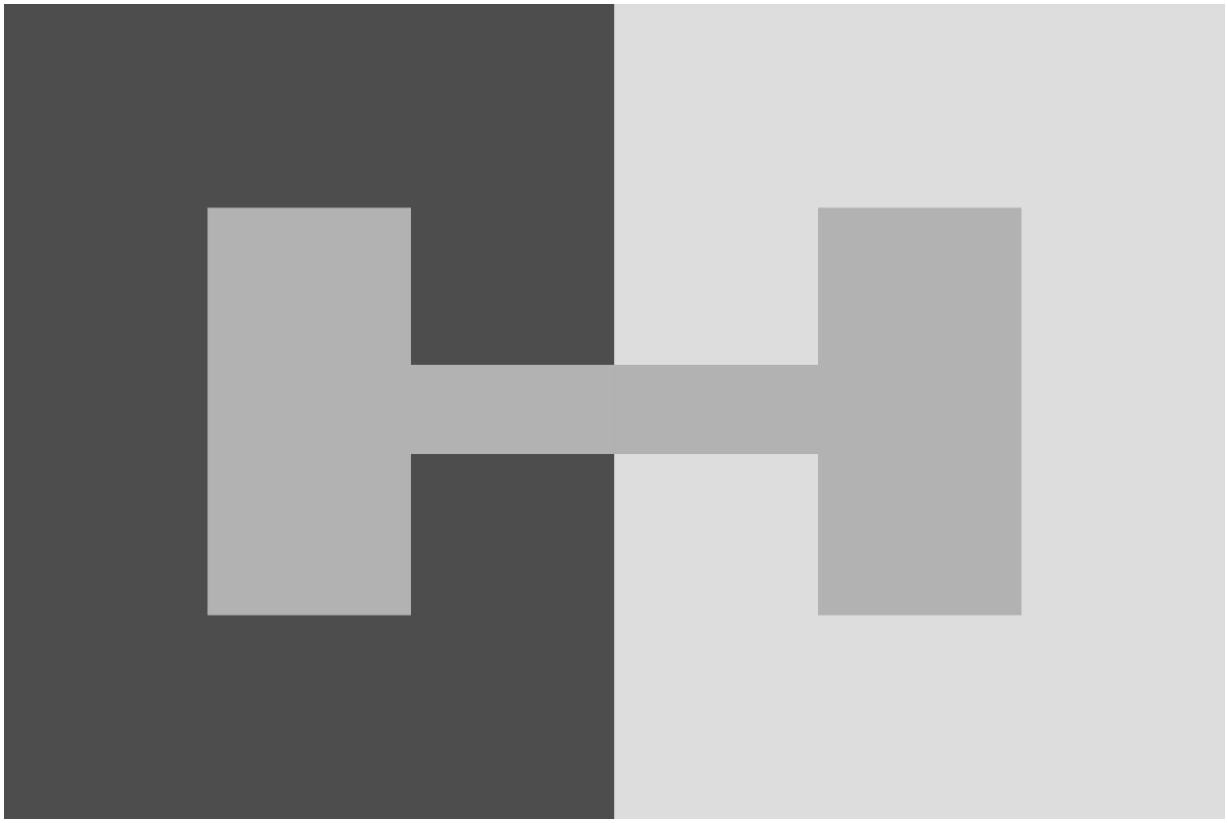
# 先来做几个小测验-2

- A，B两个方格的颜色一样么？

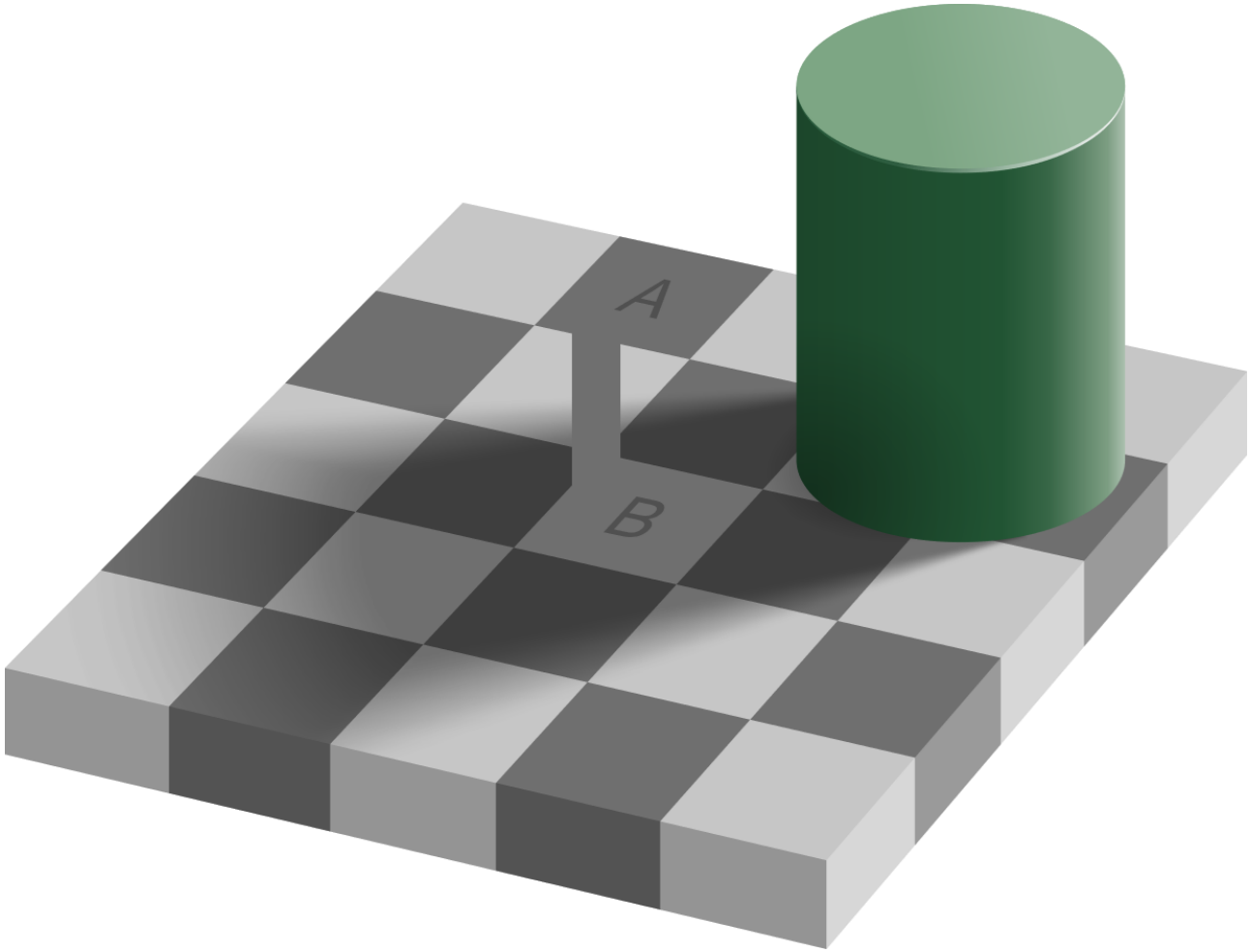



By Original: Edward H. Adelson, vectorized by Pbroks13. - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=75000950

# 答案揭晓！



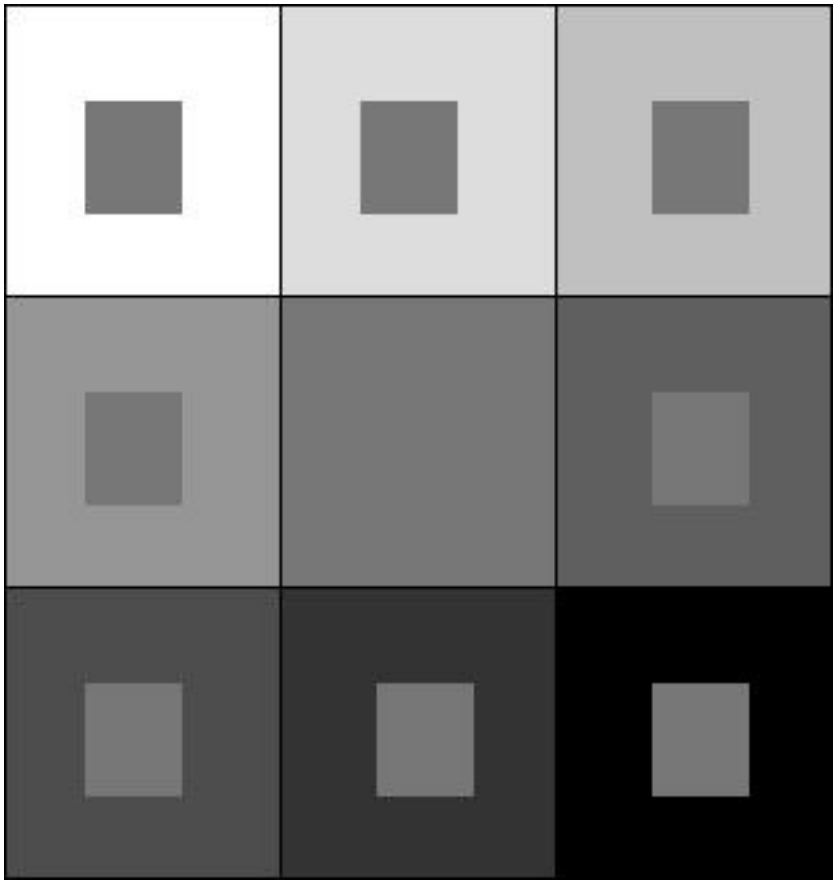
# 答案揭晓！



# 同时对比

- 11世纪被 Ibn al-Haytham发现
- 18世纪被歌德 Johann Wolfgang von Goethe

（对，就是写《少年维特的烦恼》那个歌德）记录，而广为人知

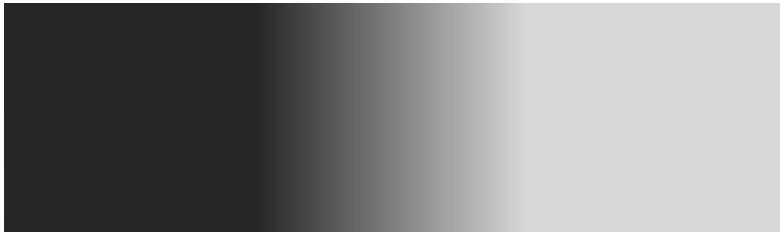


Perception and color in images (parisdescartes.fr)

# 马赫带

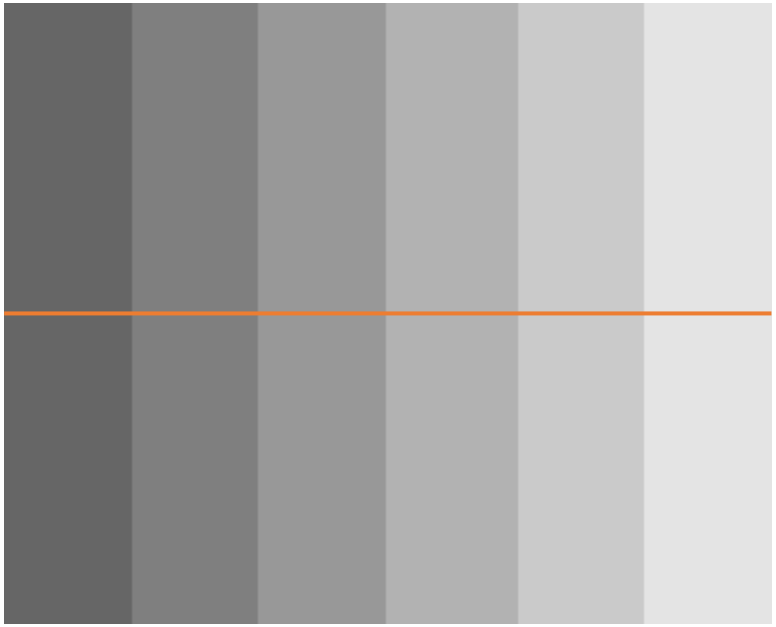
- 条带交界处亮度和条带内部相比增加了么?

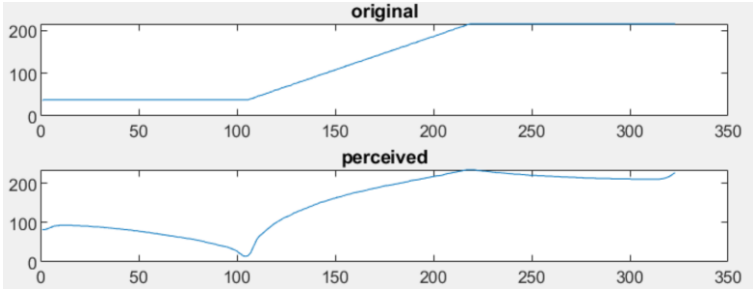
By The original uploader was Aliwiki at French Wikipedia. - Transferred from fr.wikipedia to Commons by Korrigan using CommonsHelper., FAL, https://commons.wikimedia.org/w/index.php?curid=4770182

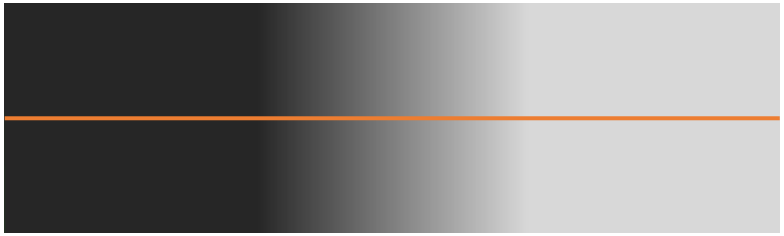


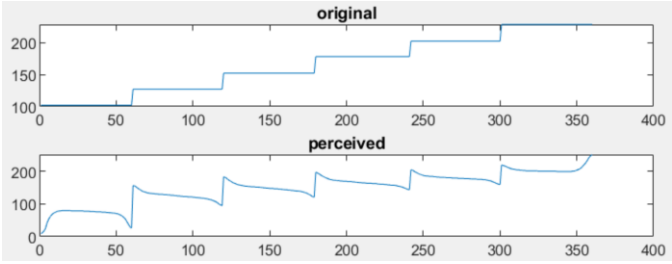
# 马赫带

- 答案是，并没有
- 视觉感知系统会为交界处添加对比度增强滤镜







# 光——光强、亮度与明度

- 发光强弱即**光强**
- 单位面积上接收的光强即**亮度**
- 我们感知到的亮度叫做**明度**。明度的差异叫做对比度
- 我们的视觉系统对对比度进行了处理

太阳光
荧光灯
白炽灯
白色物体
常见物体
阴影
黑色

| | | |
|---|---|---|
| Sunlight | = 1,600,000,000 nits | |
| Fluorescent light | = 10,000 nits | |
| Highlights | = 1,000 | to 10,000 nits |
| White Range | = 250 | to 1,000 nits |
| Most typical objects | = 1 | to 250 nits |
| Shadow details | = 0.01 | to 1 nit |
| Ultra Blacks | = 0 | to 0.01 nit |
| Most Current PC displays = 0.1 to 250 nits max | | |
| Excellent Current LCD HDTVs = 0.1 to 350-400 nits max | | |

AMD RTG technology summit 2015

太阳光

rayos-de-sol.jpg (1920×1236) (publicdomainpictures.net)

荧光灯

7412976884_89051abc54_b.jpg (683×1024) (staticflickr.com)

白炽灯

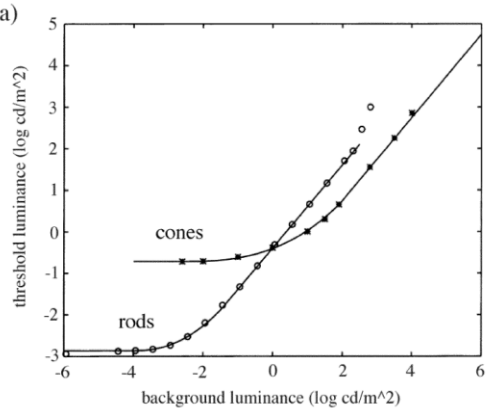
empty-electric-light-bulb.jpg (1920×1271) (publicdomainpictures.net)

白墙

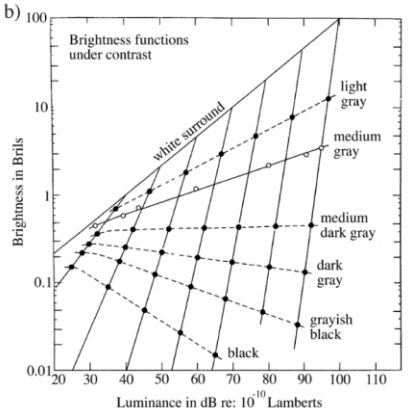
white-wall.jpg (1920×1272) (publicdomainpictures.net)

# 亮度与对比度

- 能被感知到的最小亮度（阈值视觉）；不同亮度背景下同亮度物体的明度（超阈值视觉）。
- **对比度**是亮度的差异
- 我们通过感知的对比度获取物体的边缘和细节
- 我们的**对比度感知敏感度**在不同空间频率下不同

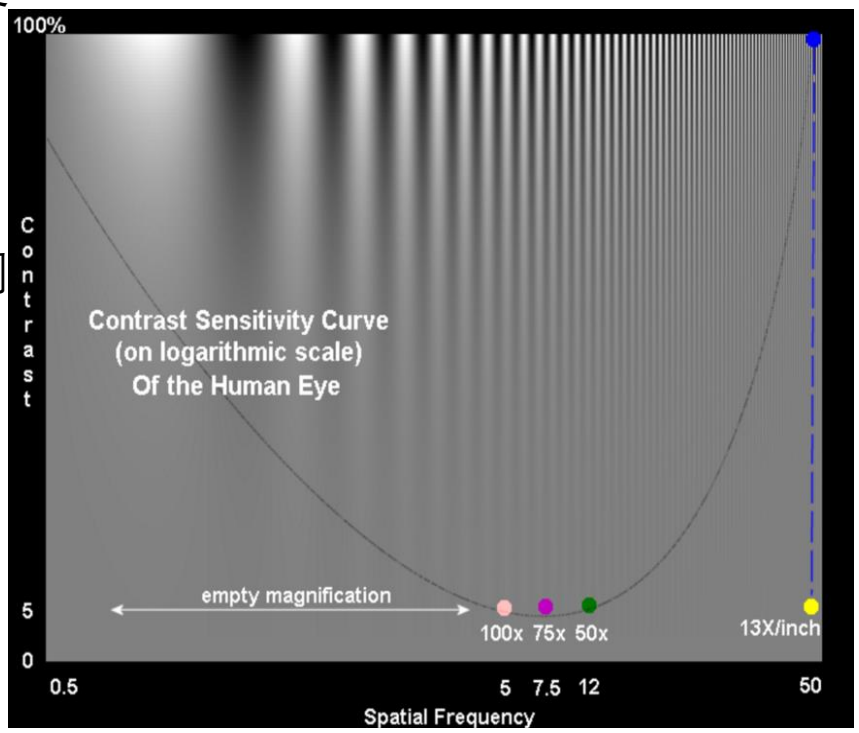



阈值视觉




超阈值视觉

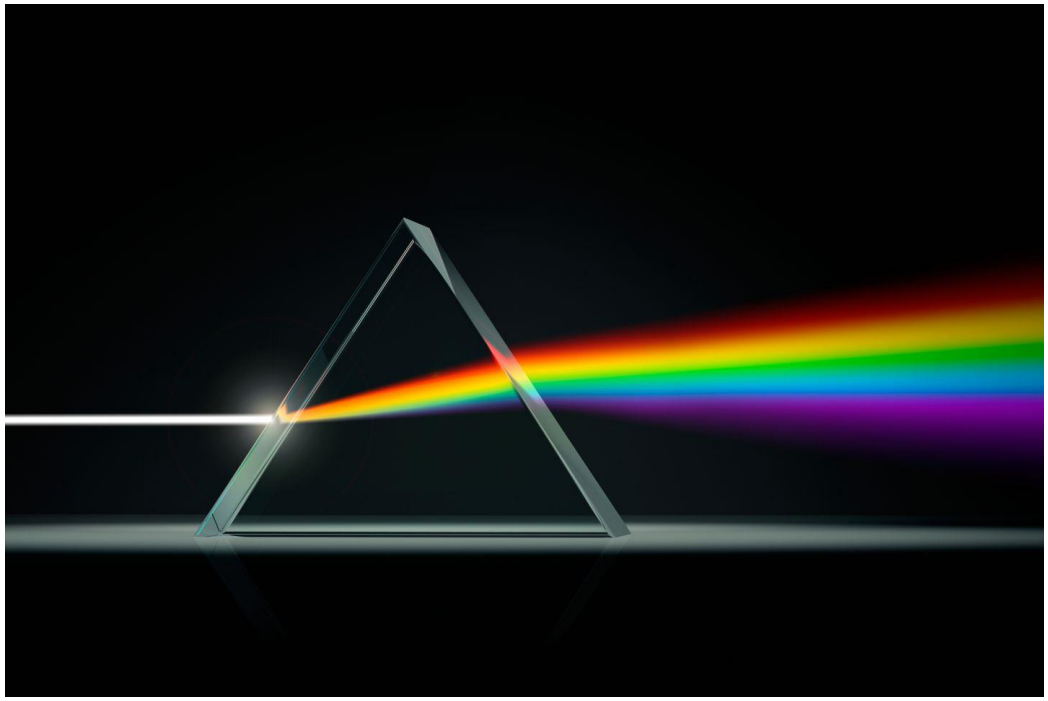
对比度敏感曲线



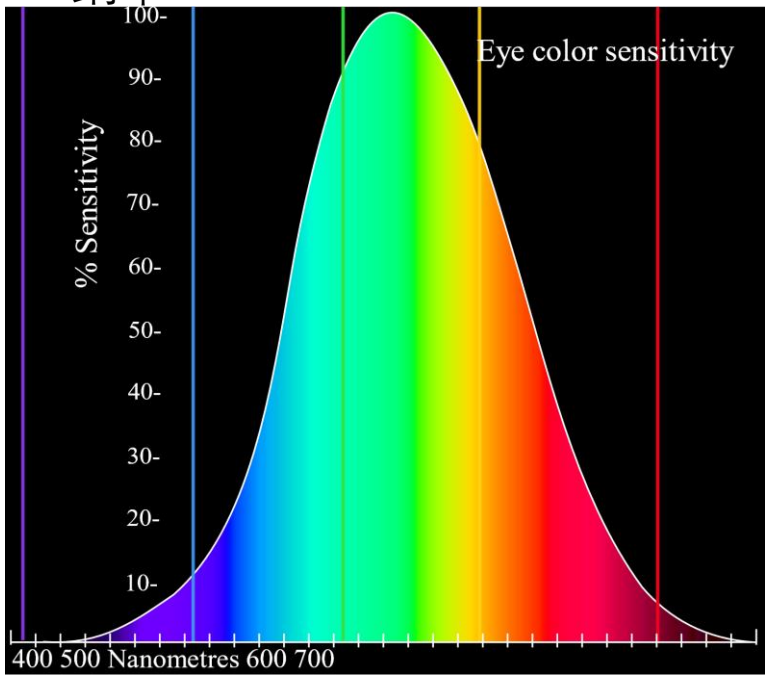

http://www.cityastronomy.com/rez-mag-contrast.htm

# 光——波长

- 白光由不同波长的光组成，可见光范围约为380—740纳米



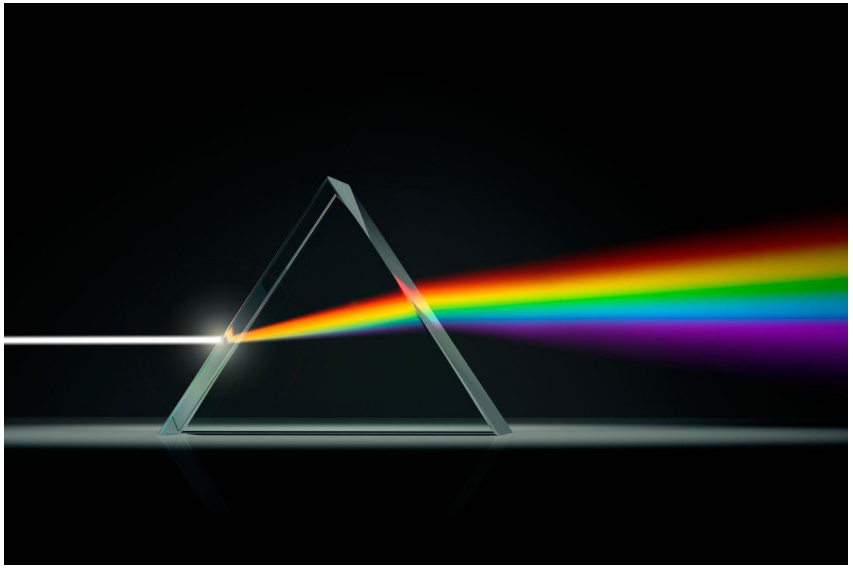
http://www.dkfindout.com/uk/science/light/splitting-light/



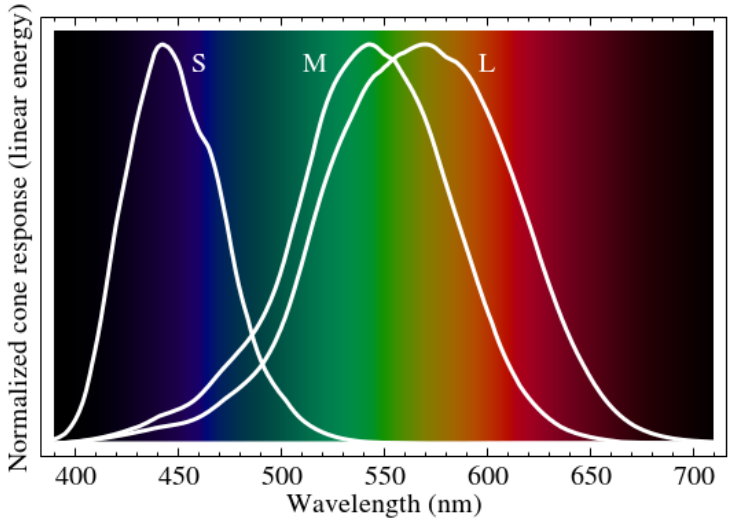

By Skatebiker, vector by Adam Rędzikowski - File:Evesensitivity.svg, vectorised, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=24492291

# 光的波长与颜色

- 人眼中三种视锥细胞分别响应短，中，长波长光波
- 对可见光的刺激感叠加使人产生彩色视觉
- 所以，颜色是我们视觉感知到的产物!
- 其他动物看到的颜色和我们一样么?



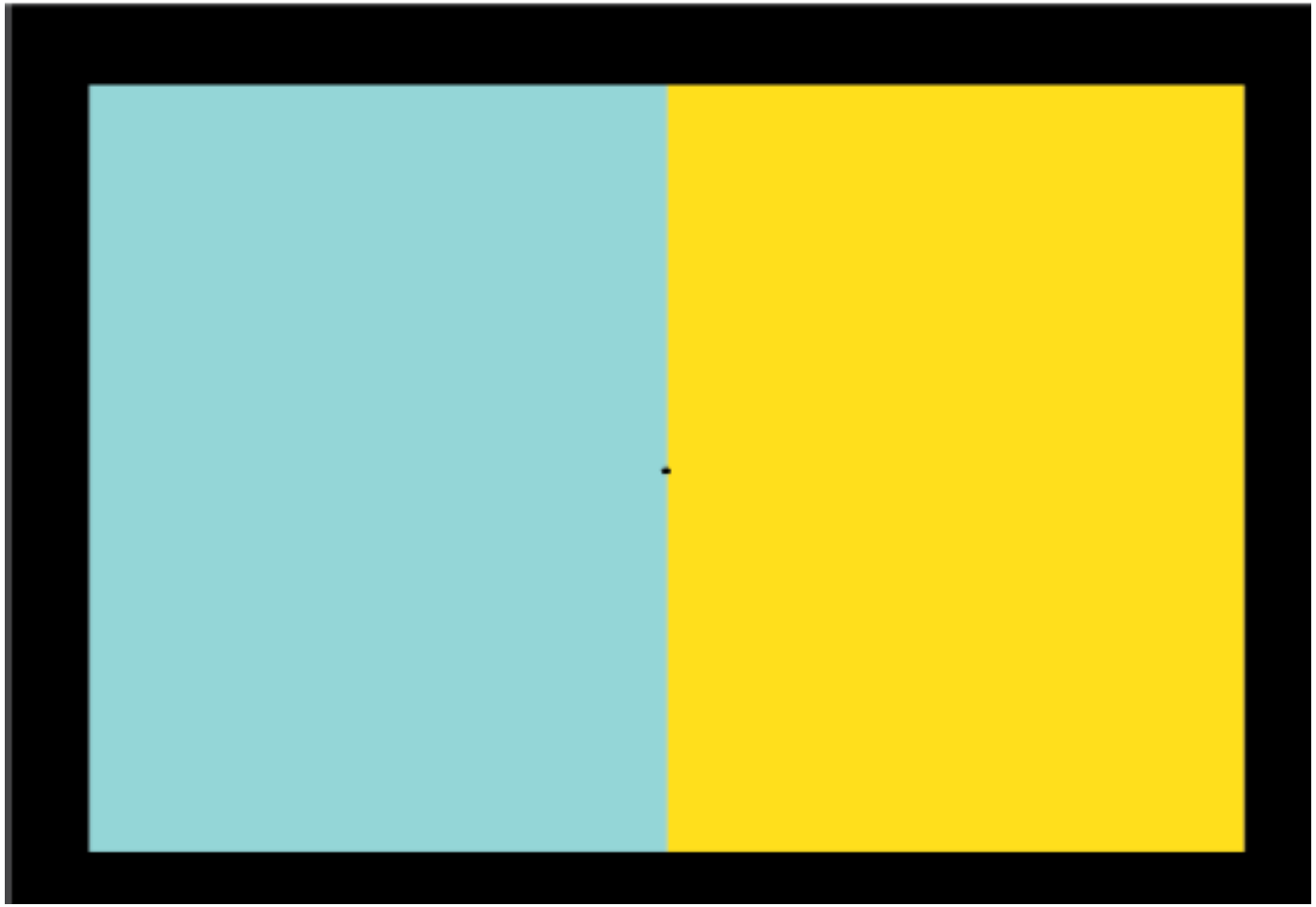
http://www.dkfindout.com/uk/science/light/splitting-light/




人眼S、M和L类别视锥细胞对单色光谱刺激的归一化的响应光谱
https://zh.wikipedia.org/wiki/彩色视觉

# 色彩适应

- 先注视图中黑点30秒，再看下边的图



Perception and color in images (parisdescartes.fr)

# 色彩适应

Perception and color in images (parisdescartes.fr)

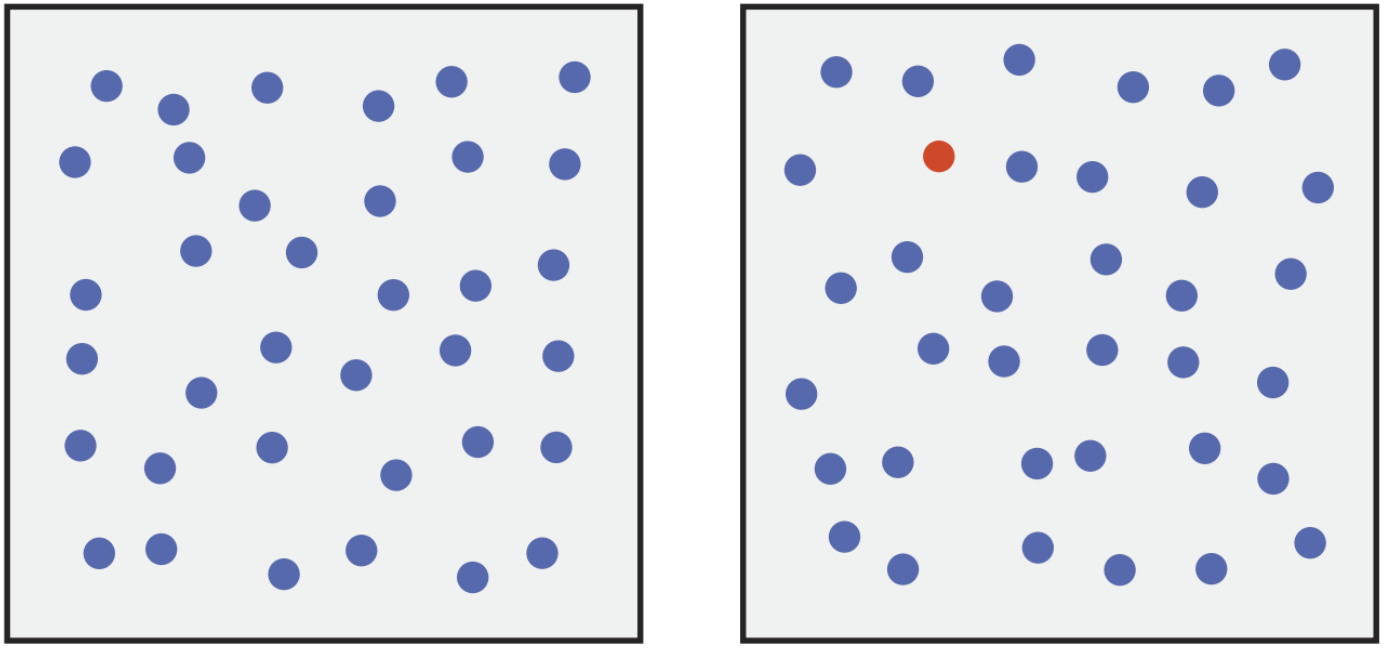
# 残像颜色反转

- 先注视左边的图黑点30秒，再看右边的图

Perception and color in images (parisdescartes.fr)

# 前注意过程

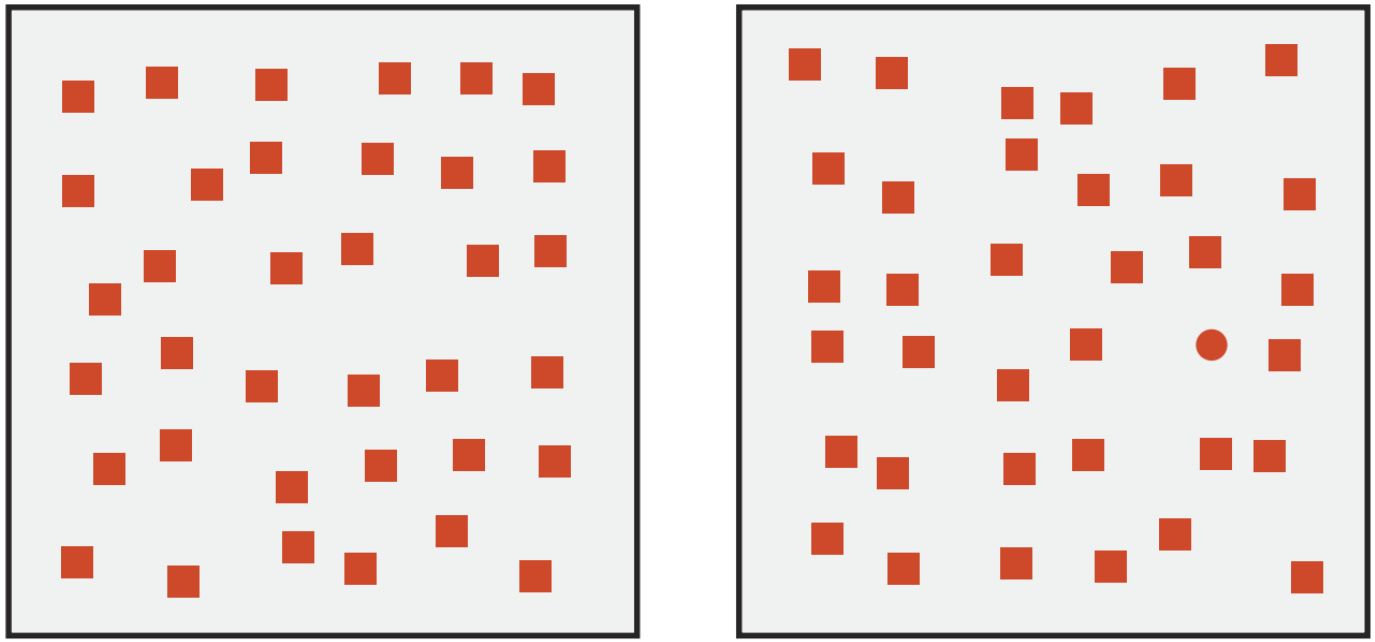
- 试试多快能找出与众不同的元素?



C. Healey and J. Enns, "Attention and Visual Memory in Visualization and Computer Graphics,", doi: 10.1109/TVCG.2011.127.

# 前注意元素

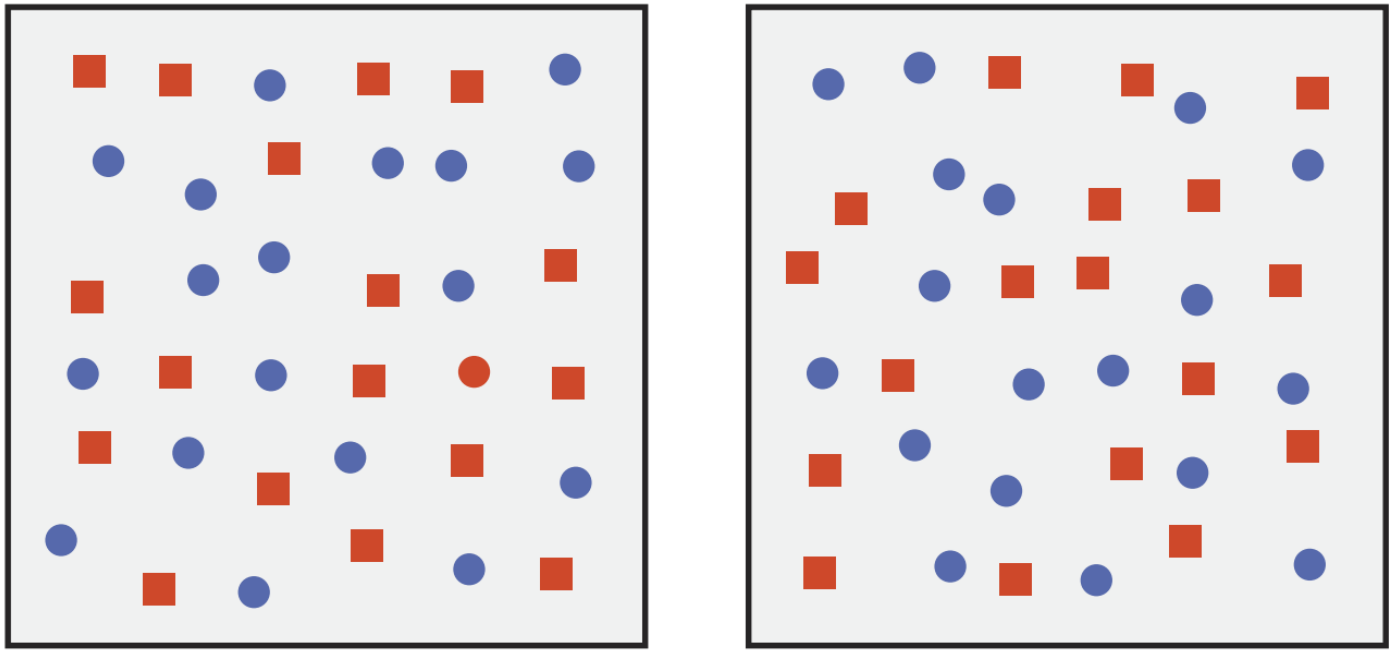
- 试试多快能找出与众不同的元素?



C. Healey and J. Enns, "Attention and Visual Memory in Visualization and Computer Graphics,", doi: 10.1109/TVCG.2011.127.

# 前注意元素

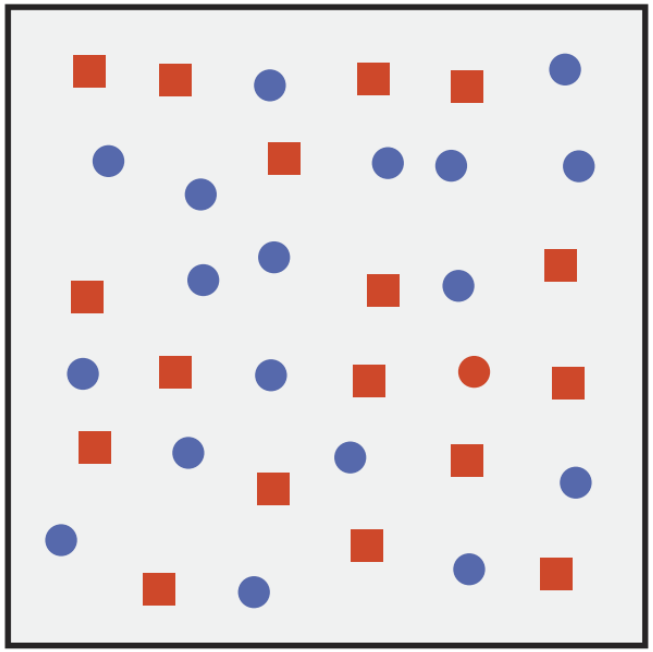
- 试试多快能找出与众不同的元素?

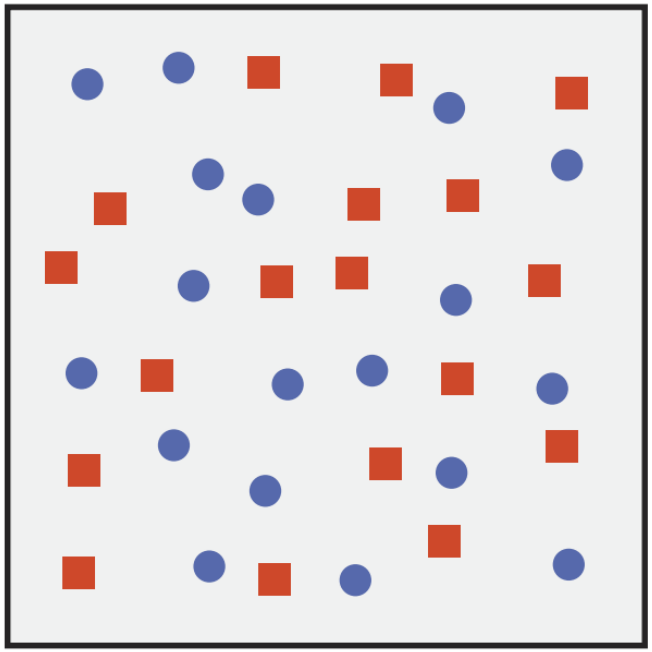


C. Healey and J. Enns, "Attention and Visual Memory in Visualization and Computer Graphics,", doi: 10.1109/TVCG.2011.127.

# 前注意元素

- 前注意属性能让人在很短时间内（小于0.25秒）不需思考就找出独特的元素。
- 但是，前注意属性的组合可能不是前注意属性！



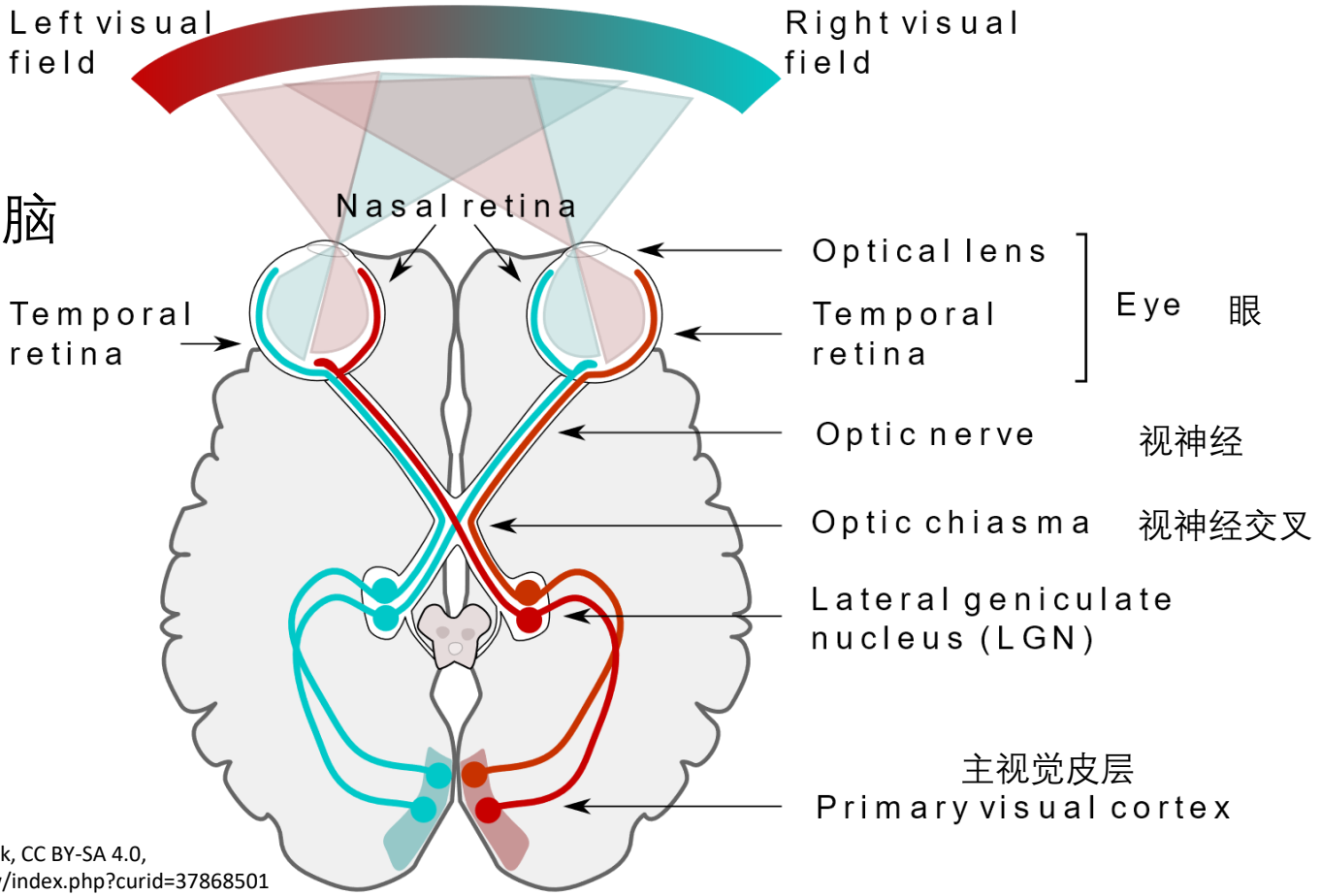


C. Healey and J. Enns, "Attention and Visual Memory in Visualization and Computer Graphics,", doi: 10.1109/TVCG.2011.127.

# 人类视觉系统

- 视觉感知：

  眼→视神经→大脑




By Miquel Perello Nieto - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=37868501

# 为什么视觉系统要“骗”我们?

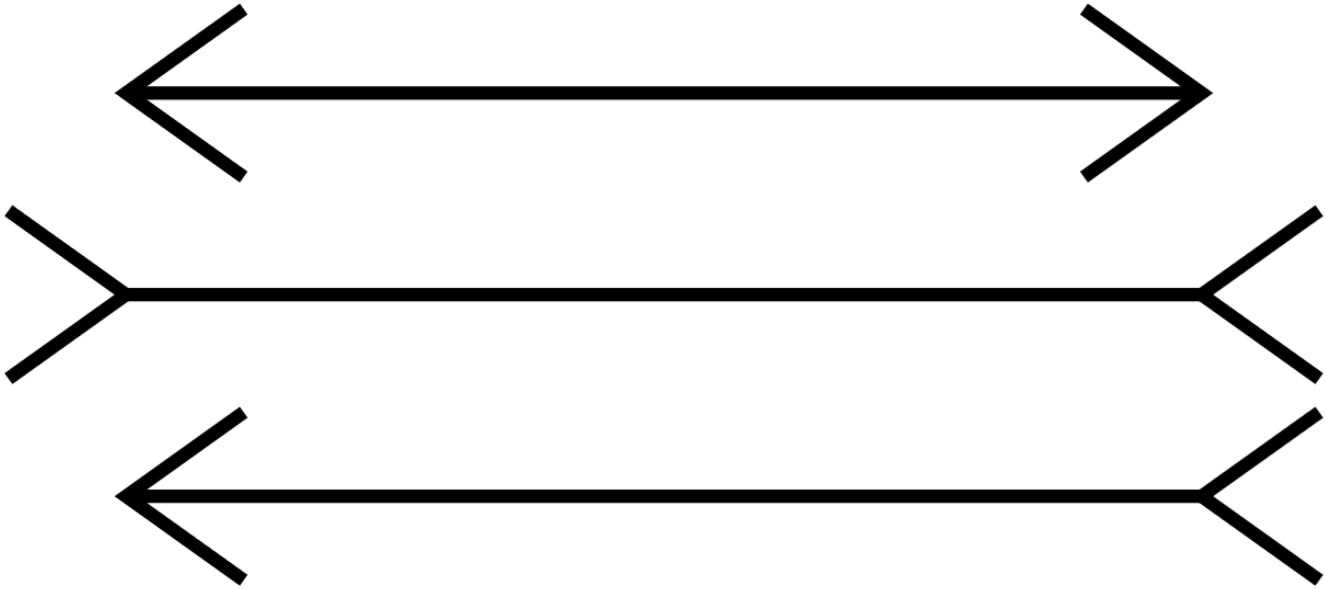
- 现在并不清楚→试图通过生物进化角度解释
  - 人能看到红色可以分辨更多好吃的果子，但狗不行
  - 神经系统的侧向抑制被用来解释马赫带效应

fruit-657491_960_720.jpg (960×625) (pixabay.com)
creative commons

Dog Vision (andraspeter.com) 模拟狗视觉感知结果

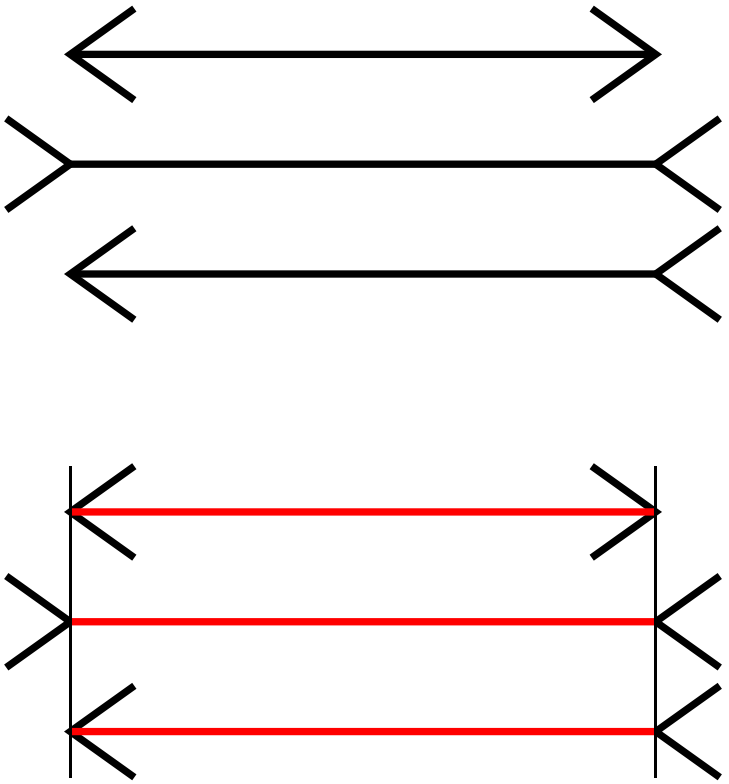
# 更多有趣的感知现象——几何视错觉—1

- 箭头中间的线段一样长么?



By Fibonacci - Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=1792612

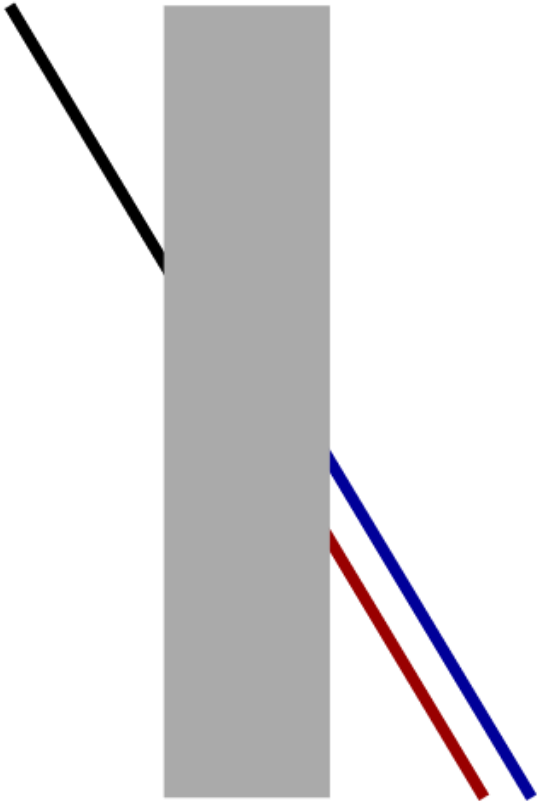
# Müller-Lyer错觉



By Fibonacci - Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=1792612

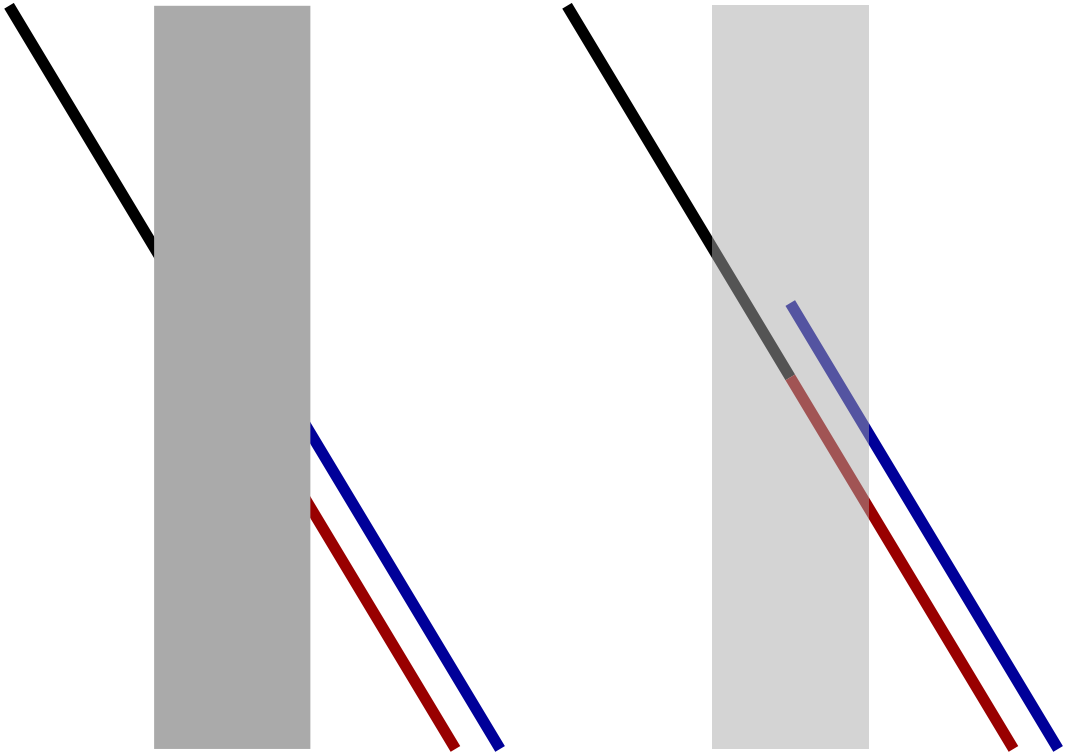
# 几何视错觉—2

- 哪条线段与黑色线段相连?



By Fibonacci. - Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=2073873

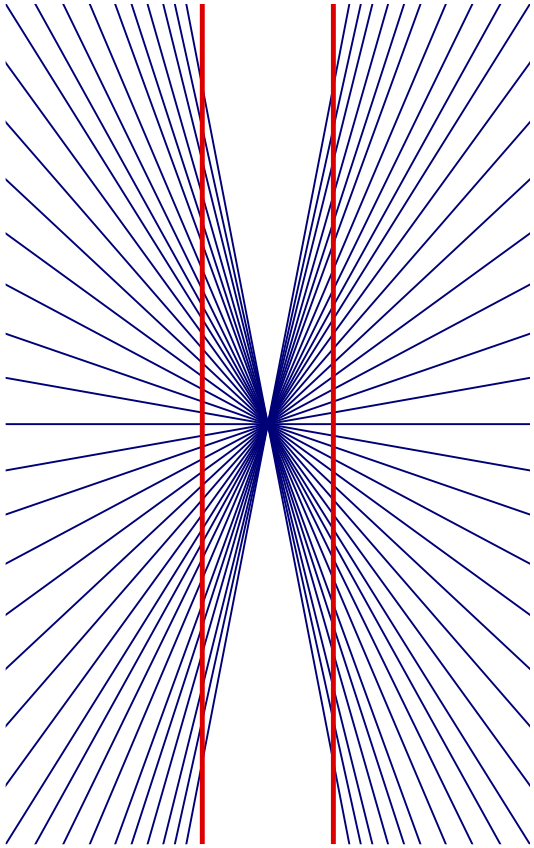
# Poggendorf错觉



By Fibonacci. - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2073873

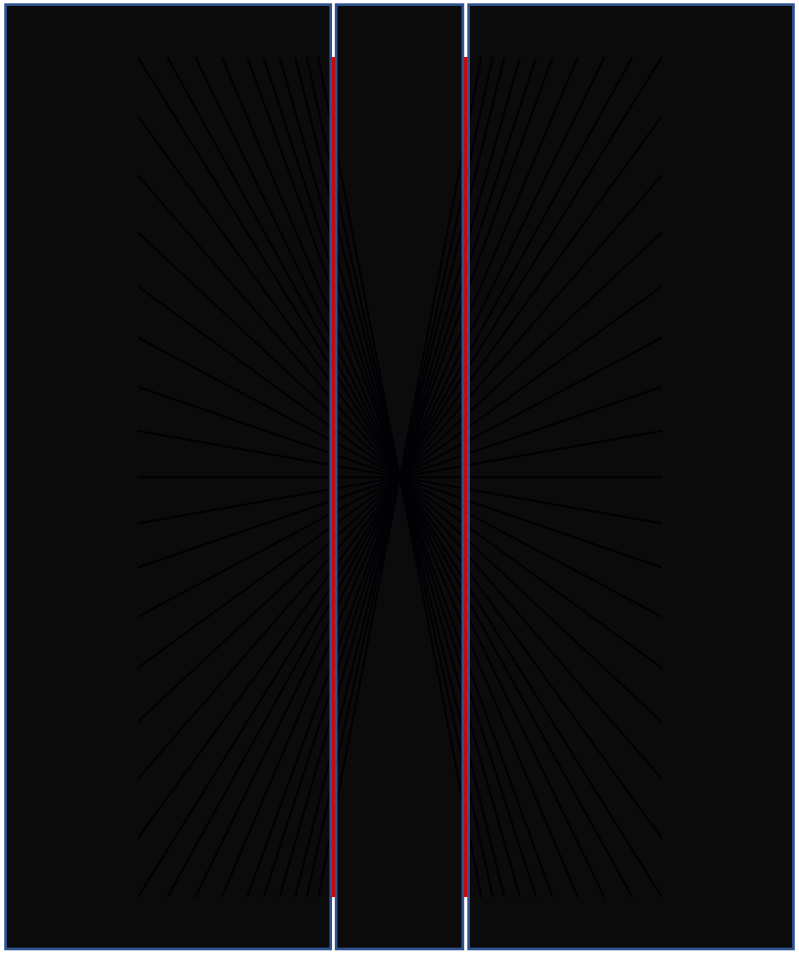
# 几何视错觉—3

- 红色线段是弯曲的么?



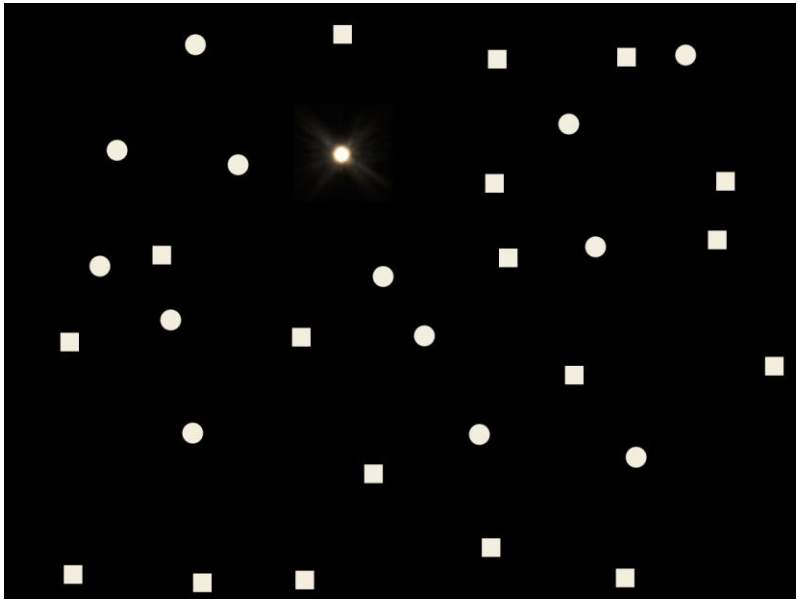
By Fibonacci - Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=1791975

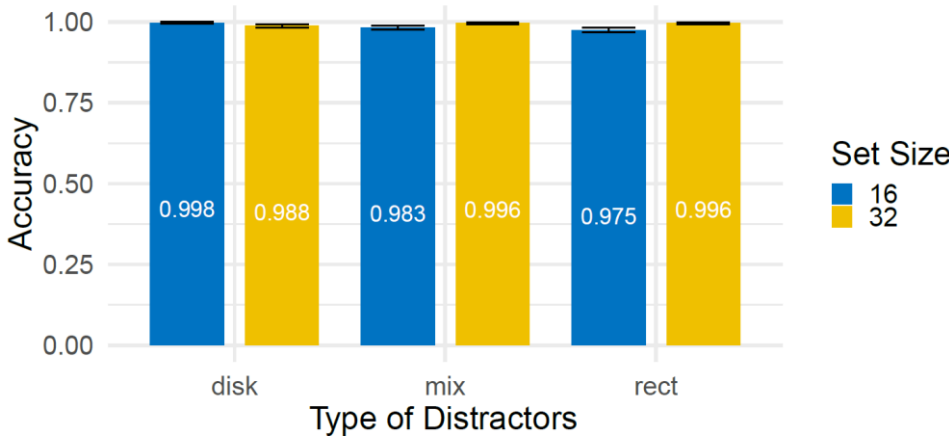
# Hering错觉



# 基于感知特性的可视化设计——视觉感知实验

- 前注意(preattentive)视觉元素——只需看，不需想，在250ms内就能判断是否出现
- 通过感知实验得知眩光是前注意视觉元素

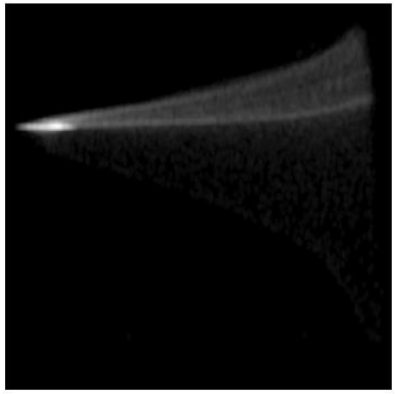




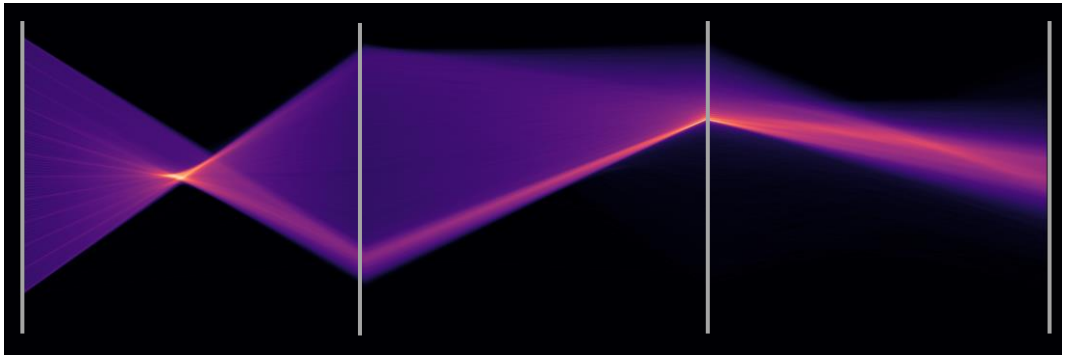

L. Zhou, M. Rivinius, C. R. Johnson, and D. Weiskopf, "Photographic High-Dynamic-Range Scalar Visualization," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 26, no. 6, pp. 2156-2167, 2020. doi: 10.1109/TVCG.2020.2970522

# Visualizing High-Dynamic-Range (HDR) scalar data

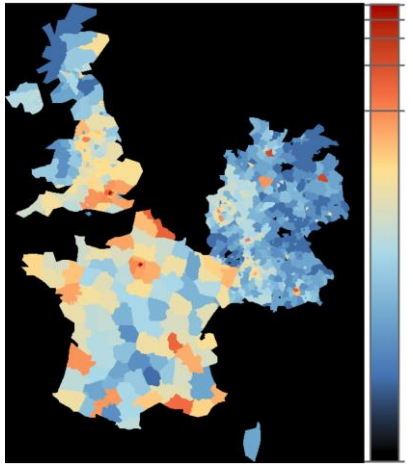
- HDR scalar data = scalar data values of very large (unbounded) ranges + 2D diagrams
- Scatterplots (matrices), parallel coordinates, trajectory plots, choropleth, node-link diagrams
- Visualizing with global transformation + color mapping



scatterplot



parallel coordinates



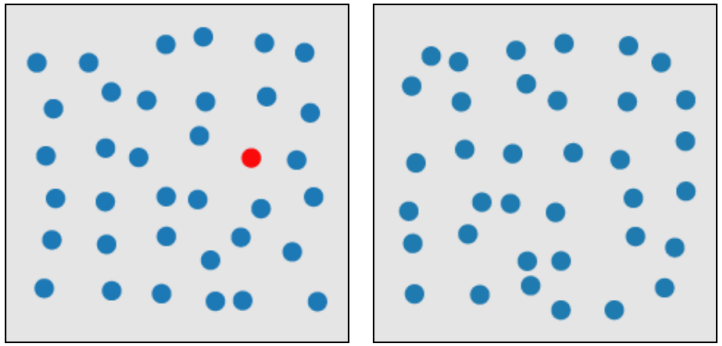
choropleth

# Related Work

- Tone-mapping operators (TMOs)
- HDR processing in visualization
- Glare
- Preattentive processing

[Mai et al. 2011]

[Mantiuk et al. 2006]



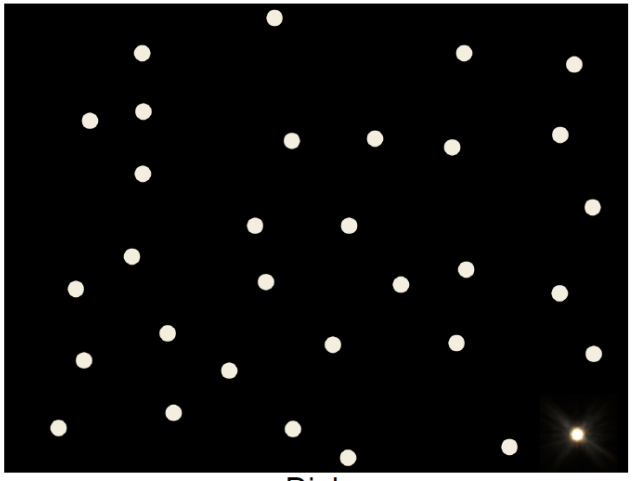
[Healey and Enns 2012]

[Ritschel et al. 2009]

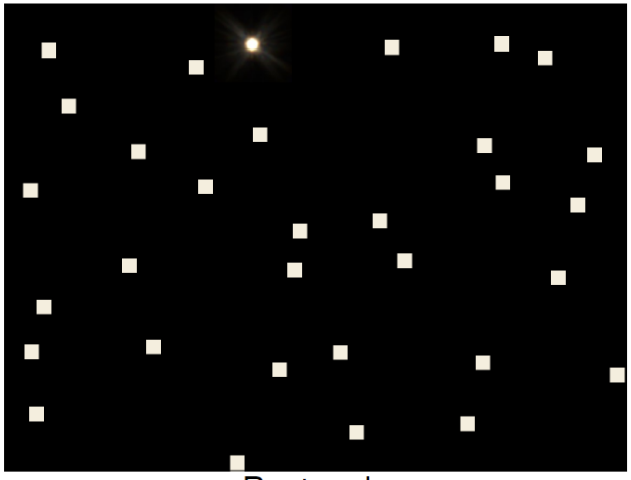
[Elmqvist et al. 2011]

# Perception study

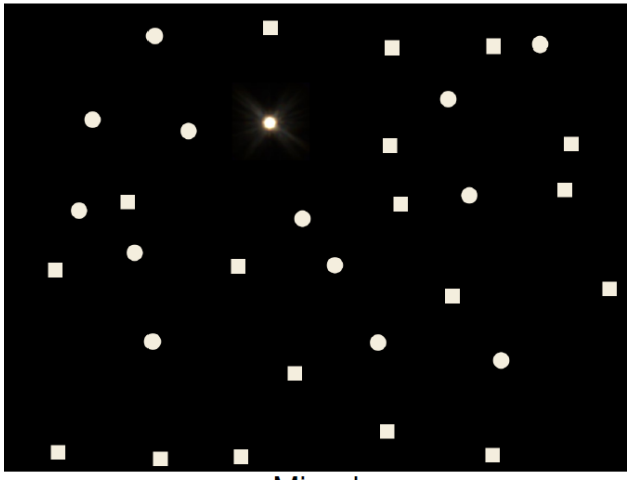
- Hypothesis: **glare is a preattentive visual cue**
- Typical state-of-the-art preattentive study design ([Krekhov and Krüger 19; Krekhov et al. 20])
  - Main factor: number of objects; second factor: type of distractors
  - Each condition has 48 tests → 48 * 2 * 3 = 288 tests per participant
  - The horizontal size of the test image is about 15°
- Task: each stimuli is shown for 250ms → participants indicate whether a glare was present



Disk



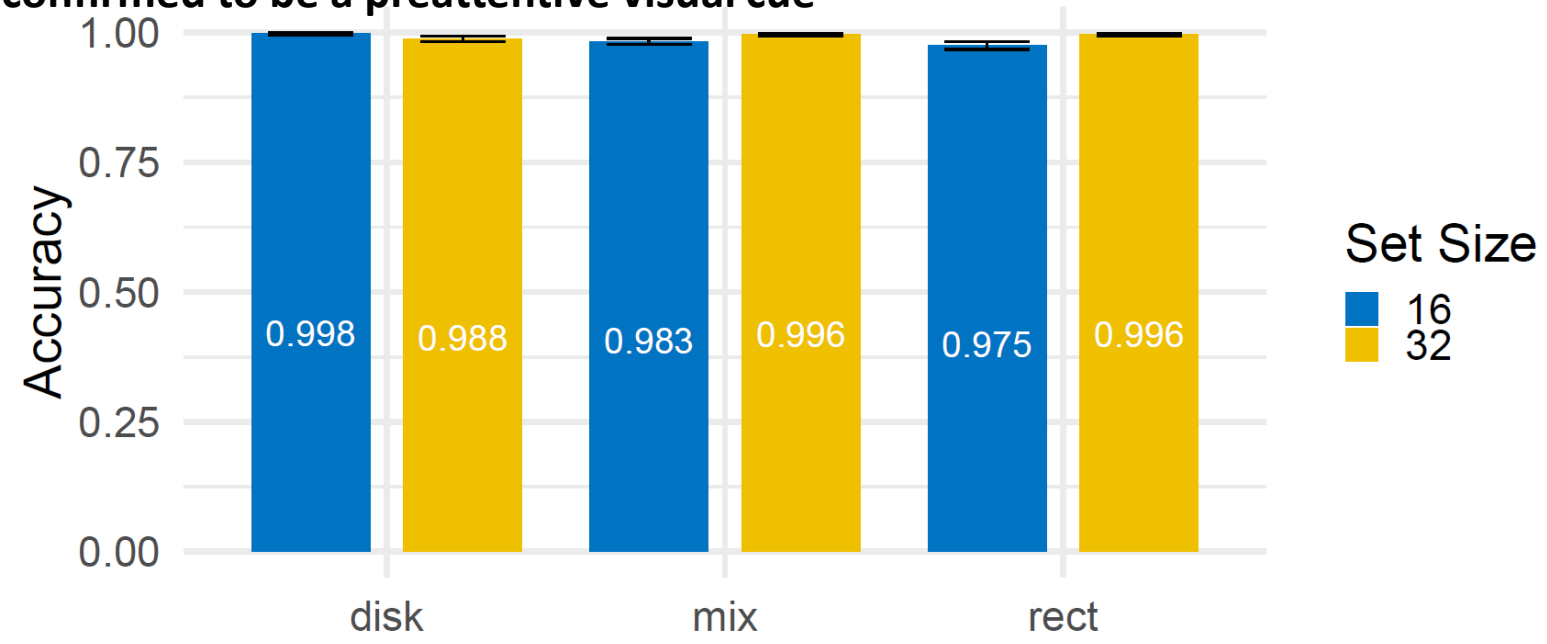
Rectangle



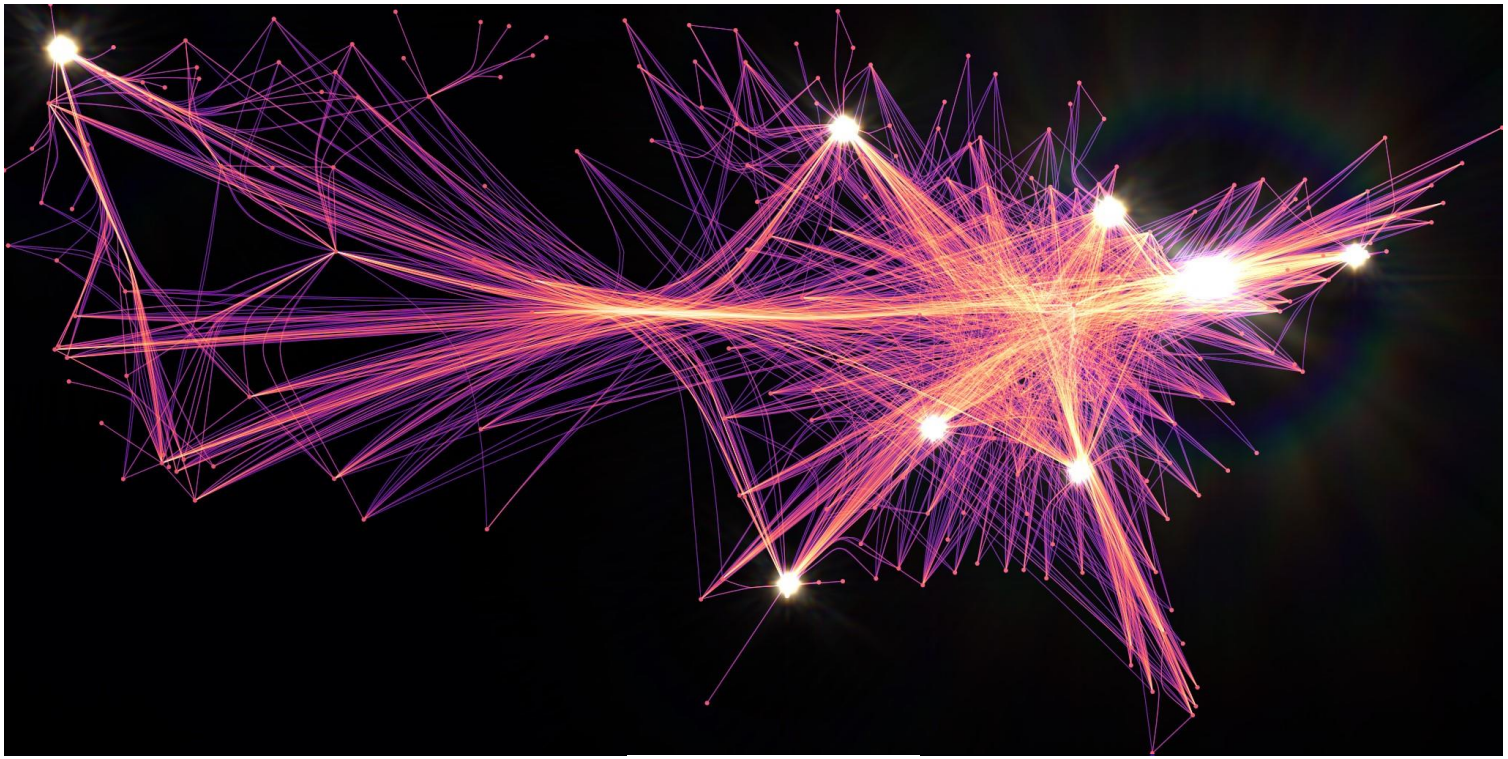
Mixed

# Perception study results

- Ten subjects (3 females, 7 males)
- High accuracies across all conditions→ similar to other preattentive visual cues
- Two-way ANOVA: no significant difference in accuracy between set size ($F(1; 9) = 1.678$; $p = 0.227$) nor type of distractors ($F(2; 18) = 1.316$; $p = 0.293$)
- **Glare is confirmed to be a preattentive visual cue**

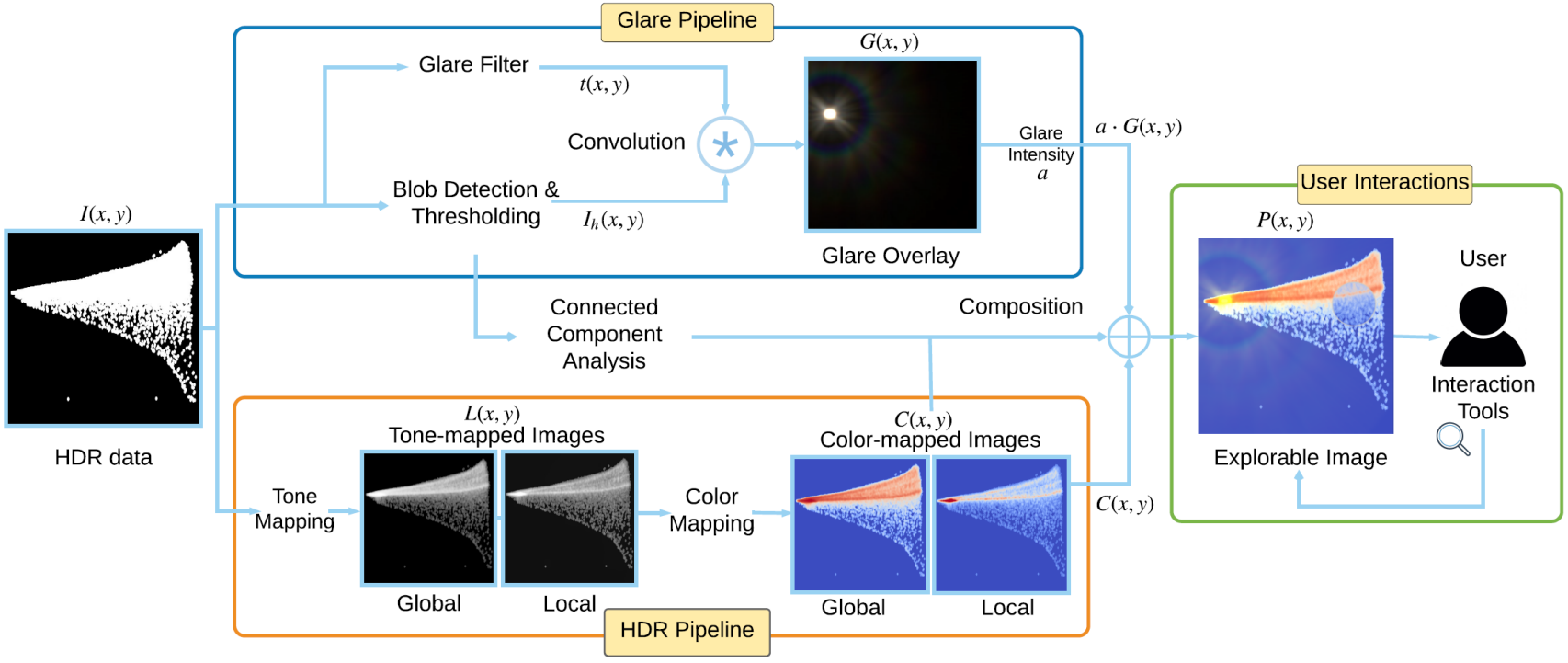


# Visualizing High-Dynamic-Range (HDR) Scalar Data



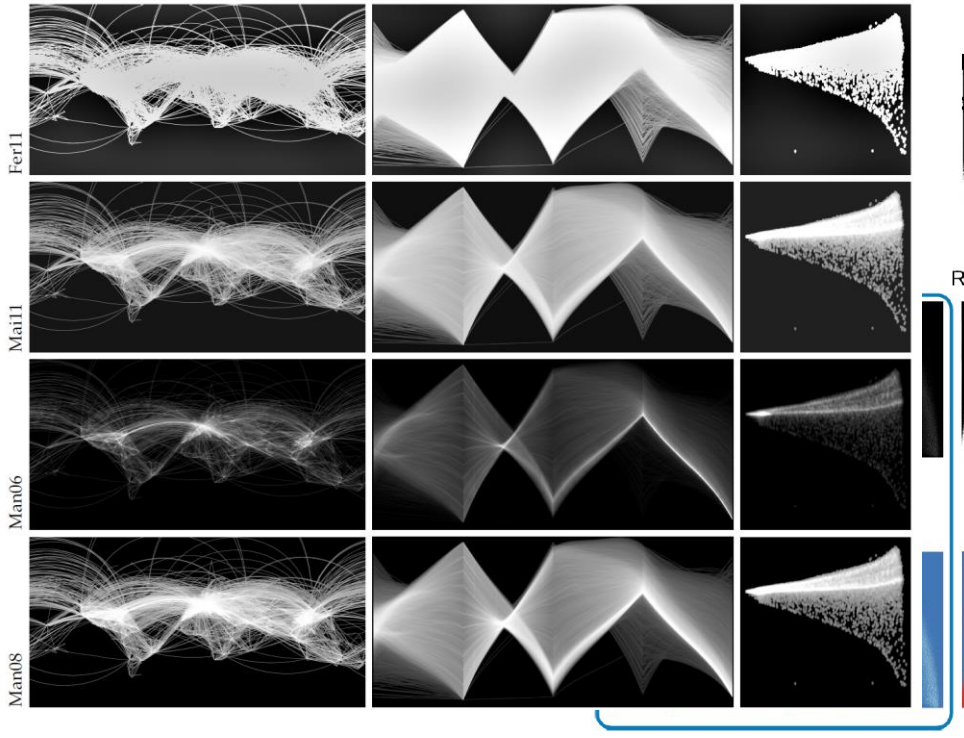

Our new photographic HDR method

# The workflow



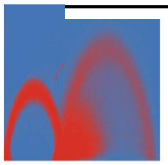
# The HDR pipeline

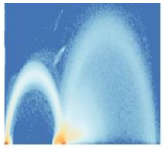
- Tone-mapping operator → color mapping
- Systematic, quantitative evaluation ([Aydin et al. 08]) on TMOs for visualization
- Customize TMOs for visualization









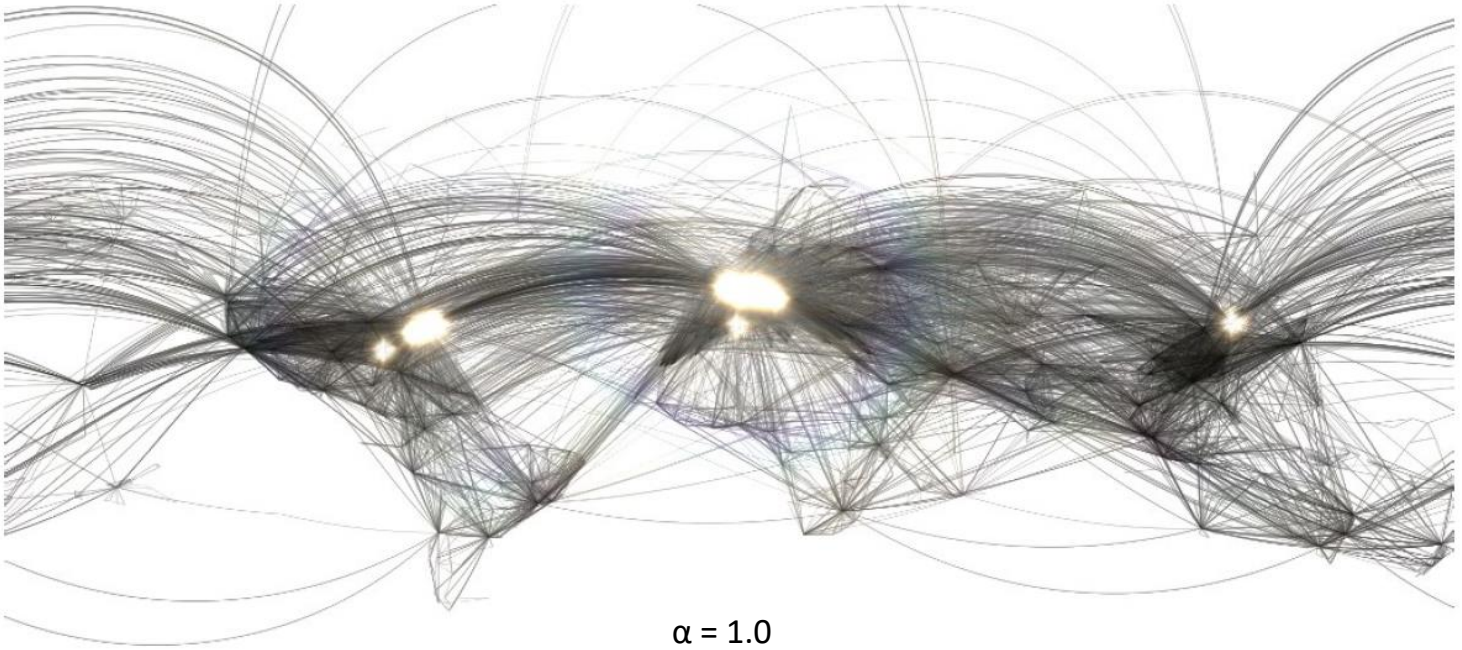
Color-mapped Image

Mean distortion metric of tone-mapping operators in our evaluation.

| TMO | IsabelTvP | World Flights | IsabelPC | Averaged |
|---|---|---|---|---|
| Man08 [4] | 0.483 | 0.372 | 0.698 | 0.517 |
| Man06 [3] | 0.541 | 0.796 | 0.558 | 0.632 |
| Mai11 [5] | 0.532 | 0.610 | 1.076 | 0.739 |
| Ash02 [1] | 0.749 | 1.653 | 0.731 | 1.044 |
| Rei05 [11] | 0.650 | 0.685 | 1.850 | 1.062 |
| log | 0.756 | 0.954 | 1.604 | 1.105 |
| Dur02 [9] | 0.803 | 1.211 | 1.632 | 1.216 |
| Fat02 [7] | 0.802 | 1.350 | 1.645 | 1.266 |
| Fer11 [6] | 1.267 | 1.666 | 1.681 | 1.538 |
| Dra03 [8] | 1.280 | 1.838 | 1.590 | 1.570 |
| Pat00 [2] | 1.339 | 1.684 | 1.696 | 1.573 |
| Rei02 [10] | 1.259 | 1.792 | 1.781 | 1.610 |
| gamma | 1.564 | 1.801 | 1.962 | 1.775 |
| linear | 2.580 | 2.663 | 2.626 | 2.623 |

# Effect of glare intensity

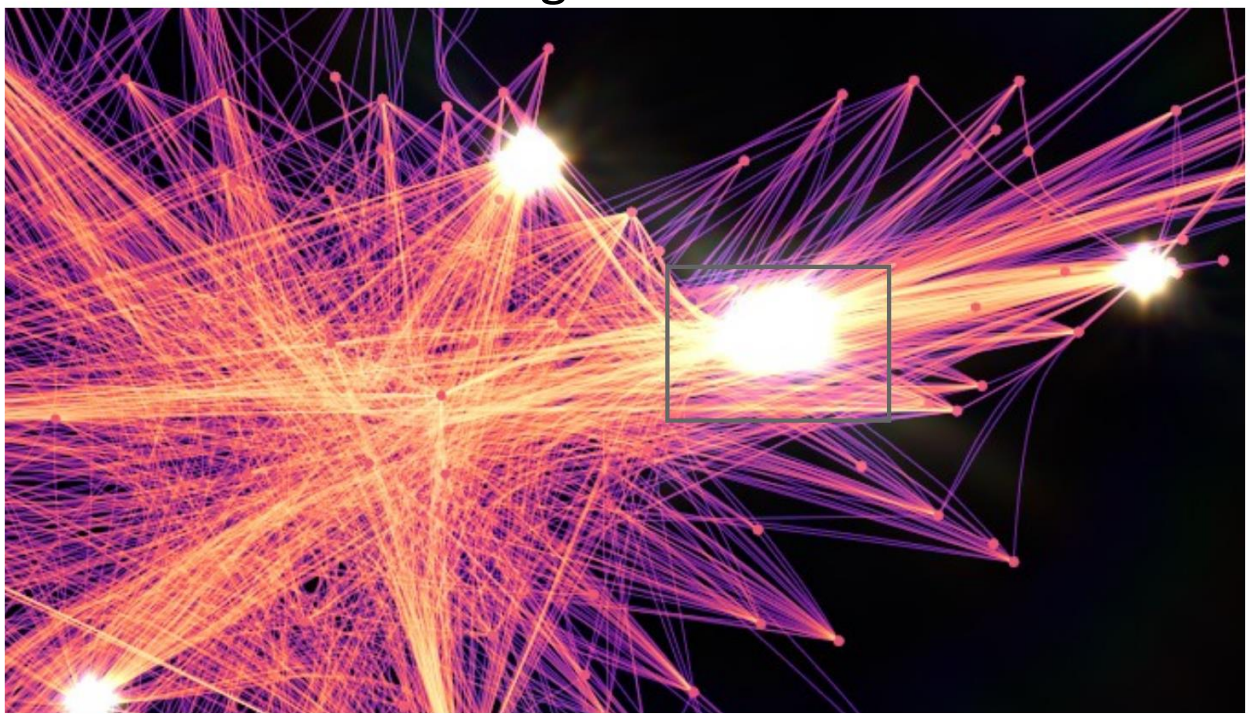
- Glare intensity α

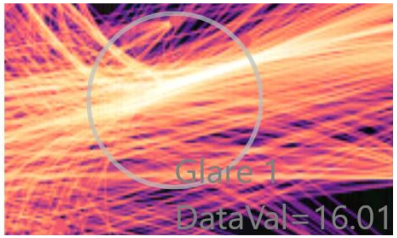


α = 1.0

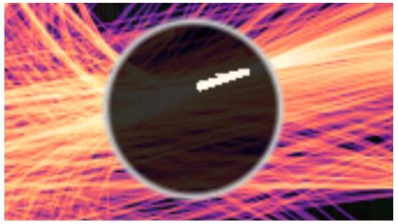
# User interaction

- Magic lens and glare switch to “see through” glares
- Three modes of the magic lens

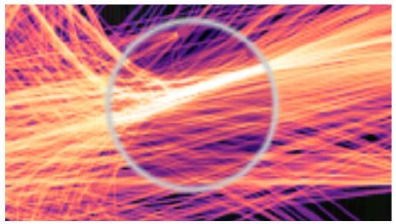





Reveal mode



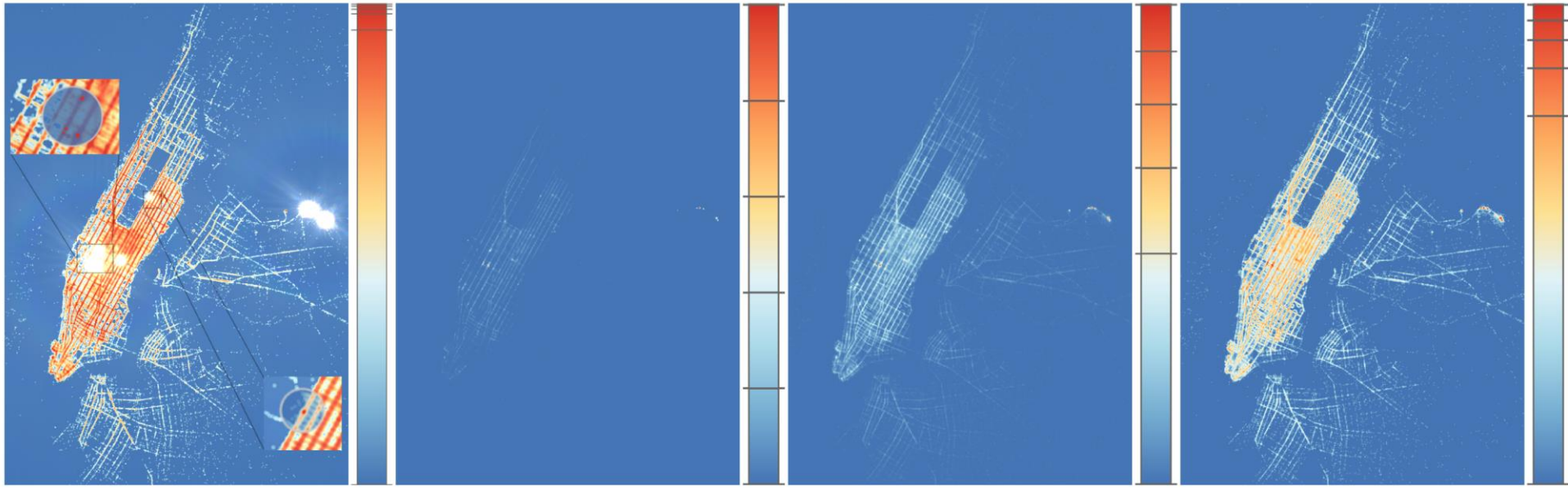
Bright pixel mode



Contrast enhanced mode

# Examples: dot-based geospatial data

- NYC taxi pick-up data

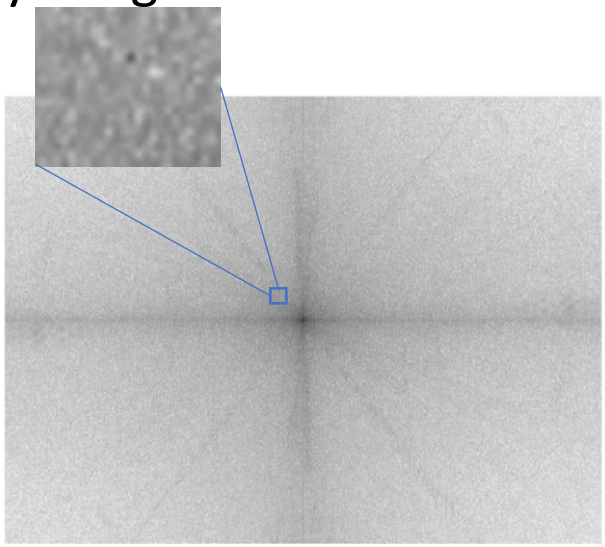


ours | linear mapping | gamma mapping | logarithmic mapping

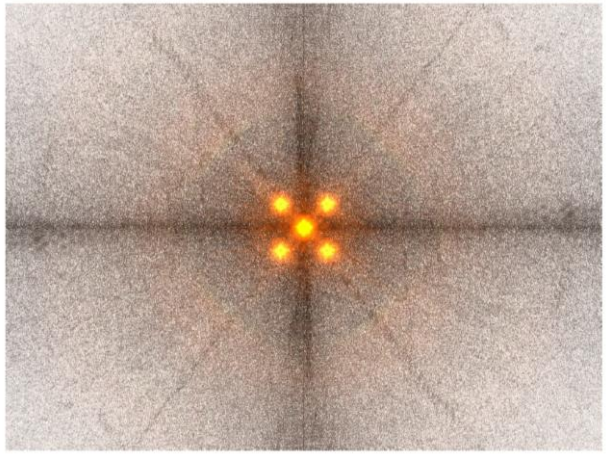
# Examples: Image processing

- Power spectrum of a noisy image

Image corrupted by sine functions



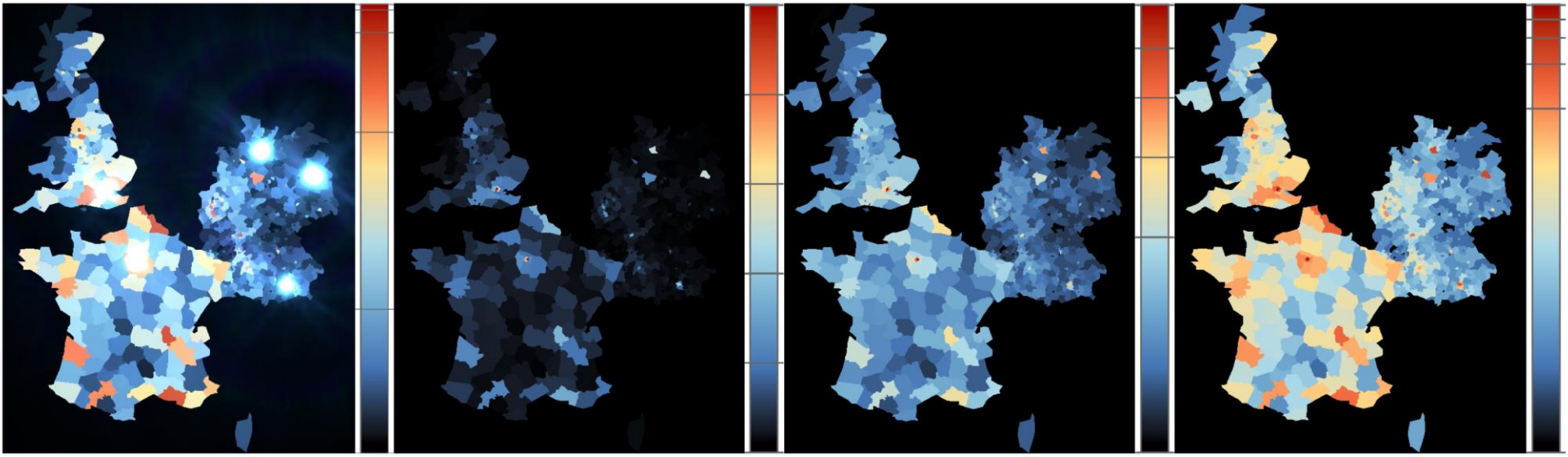
logarithmic mapping



ours

# Examples: choropleth

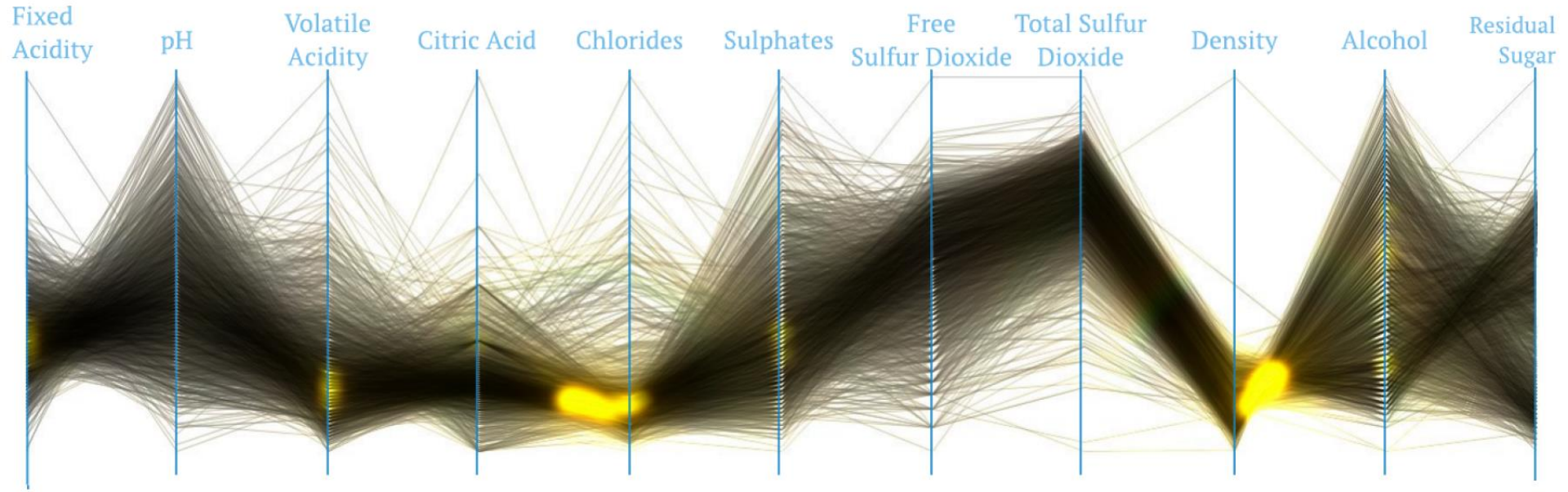
- GDP per-person of Germany, France, and Great Britain of year 2008



ours | linear mapping | gamma mapping | logarithmic mapping

# Examples: parallel coordinates

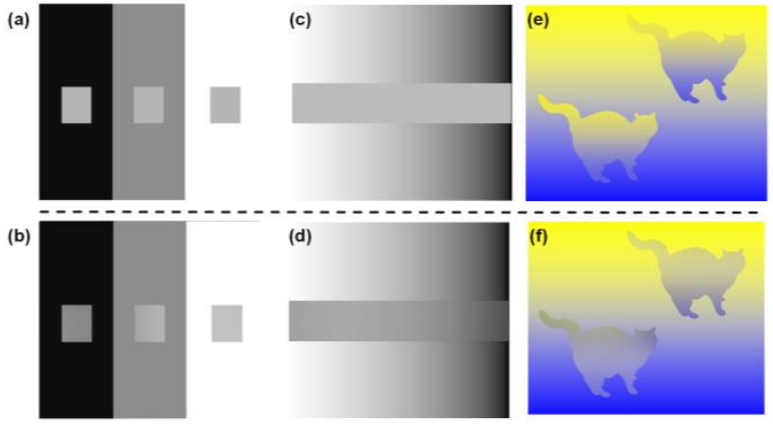
- Wine quality dataset



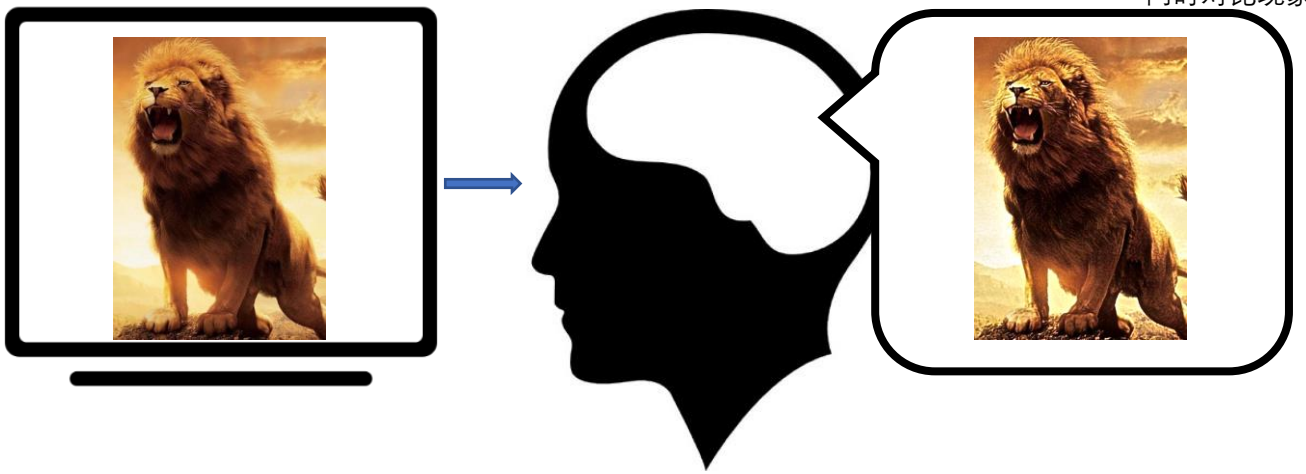
# User interaction demo

# 利用视觉感知数学模型优化可视化

- 可视化研究中工作较少的领域
- 基于观测距离的可视化图像对比度补偿和增强技术
  - 阈值空间视觉模型
  - 视觉感知频谱模型

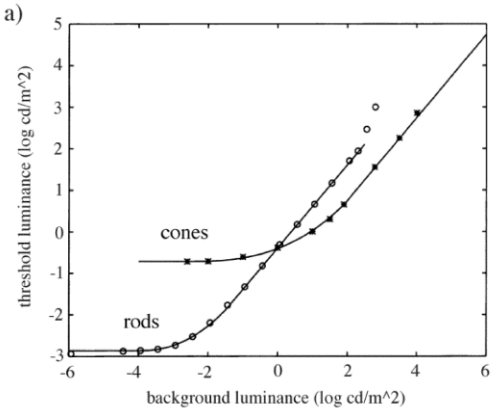



同时对比现象补偿 [Mittelstädt and Keim 2014,2015]

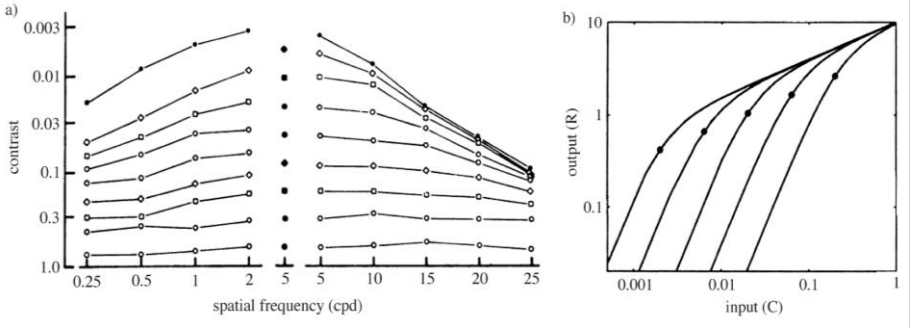


# 复杂的人类视觉系统

- 阈值与超阈值视觉
  - 物理亮度与可见性（阈值视觉）
  - 感知到的亮度（超阈值视觉）
- 阈值空间视觉
  - 对比度敏感函数(CSFs)
- 超阈值空间视觉
  - 对比度常衡和非线性转换器

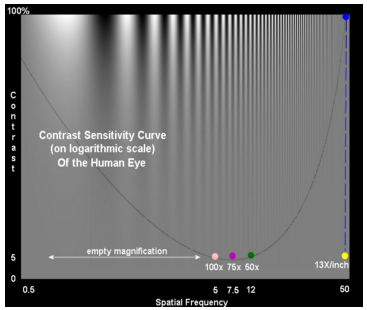



Threshold vision　　Suprathreshold vision

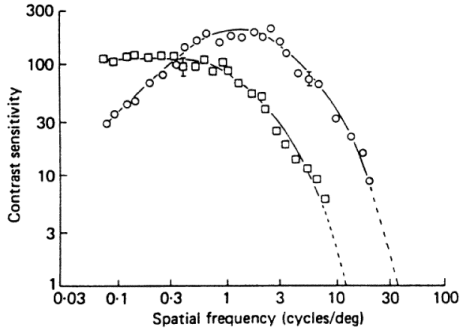



Contrast constancy　　Nonlinear transducers

Figures from [Pattanaik et al. 98]



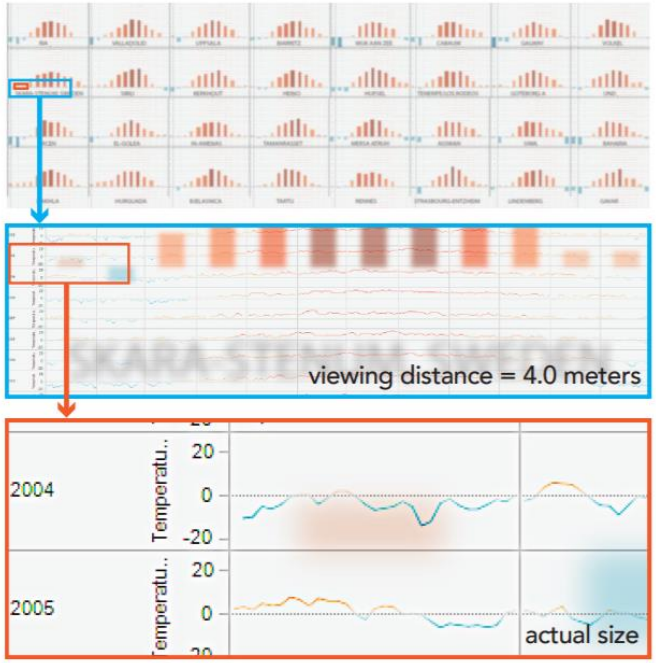

http://www.cityastronomy.com/rez-mag-contrast.htm



# Related Work in Visualization

- Perceptual methods based on viewing distances and contrast sensitivity functions (CSFs)

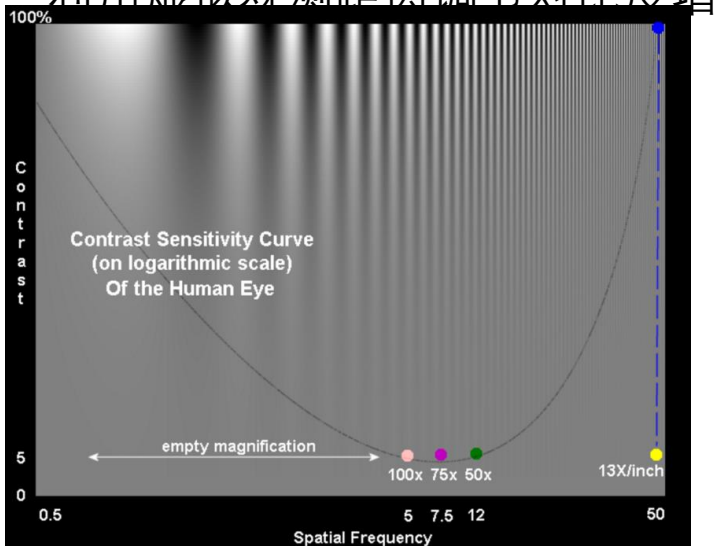
Hybrid visualization: [Isenberg et al.'13]



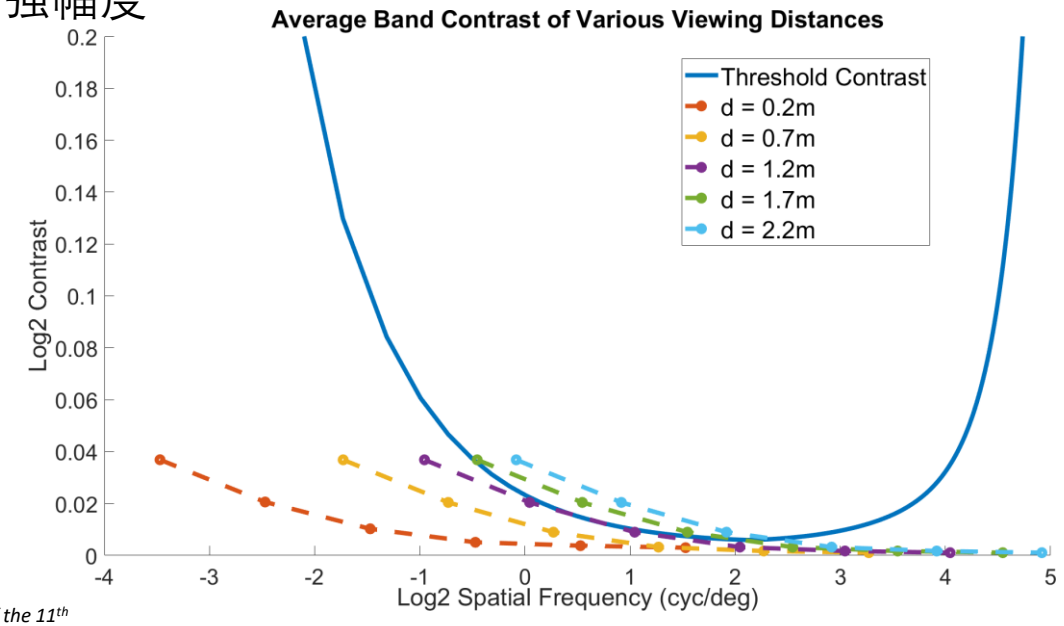

P. Isenberg, P. Dragicevic, W. Willett, A. Bezerianos, and J.-D. Fekete. 2013. Hybrid-Image Visualization for Large Viewing Environments. IEEE Transactions on Visualization and Computer Graphics 19, 12 (2013), 2346–2355.

# 基于阈值空间视觉的感知增强

- 对比敏感度函数（Contrast Sensitivity Function)---Daly's CSF
- 计算不同图像不同频段的对比度
- 利用虚拟观测距离调节对比度增强幅度




http://www.cityastronomy.com/rez-mag-contrast.htm

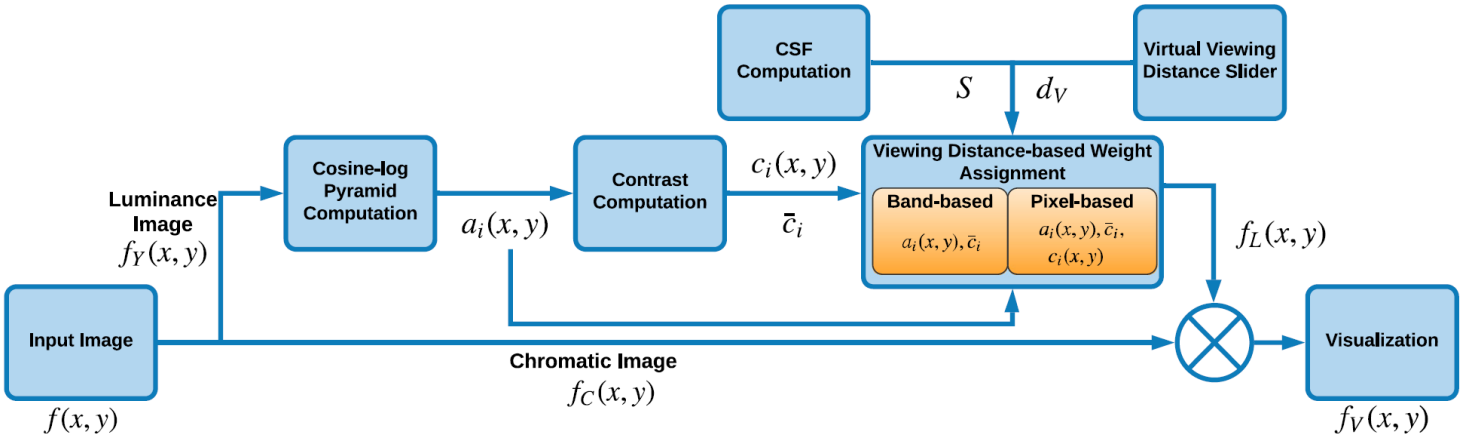




L. Zhou and D. Weiskopf. Contrast Enhancement based on Viewing Distance. *Proceedings of the 11th International Symposium on Visual Information Communication and Interaction (VINCI'18)*, pp.25-32, 2018, Best Paper.

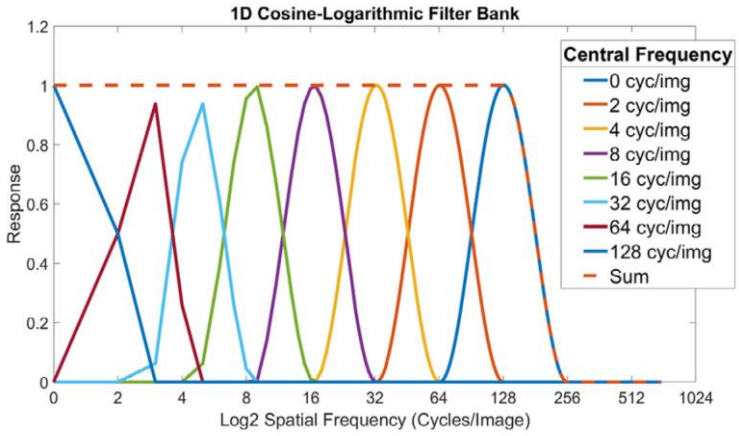
L. Zhou, D. Weiskopf, and C. R. Johnson. Perceptually Guided Contrast Enhancement Based on Viewing Distance. *Journal of Computer Languages,* Vol 55, 100911.

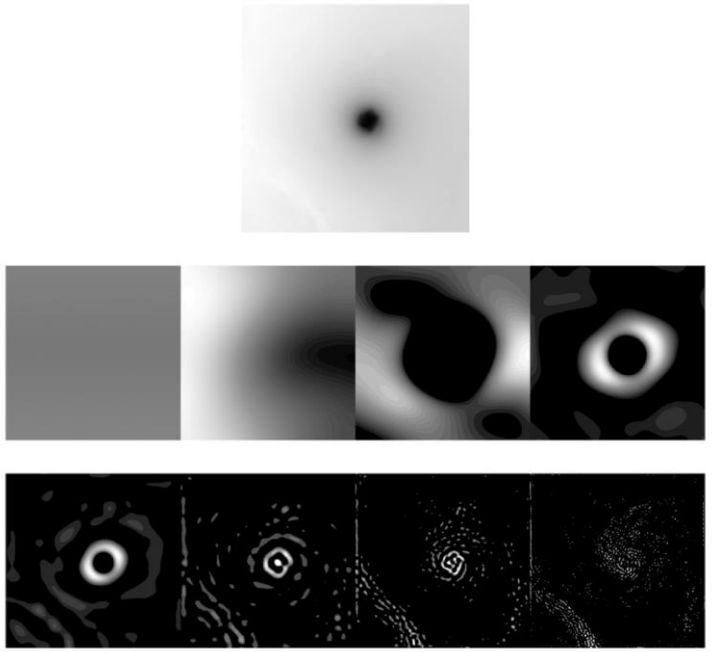
# 基于阈值空间视觉的感知增强



# 计算不同图像不同频段的对比度

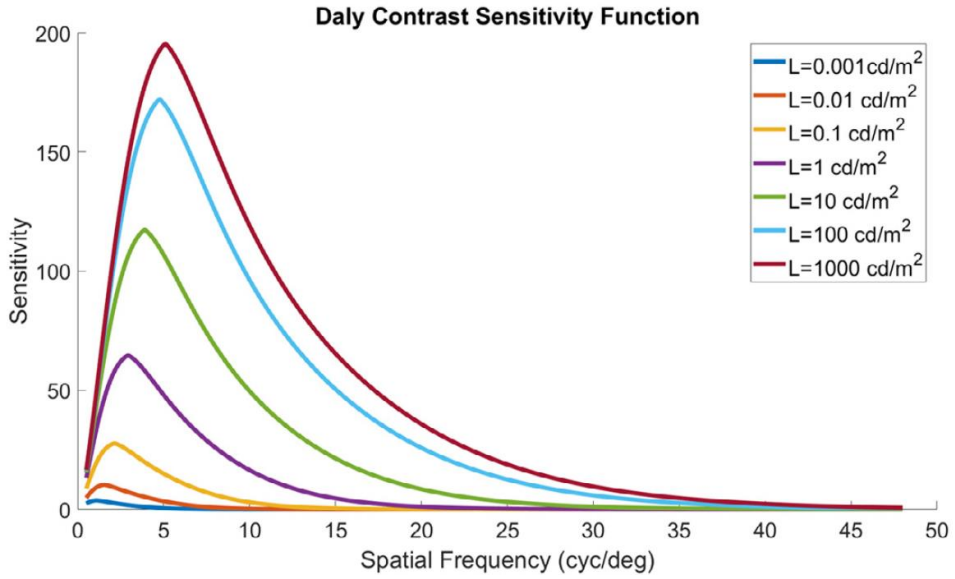
- 计算cosine-log图像金字塔
- 计算各频段分解图像对比度



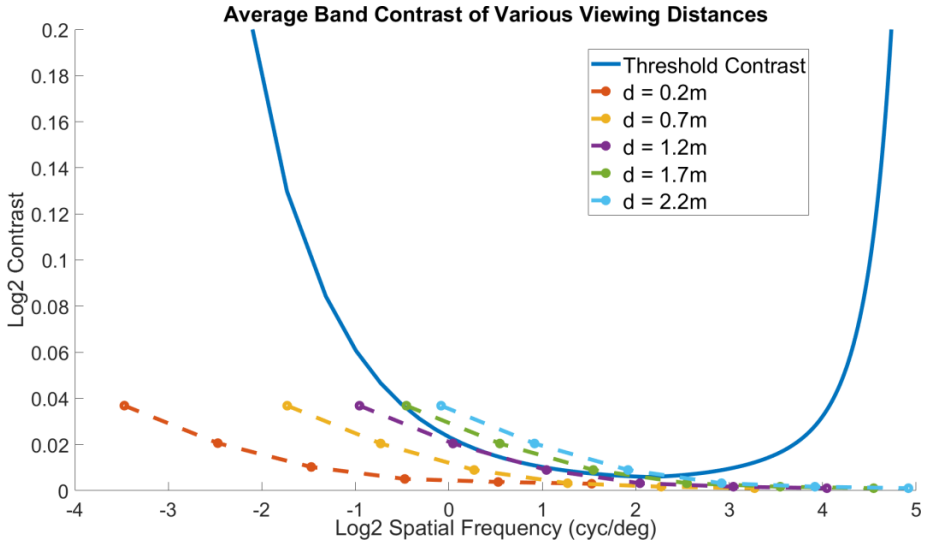
# 对比敏感度函数

- Daly 对比敏感度函数



# 利用虚拟观测距离调节对比度增强幅度

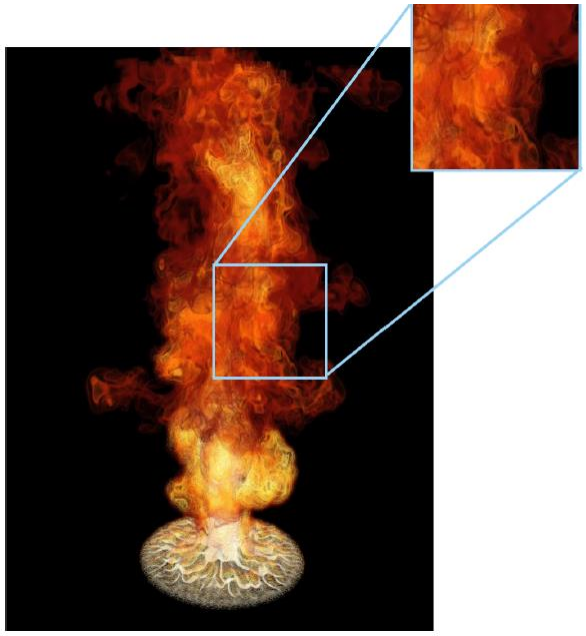
- 比较阈值对比度曲线（对比敏感度函数的倒数）和图像对比度
- 利用观测距离改变频带图像的（虚拟）空间频率
- 增强对比度：提升图像对比度至阈值对比度



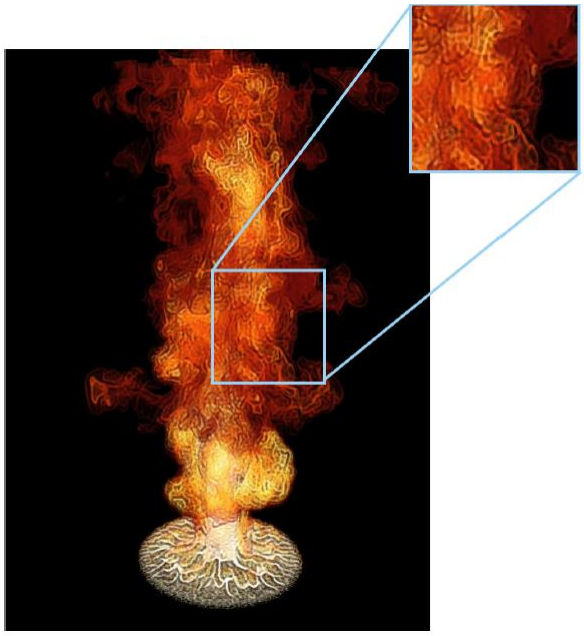
# 基于阈值空间视觉的感知增强

- 观看距离作为唯一参数调节对比度
- 结合阈值空间视觉模型和对比度转换器(contrast transducer)---基于像素的对比度增强

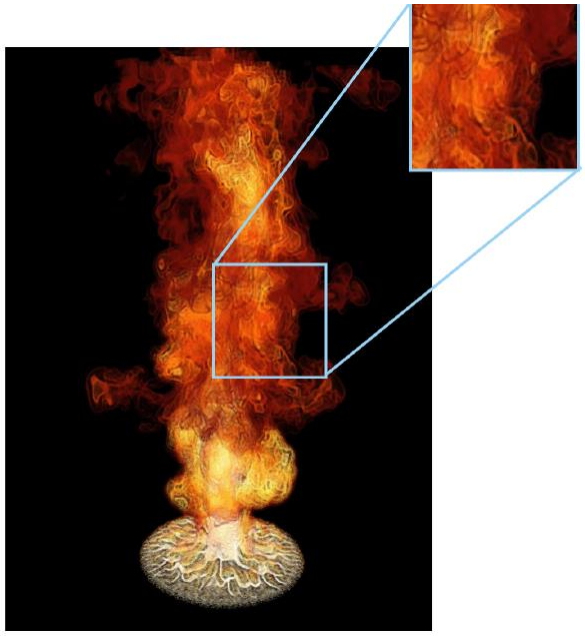
Volume rendering of combustion



原始可视化

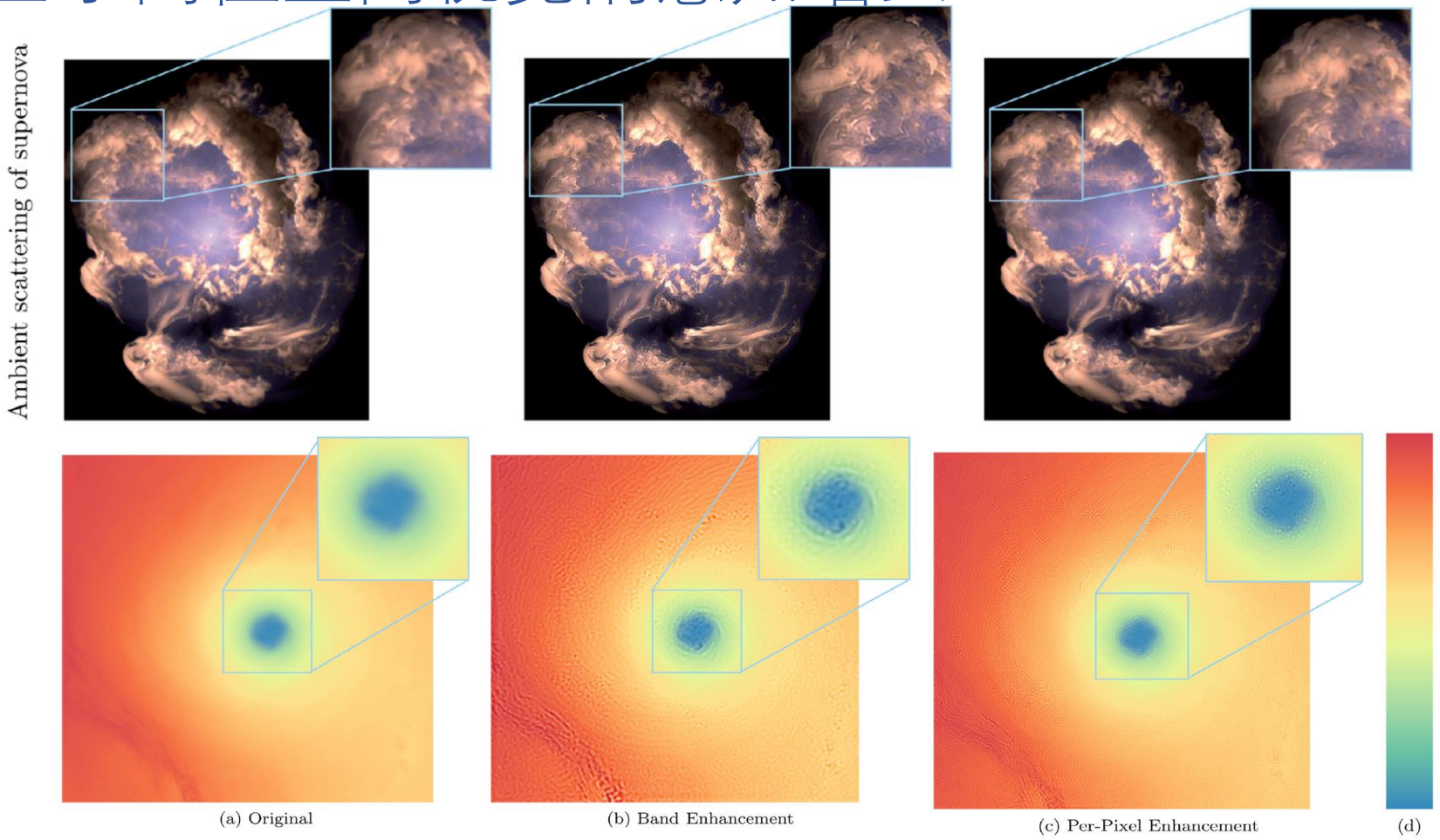


基于频带的对比度增强



基于像素的对比度增强

# 基于阈值空间视觉的感知增强

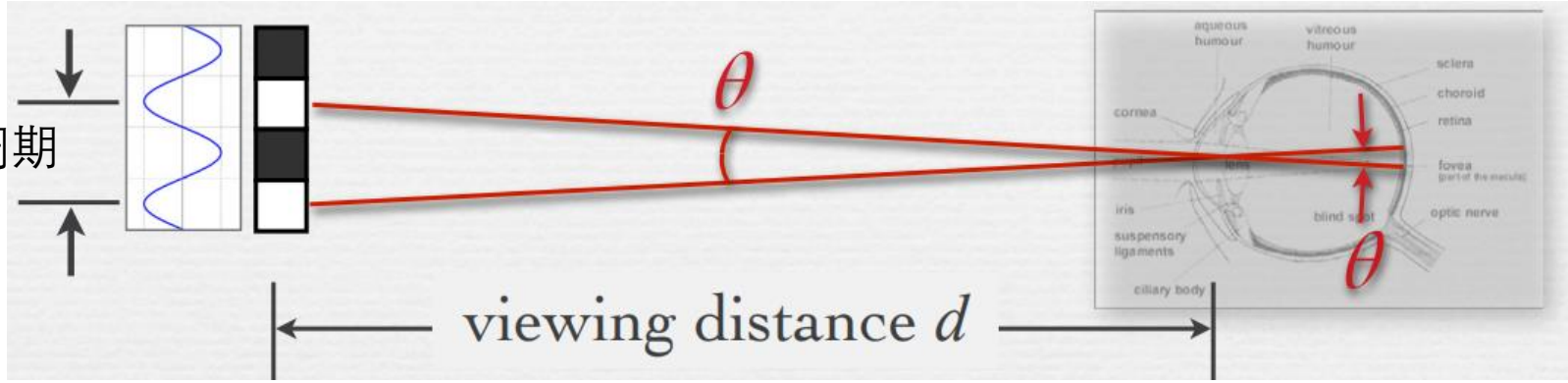


# 推荐阅读

- 推荐阅读： https://www.csc2.ncsu.edu/faculty/healey/PP/
- C. Healey and J. Enns, "Attention and Visual Memory in Visualization and Computer Graphics,", doi: 10.1109/TVCG.2011.127
- See For Yourself | Purves Lab

# 感知分辨率的计算

- 单位：周期每度（cycles/degree，cpd)
  - 正弦函数的周期
  - 视场角度

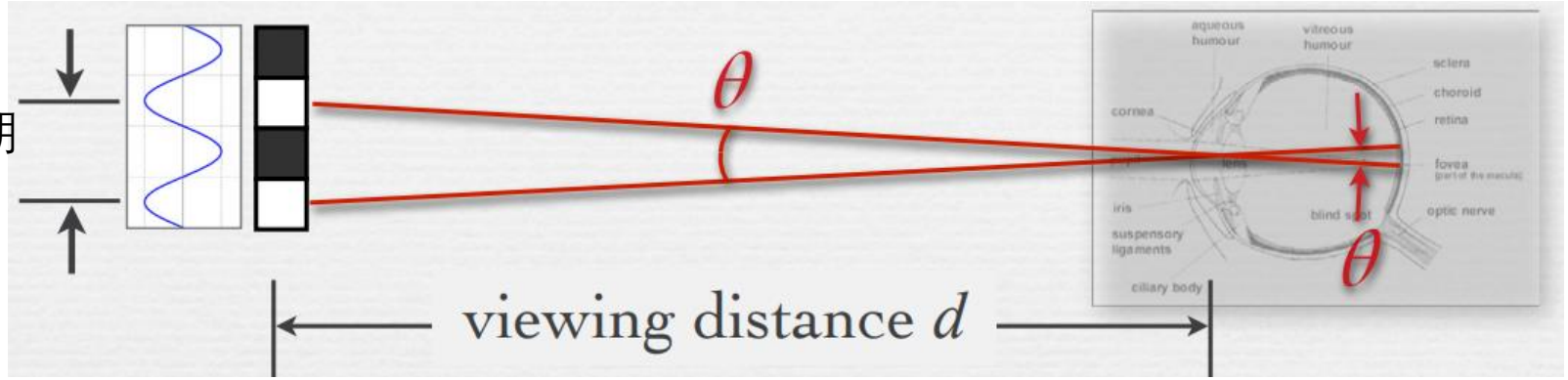



sampling-23apr13.key (stanford.edu)

# 感知分辨率的计算

- 感知分辨率 $r = \frac{1}{\theta}$，θ （角度）
  - $\theta = \arctan(\frac{p}{2d})$ （弧度）= $\frac{\arctan\left(\frac{p}{2d}\right)180}{\pi}$ （角度）
- 和设备的物理分辨率什么关系？
  - $p = \frac{2W_{dev}}{N_{px}}$， $W_{dev}$— 设备物理宽度， $N_{px}$—设备宽度上的像素数

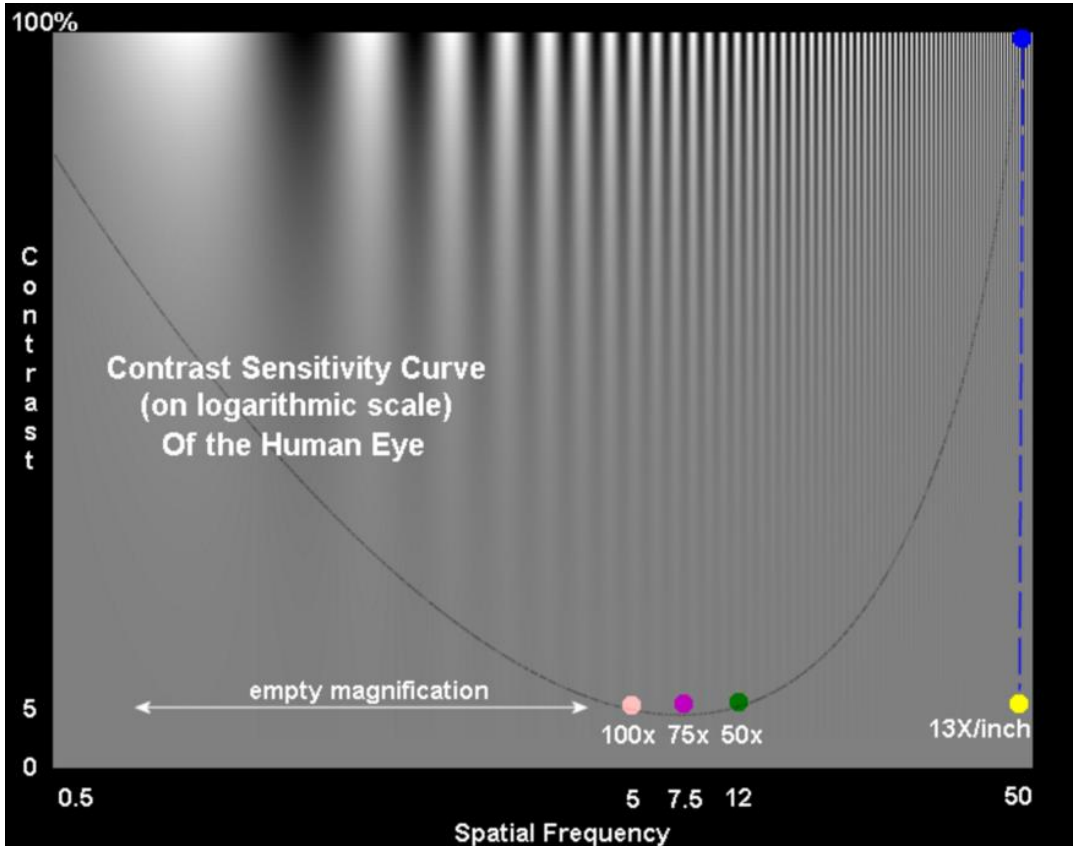
一个周期 cycle, 宽度$p$




sampling-23apr13.key (stanford.edu)

# 感知分辨率的计算

- 什么样的设备分辨率可以让人看得舒服？视网膜屏是什么？
- 回忆对比度敏感函数（contrast sensitivity function）——人眼空间阈值视觉的空间频率上限为50 cpd (visual acuity)
- 所以设备分辨率需要使得人在观看距离上达到感知分辨率$r \geq 50\text{cpd}$




http://www.cityastronomy.com/rez-mag-contrast.htm

# 感知分辨率的计算

- Example #1: Macbook Air viewed at $d = 18$”
  - 900 pixels on 7” high display, $p = 2 \times 0.0078$”
  - retinal arc $\theta = 2 \arctan(p / 2d) = 0.05°$
  - spatial frequency on retina $1/\theta = 20$ cycles per degree

- Example #2: gigapixel photo viewed at $d = 48$”
  - 20,000 pixels on 36” high print, $p = 2 \times 0.0018$”
  - spatial frequency on retina $1/\theta = 232$ cycles per degree

much finer than human acuity

- 视网膜屏的最小分辨率？
- 4K显示器？

sampling-23apr13.key (stanford.edu)