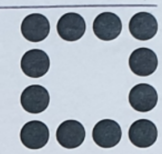
Exam 2023

1\. (3p)

Gestalt laws. Starting from this configuration of 12 circles:



(a) By moving precisely five circles, and using a Gestalt law, draw a new, static configuration that appears composed of two units.

(b) Repeat problem (a) using a different Gestalt law.

(c) Assume you are instead making a moving image. How can you undo your efforts in (a) and (b)? I.e., describe how can you make these configurations appear like one unit again?

2\. (2p)

Colors. Assume you want to use color to distinguish between five categories of data points represented by filled circles. How does the size of the symbol affect the optimal choice of color?

3\. (2p)

Acuity. Telling whether or not two line segments are aligned is an example of where human vision can achieve *superacuity* (also known as *hyperacuity*). Answer very briefly (1–2 sentences per sub-problem):

(a) What does this mean in terms of the visual system's performance?

(b) What is required of our visual system to achieve superacuity? (In addition to normal visual acuity.)

4\. (10p)

Essay. Write a (2–3 page) essay on one (but not more than one) of these two topics:

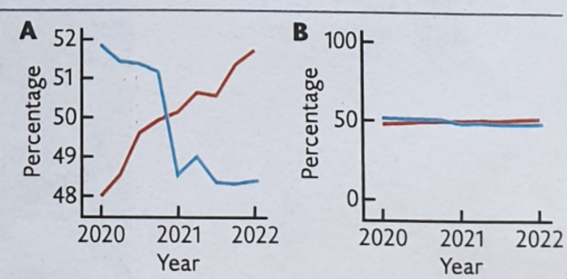
› The past, present, and future of information visualization.

› The purpose and challenges of interactive data visualization.

Imagine the reader to be a fellow student at the beginning of the course—someone with the necessary prerequisites to take this course but who has not taken it.

5\. (3p)

Statistic plotting techniques. Consider the two line plots of two variables to the right. Panel B shows the entire scale from 0 to 100%, whereas A is a 25-fold zoom.



(a) What is the main advantage of plotting the data as in panel A compared to plotting it as panel B?

(b) In what sense could it be misleading to plot the data as in panel A compared to plotting it as in B?

(c) Even though one could get the benefits of both panels by plotting both, that could be a bad idea. Why?

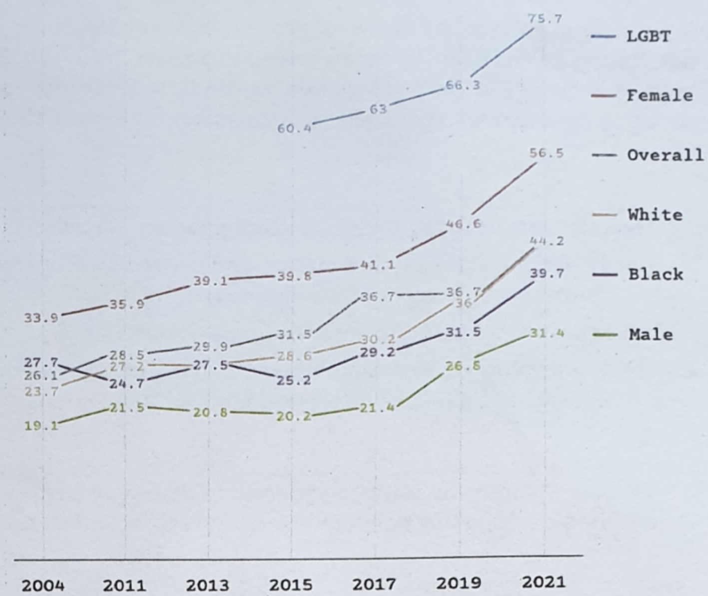
6\. (5p)

Glyph design.

(a) What are pre-attentive visual features, and why are they important in visualization? Explain and demonstrate by drawing at least four distinct pre-attentive visual features.

(b) Design a glyph to illustrate three socioeconomic variables of Finnish municipalities—population (varying between 100 and 650,000), municipal tax rate (ranging between 16% and 24%), and age distribution (percentages in three age classes). One should perceive the features as efficiently as possible, and it should be possible to position several glyphs in different geographic positions on a map. Discuss your design choices from the viewpoint of human perception and the properties of the resulting visualization.

7. (2p) **Visualization principles.** The plot to the right shows the fraction of youth who experienced symptoms of depression. Mention at least two weaknesses of the plot and how one could improve them.

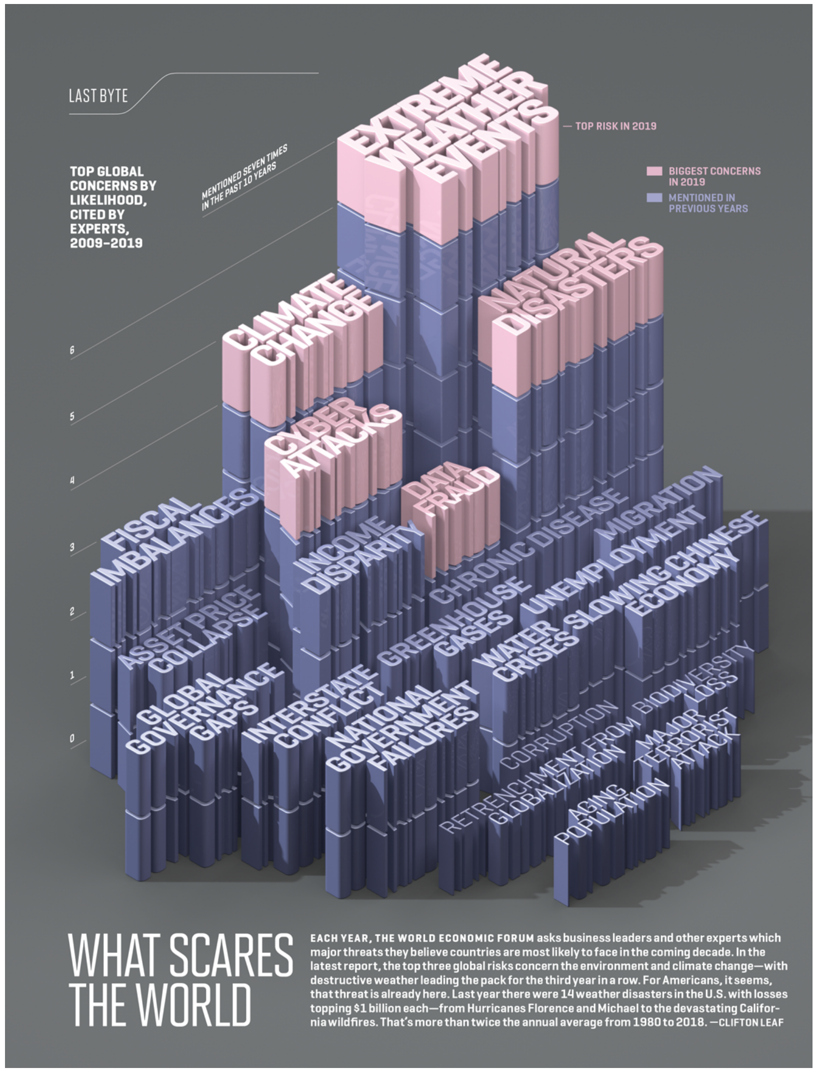


8. **Visualization principles.**

(3p)

(a) Discuss briefly how this infographic fails to "communicate complex ideas with clarity, precision and efficiency" (Tufte's definition of graphical excellence).

(b) Construct a question that would take significantly longer to answer with this visualization compared to if the data was presented in a simple bar graph.



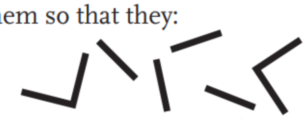
Exam 2022

1. **Gestalt laws.** Sketch arrangements of these six shapes by rotating and displacing them so that they:

(2p)

(a) Appear as much as possible as one unit.

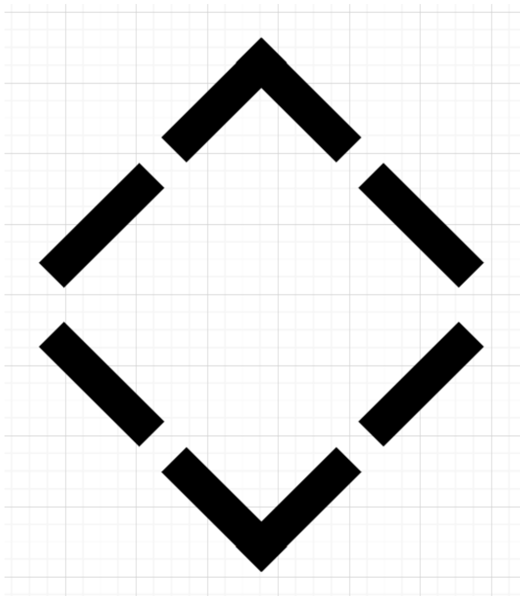
(b) Appear as much as possible as two units.



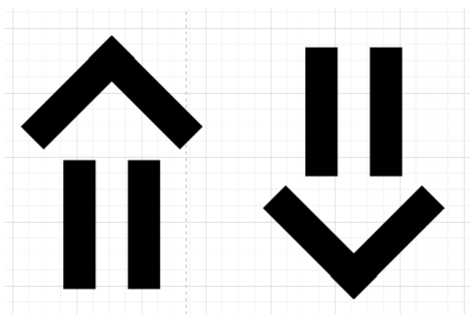
The shapes must not overlap, and the gap between them should be roughly the same (about the width of the lines). There is no need to write an explanation—we will grade only your sketch.

Gestalt laws. Sketch arrangements of these six shapes by rotating and displacing them so that they:

(a) Appear as much as possible as one unit.



(b) Appear as much as possible as two units.

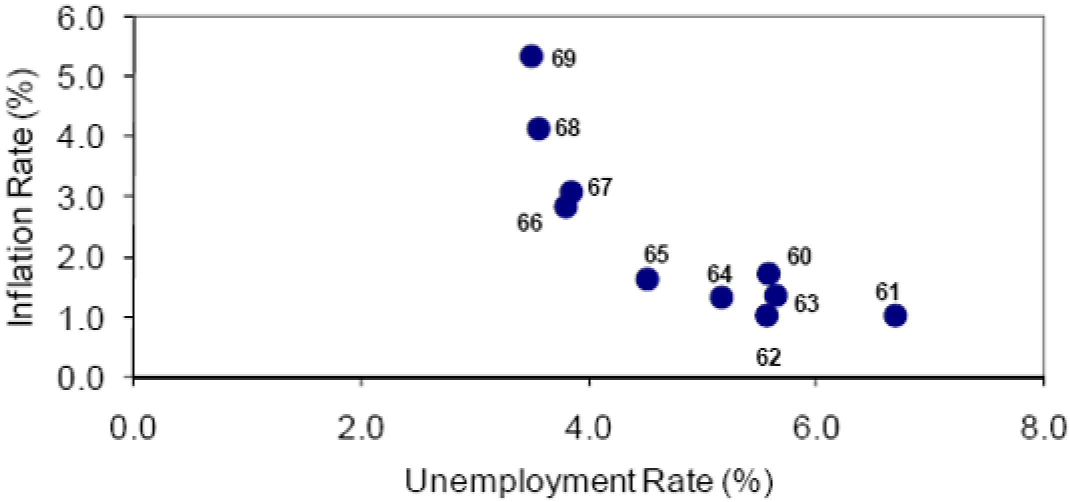


The shapes must not overlap, and the gap between them should be roughly the same (about the width of the lines). There is no need to write an explanation—we will grade only your sketch.

2. (4p) **Colors.** Imagine that you are making a scatter plot of the World's countries to show the relation between two socioeconomic indicators (say inflation rate and unemployment rate) and you want to highlight the continents of the countries (i.e., a nominal variable) by different colors. Describe (in less than a page) how you would reason when selecting colors.

Colors. Imagine that you are making a scatter plot of the World's countries to show the relation between two socioeconomic indicators (say inflation rate and unemployment rate) and you want to highlight the continents of the countries (i.e., a nominal variable) by different colors. Describe (in less than a page) how you would reason when selecting colors.

The graph should be looking like this, except that instead of the number (69, 68 etc), it is the country name and each point is colored differently according to the continent the country is in



• For nominal data (colored symbols represent continents of each country), we need to ensure the following when choosing colors for labels:

• color blindness (avoid red-green distinctions): if the nominals contain red color, they must not contain the green-shaded color and vice versa

• distinctiveness: Colors should be as distinctive as possible. For example, there are 6 inhabited continents on Earth, so there should be 6 distinctive colors (They must share unique hue).

• maximal contrast with the background. If the background is white and the color is weakly reflective against the white background (green, yellow, etc), I would consider adding a black border around the datapoint to make them more noticeable. In contrast, if the background is black and the color is weakly reflective against the black background (blue, gray, etc), I can add a white border around the datapoint.

Intensity: We want to choose colors that are intense enough to be easily distinguishable, but not so intense that they are overwhelming.

Saturation: We want to choose colors that are saturated enough to be easily distinguishable, but not so saturated that they become distracting.

Contrast: We want to choose colors that have high contrast with each other to ensure that they can be easily differentiated.

• preattentive processing: human eyes can rapidly distinguish between 5-10 distinct colors, and there are 6 continents, so preattentive processing is guaranteed

• field size: I would consider a size of the marker point to be proportional to the ticks along the x-axis and y-axis, such that the graph does not cluster nor sparsely scattered. If the marker size is too small, people may suffer from small field color blindness and cannot read the colors.

• convention: the graph should conform to the current culture/country that this graph is presented to. For example, red is the strongest color, so it should be assigned to the continent whose country this graph is presented in. This way, the main viewers can pick out how their continental countries perform against other countries in other continents regarding the unemployment-inflation rate.

Consistency: We should aim for consistency in the use of colors across different charts or graphs to ensure that readers can easily compare data across different visualizations. This means the above settings should be universally true in different contexts

3. (4p) **Factors affecting visual search.** Consider strings of around 90 non-white letters, numbers, and common symbols containing one "**5**". Assume it is typeset with a standard sans-serif font (Helvetica, Arial, etc.) in a fixed size and weight, like this example:

hFR9L.wH7kLJN2gs-JSp---+-hdh–}ooo5ooooemz2w4$asDG$dfjsky8bK[][[[[[[[11!!b3jfdKLSlli{Bhd

(a) Describe at least three ways to make a string where the "**5**" is more hidden from visual search than in the above example.

(b) Describe a string where it would as easy as possible to spot the "**5**".

Answer with general principles. You can make example strings to illustrate your points, but not longer than five symbols.

Factors affecting visual search. Consider strings of around 90 non-white letters, numbers, and common symbols containing one "5". Assume it is typeset with a standard sans-serif font (Helvetica, Arial, etc.) in a fixed size and weight, like this example: hFR9L.wH7kLJN2gs-JSp---+-hdh–}ooo5ooooemz2w4$asDG$dfjsky8bK[][[[[[[[11!!b3jfdKLS|li{Bh d This string has 3 colors: blue, purple and black. You are given the knowledge that all 5s are colored black, while the rest are colored randomly in any 3 colors. (a) Describe at least three ways to make a string where the "5" is more hidden from visual search than in the above example. (b) Describe a string where it would as easy as possible to spot the "5". Answer with general principles. You can make example strings to illustrate your points, but not longer than five symbols

(a) To make the "5" more hidden from visual search, we could:

1. Use colors that are more similar to black in hue or brightness, such as dark gray, for the other characters. This would make the black "5" blend in more with the surrounding characters and be harder to distinguish. If possible, color all characters as black. Human visual system is good at picking contrast, so low contrast would make it harder to spot

2. Increase the number of colors used in the string. By using more colors, the visual system would have to process more information, which could make the "5" harder to spot. The visual channel for color usually distinguishes at most 5-10 colors => Use like 20 colors

3. Vary the font type or font weight of the characters. By making some other characters larger or in different font style, the "5" would appear less distinct in comparison and be harder to locate.

4. One way to make the "5" more hidden would be to surround it with characters that have a similar shape or appearance, such as "6" or "S". For example: `S6S56S`.

(b) To make a string where the "5" is as easy as possible to spot, we could:

1. To make a string where it would be as easy as possible to spot the "5", I would use a color scheme where the color of the "5" stands out from the colors of the other characters. For example, if the other characters are blue and purple, using a bright color like yellow or red for the "5" would make it easier to spot

2. Place the "5" in a position of prominence, such as the center/beginning/ end of the string. This would make the "5" more salient and draw the viewer's attention to it.

3. Use a font size or weight that is different from the other characters. By making the "5" larger or bolder than the other characters, it would be easier to spot in the visual field.

4. I would surround number 5 with other chars that make it easy to distinguish between 5 and other characters. For example: `LLL5LLL`.

4. (10p) **Essay.** Write a (2–3 page) essay on one (but not more than one) of these three topics:

- Tufte's principles of data visualization.
- The use of dimensionality reduction for data visualization.
- Techniques for presenting both context and details in a visualization.

Write your essay in complete sentences. Structure it into paragraphs. Explain all of the technical terms and write it in a manner understandable to a fellow student—someone having the necessary prerequisites to take this course but has not taken it.

<In Infoviz Essay>

5. (5p) **Glyph design.**

(a) What are pre-attentive visual features, and why are they important in visualization? Explain and demonstrate by drawing at least four distinct pre-attentive visual features.

(b) Design a glyph that shows four features (temperature, air pressure, wind speed, and wind direction) for a location on a map and demonstrate it by a drawing. One should perceive the features as efficiently as possible, and it should be possible to position several glyphs in different geographic positions on a map. Discuss your design choices from the viewpoint of human perception and the properties of the resulting visualization. What are the concepts one needs to take into account?

(a) What are pre-attentive visual features, and why are they important in visualization? Explain and demonstrate by drawing at least four distinct pre-attentive visual features.

Pre-attentive visual features refer to the visual cues that our brains automatically process before we focus our attention on a specific object or area. These cues are important in visualization because they help viewers quickly identify patterns, relationships, and anomalies in large amounts of data. By leveraging pre-attentive visual features, visualization designers can create more effective and efficient visualizations that convey information quickly and accurately.

Here are four distinct pre-attentive visual features:

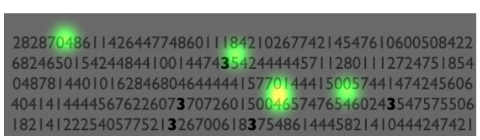
Color: Color is one of the most powerful pre-attentive visual features, and can be used to highlight specific data points or draw attention to certain areas of a visualization. For example, a heat map might use red to indicate high values and blue to indicate low values, making it easy to quickly identify patterns in the data.

Size: Changes in size can also be used to highlight specific data points or draw attention to certain areas of a visualization. For example, a bubble chart might use bubble size to indicate the magnitude of a data point, making it easy to quickly identify outliers.

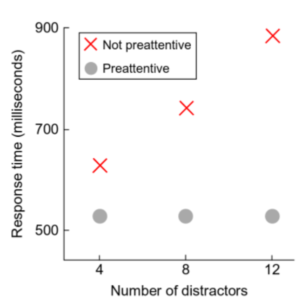
Orientation: Changes in orientation can be used to create contrast and draw attention to specific areas of a visualization. For example, a bar chart might use horizontal bars instead of vertical bars to make it easier to compare the lengths of the bars.

Shape: Changes in shape can also be used to create contrast and draw attention to specific areas of a visualization. For example, a scatter plot might use different shapes to represent different categories of data, making it easy to quickly identify patterns in the data.

Pre-attentive processing



- Some visual objects are processed pre-attentively, before the conscious attention
- Pre-attentive features "pop out"
- Pre-attentive processing speed is independent of the number of distractors
- Processing speed of non-pre-attentive features is slower and the speed decreases as the number of distractors increases (i.e., you must go through all numbers to find 3s)



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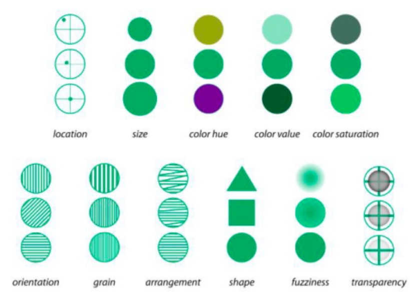
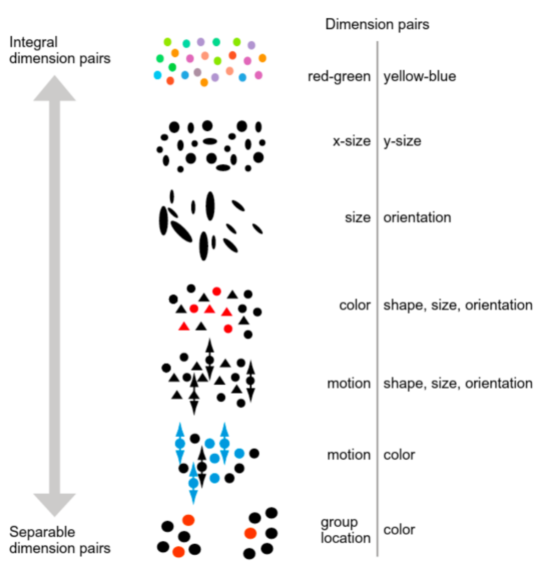
Pre-attentively distinct properties

- Try to find the right-slanted line on the right
- Pre-attentive symbols become less distinct as the variety of distractors increases
- For maximum pop-out, a symbol should be the only object in a display that is distinctive on a particular feature channel
  - e.g., it might be the only item that is colored in a display where everything else is black and white

- Glyphs are symbols used to represent multivariate data
- A single glyph corresponds to one sample in a data set
- Data values are mapped to the visual properties of the glyph
- **How to design a glyph so that the data values can be perceived pre-attentively?**

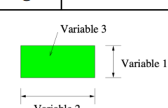


Mackinlay 1986, https://doi.org/10.1145/22949.22950



- All channels are not independent
  - try to use separable channels
  - in practice the number of channels to be used at once is limited
- If we want pre-attentive processing, we typically have 4-8 resolvable steps in each dimension (e.g., the number of size steps we can easily distinguish is ~4)

Visual variable	Dimensionality
Spatial position	3 (X, Y, Z)
Color of glyph	3
Shape	2-3?
Orientation	(1-)3
Surface texture	3
Motion coding	2-3?
Blink coding	1



(b) Design a glyph that shows four features (temperature, air pressure, wind speed, and wind direction) for a location on a map and demonstrate it by a drawing. One should perceive the features as efficiently as possible, and it should be possible to position several glyphs in different geographic positions on a map. Discuss your design choices from the viewpoint of human perception and the properties of the resulting visualization. What are the concepts one needs to take into account?

• Temperature: encoded with colors using interval sequence of different hues
Colors changes should perceptually reflect the differences in the temperature. The color scale should be based on a uniform color space or clearly defined (discretized) color steps should be used. For example, I can use blue as temperature -20 to 0, black as 0 to 20 and red as 20 to 40 celsius degrees

• Air pressure: encoded with colors from the temperature with luminance channel added. Low pressure means high luminance (white) and high pressure means low luminance (black). Human visual is good at contrast sensitivity. The human visual system is adapted to illumination levels of six orders of magnitude. However, the absolute illumination levels are essentially ignored. Therefore, using the relative luminance is enough for this case.

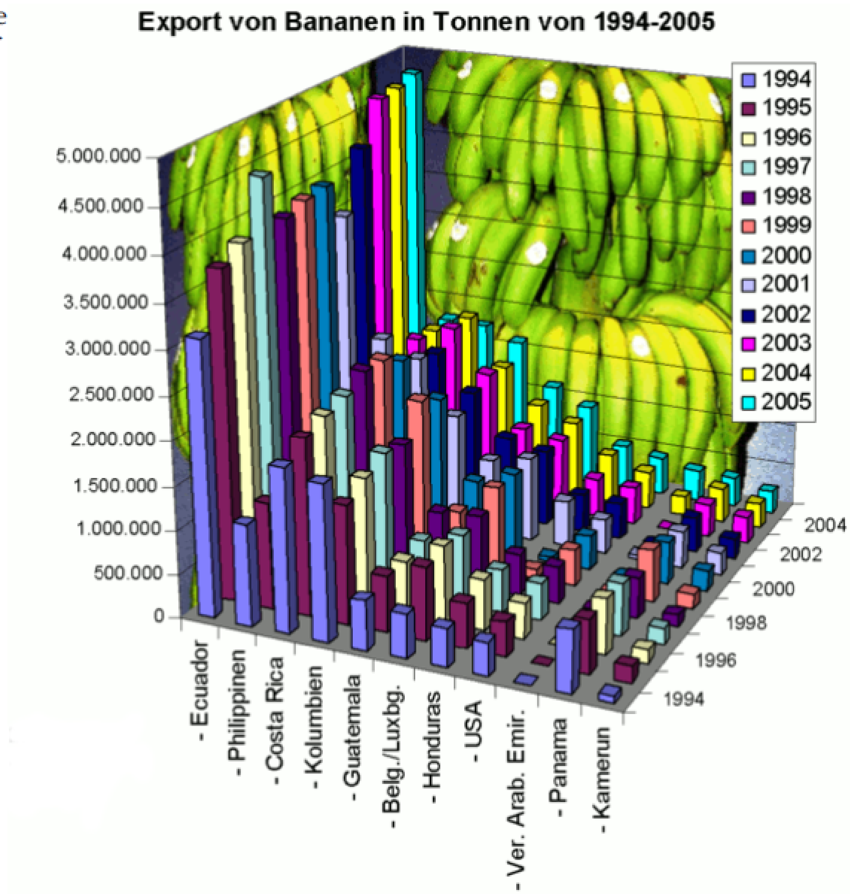
• Wind speed: encoded with size of the circular node. Humans tend to associate quantity to size of the glyph. However, correct proportions must be guaranteed to have 0 lie factor

• Wind direction: encoded with an arrow (motion). In semiotics of graphs, arrows is a universal symbol for direction in human perception.

6. (5p) **Visualization principles.** The figure to the right visualizes the export of bananas from different countries over 12 years. (The text is in German, but you don't have to understand it.)

(a) Describe at least three ways that it violates the design principles taught in class.

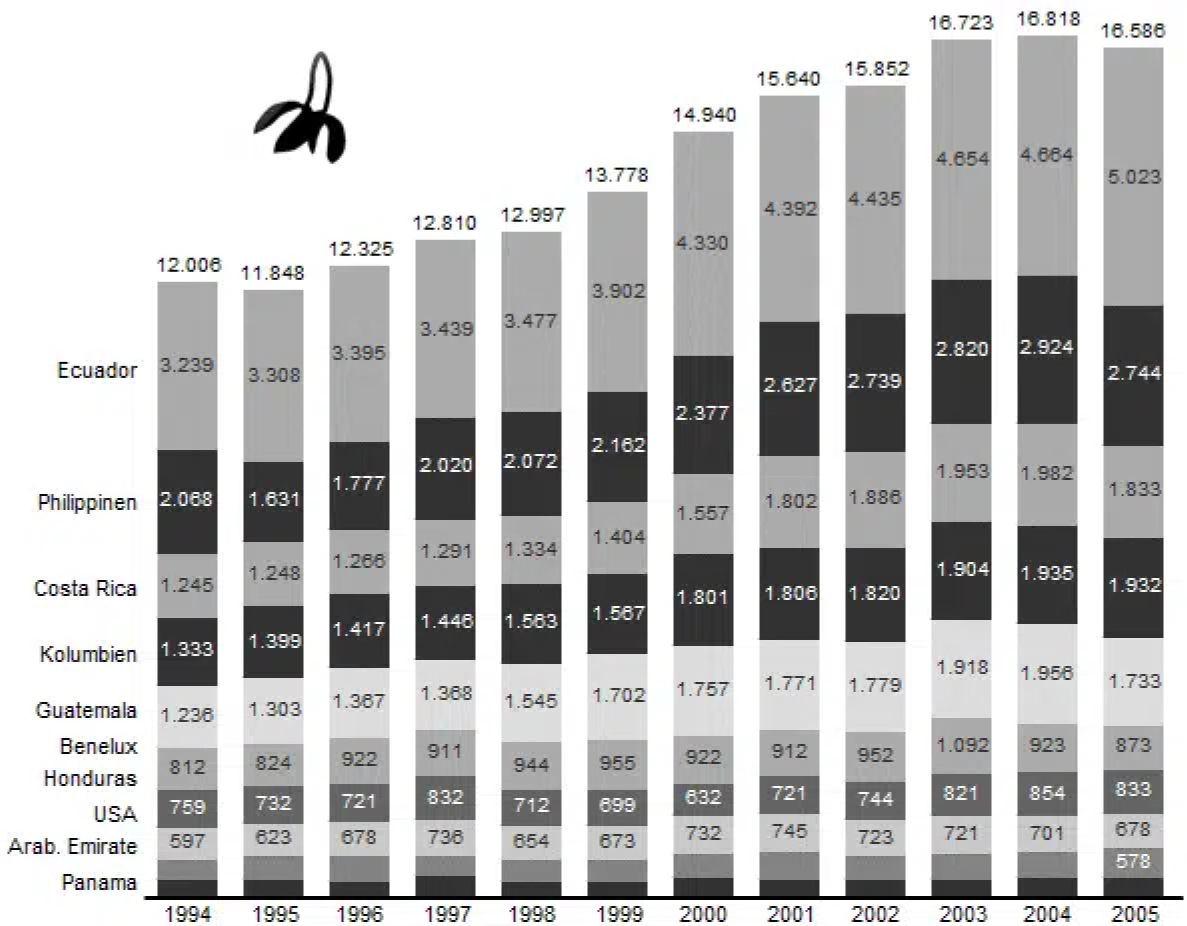
(b) Describe and sketch how you could make a better visualization of this data.



(a) Describe at least three ways that it violates the design principles taught in class.
Tufte's principles:

- Chartjunk violated: background of banana has no meaning except to decorate
- Redundant data-ink: the year labels on the top right corner simple repeat the y-axis of the year in the 3D figure.
- The 3D figure is simply unjustified. This figure makes it hard to read the banana tonnes values, causes occlusion as many bars are hidden behind others, and also there can be some perspective error, like in Arab Emirates, all the bars is simple a square on the 2D picture, which is meaningless in deciphering the values
- The color labeling is also confusing. The countries should be the one to be labeled (a color for a country) as they are the main targets for comparison. However, in this graph the year is labeled instead with different colors, which make each country have dozens colors to refer from each year.

(b) Describe and sketch how you could make a better visualization of this data.
The graph can simply be achieved with a simple stacked bar chart, where the x-axis is the year and the y-axis is the banana in tonnes, with each country stacked on another. Greyscale is enough here as there is no need to read values for the country nominal label



Exam 2021

Question 1: Concepts

Briefly explain the following concepts, and describe how they are used (or otherwise are relevant) in information visualization:

(a) Gibson's affordance theory

(b) visual acuity

(c) box plot

(d) semiotics of graphics

(e) re-expression

(f) gamut

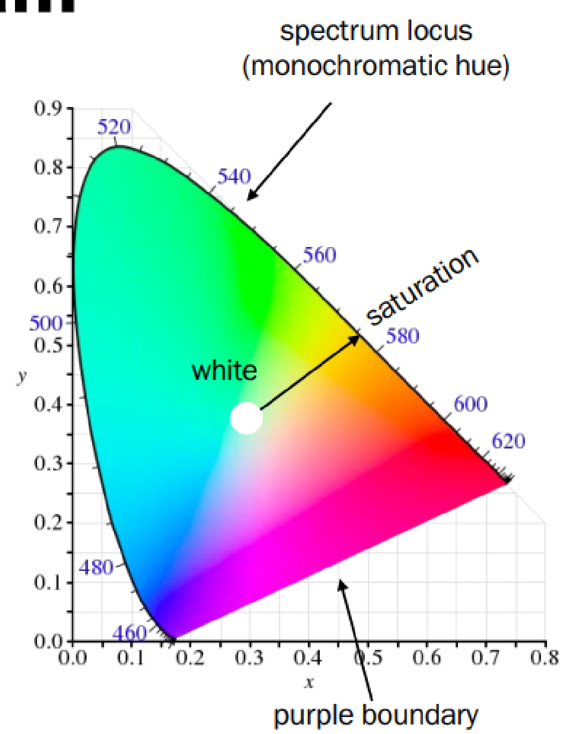
Instructions for question 1. Write in full sentences. Concept definitions should give a precise meaning of a term where available, or mention the most important aspects of a broad concept if a precise definition is not available. Concise definition of a single concept typically requires a few lines, written in a readably sized font/handwriting.

a) Gibson's affordance theory proposes that the environment and its objects have inherent affordances or possibilities for action that are perceived by individuals based on their past

experiences and context. In other words, the environment provides cues or information to individuals that guide their behavior and interaction with the world.
• Gibson’s theory suggests building interfaces that ‘beg’ to be operated so affordances are perceptually evident to the user, making the user’s task easier
b) visual acuity <discussed in Exam 2019>
b) CIEXYZ and CIELUV are color spaces used in color science. CIEXYZ is a three-dimensional color space that represents all visible colors using three color matching functions. CIELUV is a modification of CIEXYZ that includes lightness (L), chromaticity (u), and chromaticity (v) dimensions, which allow for more accurate and perceptually uniform color measurements.

CIE xyY chromaticity diagram

- All colors on a line between two colored lights can be created by mixing these two colors
- Any set of three colored lights specifies a triangle. All points within the triangle can be represented as a mixture of the given lights.
- All realisable colors fall within the spectrum locus (the set of chromaticity coordinates representing single wavelength colors)
- The purple boundary is the line connecting the chromaticity coordinates of the longest and shortest visible wavelengths
- The chromaticity coordinates of equal-energy white are 0.333, 0.333
- Excitation purity (saturation) is a measure of the distance along the line between a pure spectral wavelength and the white point



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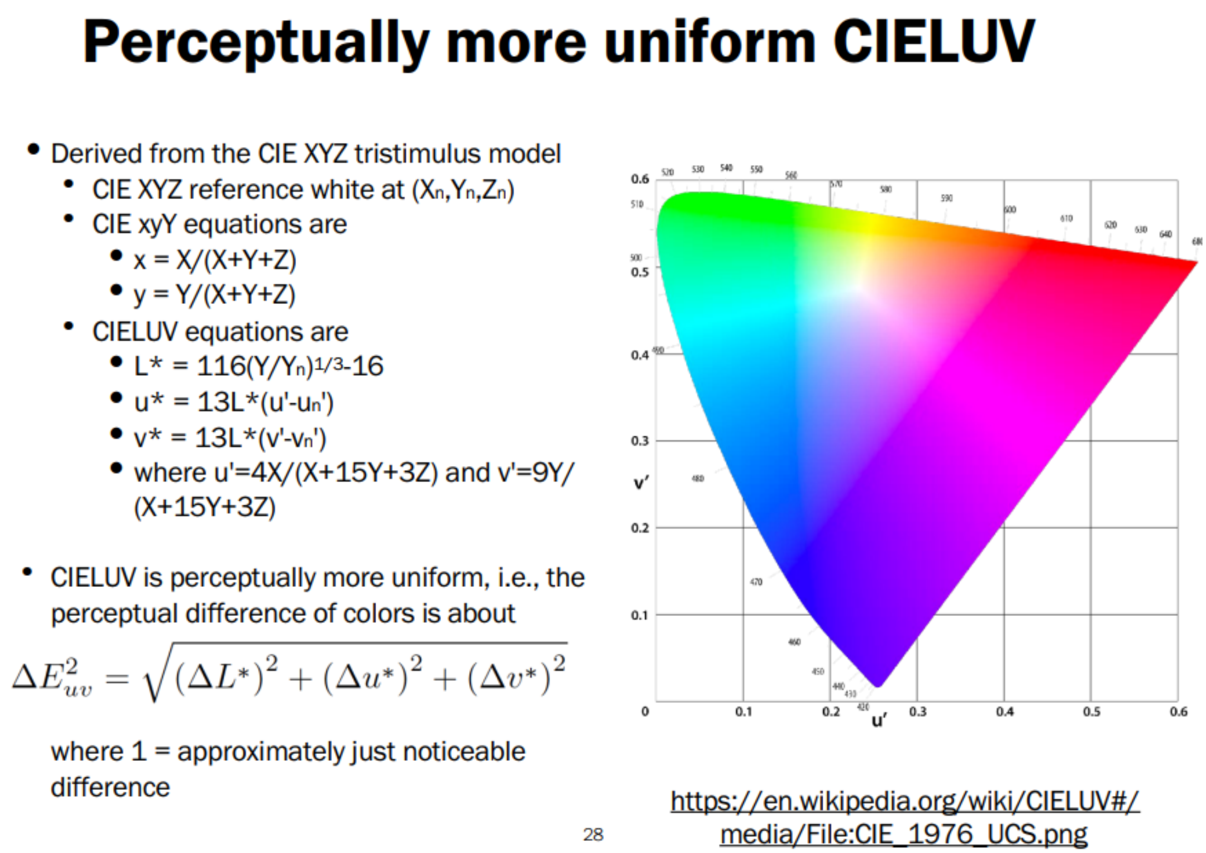
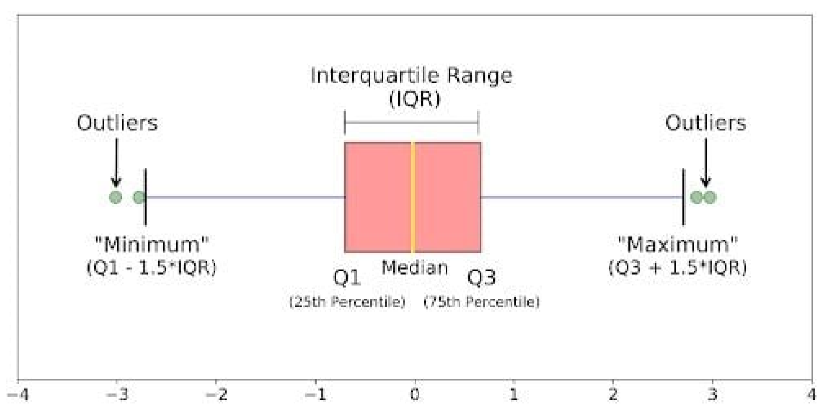


c) A box plot is a graphical representation of a dataset that shows the distribution of the data based on quartiles. It consists of a box that spans the interquartile range (IQR) of the data, with a line in the middle that represents the median. Whiskers extend from the box to the minimum and maximum values, and outliers are displayed as individual points.



d) Semiotics of graphics refers to the study of how visual elements such as symbols, signs, and codes are used to convey meaning in visual communication. It involves analyzing the visual language and grammar used in graphics and how they are interpreted by viewers.

Semiotics of graphics

- Semiotics is the study of symbols and how they convey meaning
- A visualization is made of "symbols," each conveying some information
- A picture is intended to represent something, not to be mistaken for it:
  You understand the above if you pass the mirror test: do you recognize yourself in the mirror? (Chimpanzees, orangutans, and humans pass the test, but most animals don't.)
- F. de Saussure (1857-1913) argues that
  - A symbol can be assigned any arbitrary meaning
  - Thus:
    - A symbol could have different meanings in different cultures and contexts
    - The meaning in one culture may be nonsense in another

e) Multiplots, Overview/detail, multiform, small multiples, Re-expression

Multiple plots

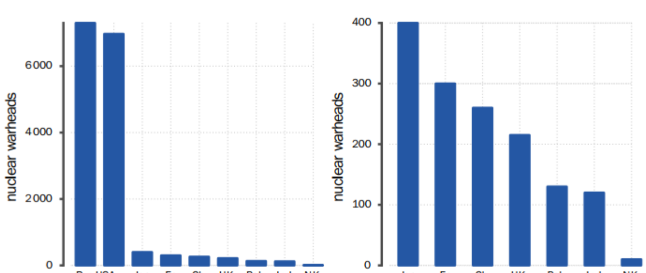
- Complex data/story is often difficult to present in one figure
  - use several figures that are somehow linked to each other to tell a story
    - pros: gives flexibility beyond a single plot
    - cons: may take a lot of space
    - cons: may create a graphical puzzle

- Common techniques for combining multiple plots
  - small multiples = trellis displays
  - overview / detail
  - multiform = multiple concurrent views

  (naming varies from author to author)

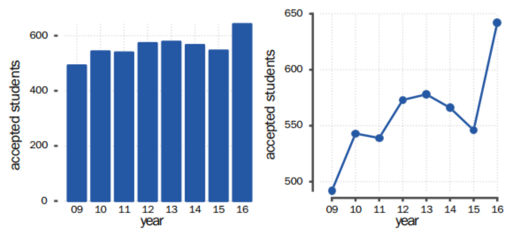
Overview / detail

- Show several graphics side-by-side
  - one graphic shows the overview of the whole data
  - other graphics show details / zoom-ins



Multiform

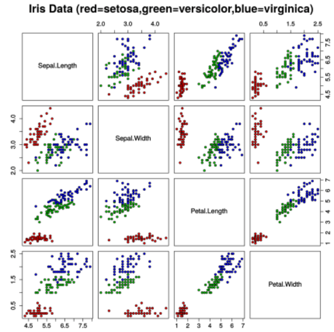
- Show the same data with different designs
  - different designs are more helpful to tell different parts of the story
  - for example, bar charts help you to compare individual values while line charts reveal trends
  - introduces redundant data-ink so needs to be justified



Small multiples (trellis)

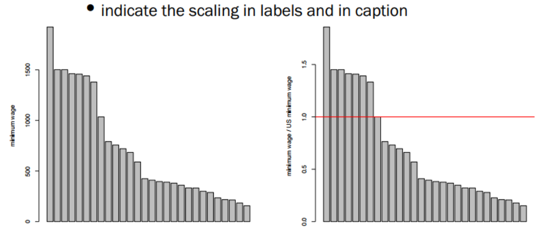
- multiple plots with the same design
- show different parts of the data
- can be arranged into a matrix or other array

Iris Data (red=setosa,green=versicolor,blue=virginica)



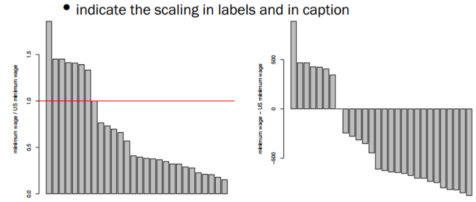
Re-expression

- relative performance to a baseline?
  - if performance relative (proportional) to a baseline b is important, then scale the y-axis by dividing with b.
  - indicate the scaling in labels and in caption



Re-expression

- difference to a baseline?
  - if the (absolute) difference to a baseline b is important, then scale the y-axis by subtracting b.
  - indicate the scaling in labels and in caption

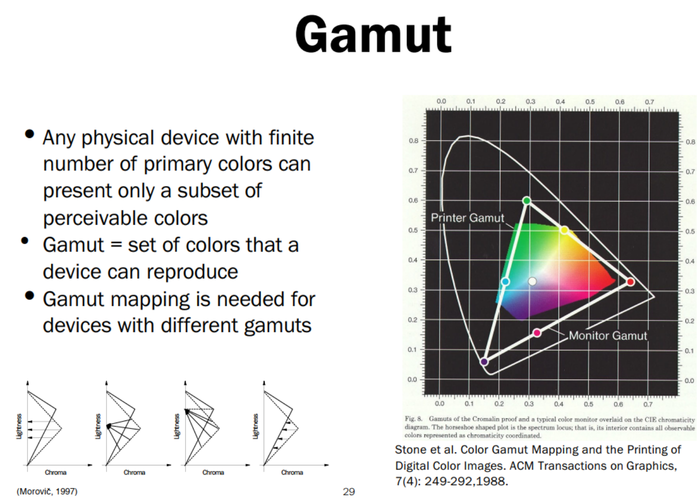


Re-expression

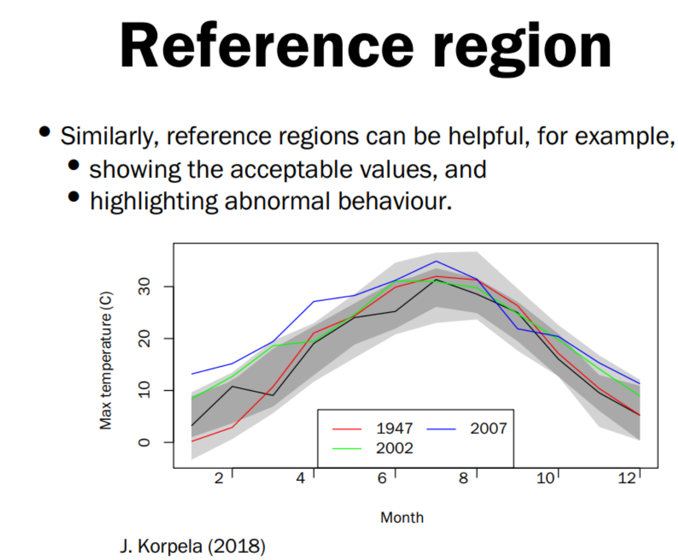
- The most relavant scale?
  - linear scale: shows absolute differences
  - log scale: if relative change (in %) is important
  - inverted scale: plot 1/y instead of y works sometimes

Re-expression is a statistical technique used to transform data to meet certain assumptions required for a particular statistical analysis. This technique involves applying a mathematical function to the data in order to change its distribution, variance, or scale. The goal of re-expression is to make the data more suitable for analysis using a specific statistical method, such as linear regression or analysis of variance. Common re-expression methods include logarithmic, square-root, and reciprocal transformations.

f) In color reproduction, the gamut, or color gamut, is a certain complete subset of colors. The most common usage refers to the subset of colors which can be accurately represented in a given circumstance, such as within a given color space or by a certain output device.



g) Reference region is a technique used in information visualization to provide context and aid in the interpretation of data. It involves including additional information or a reference point in the visualization to provide a basis for comparison or understanding. This can include benchmarks, credible intervals, historical data, or other relevant information.



h) Time series display

Time-series displays

- 7 types of graphics are useful for examining time-series:
  - Line graphs
  - Bar graphs
  - Dot plots
  - Radar graphs
  - Heat-maps
  - Box plots (and similar) for analyzing distribution over time
  - (Animated) scatter plots

Question 2: Colour in visualisation

(a) Briefly describe the opponent colour theory.

(b) There are different types of color blindness. Explain their physiological causes and their effects on visual perception.

(c) What should you take into account when making visualizations for color blind. Give examples of different cases and techniques.

(a) Briefly describe the opponent colour theory
• There are 6 elementary colors. These colors are arranged perceptually as opponent pairs along 3 axes (Hering 1920):
• black-white, red-green, and yellow-blue
• Cone signals are transformed into 3 distinct channels:
• black-white (luminance), red-green, and yellow-blue
• • People tend to divide colors to a few basic categories
• The closer the color is to the “pure color”, the easier it is to remember
•People tend to divide colors to
a few basic categories
•The closer the color is to the
“pure color”, the easier it is to
remember
•The results of an experiment in
which subjects were asked to
name 210 colors produced on a
computer monitor.
•Outlined regions show the
colors that were given the
same name with over 75% reliability

The opponent color theory is a color perception theory that states that there are six elementary colors arranged in three pairs of opposing colors: black-white, red-green, and yellow-blue. This theory proposes that cone signals in the retina are transformed into three distinct channels of black-white (luminance), red-green, and yellow-blue, which are processed in the visual system in an opponent fashion. This means that the perception of one color is influenced by the presence or absence of its opposing color. For example, red and green are opponent colors, so the perception of red is inhibited by green, and vice versa. Similarly, yellow and blue are opponent colors, and black and white represent the extremes of the luminance channel. As a result, this theory suggests that people will never perceive any colors as “reddish green” or “yellowish blue”.

The opponent color theory can be used to design color schemes that are visually balanced and aesthetically pleasing, by selecting colors that are opposite in the opponent color space. For example, opponent colors can be used for reading values from the color scale of blue-yellow colors, or encoding diverging sequences with positive and negative values.

(b) There are different types of color blindness. Explain their physiological causes and their effects on visual perception.

• most common colour blindness is red-and-green
• c. 8% of males and c. 0.5% of females suffer from pure dichromacy or anomalous trichromacy
• The most common form is to have the light response of M (green) and/or L (red)
cones to shift toward the other, which reduces range of trichromatic perception and
can have variable effects on color vision (anomalous trichromacy)
•Size of color patches affects the perception of color differences
• Small field color blindness: For very small patches inability to distinguish color differences
occurs
• Some differences are not perceived by color blind (avoid redgreen channel!)
Describe Pure dichromacy
• Pure dichromacy is due to lack of one
type of cones
• L (long-wave, red)
→ protanopia
• M (mid-wave, green)
→ deuteranopia, or
• S (short-wave, blue)
→ tritanopia
• Pure dichromacy can be seen as
collapse of the 2d chromatic space
into 1d

•Protanopia, lack of L cones
• ~ 1% males and ~ 0.01%
females

• cannot distinguish red from green

•Deuteranopia, lack of M cones
• ~ 1.5% males and c. 0.01% females
• cannot distinguish red from green

•Tritanopia, lack of S cones
• Less than 0.01%
• cannot distinguish blue from green, yellow from violet

Color blindness refers to the inability or reduced ability to perceive certain colors, most commonly red and green. The physiological cause of color blindness is a genetic mutation that affects the development or function of the cone cells in the retina that are responsible for color vision. There are different types of color blindness, including pure dichromacy and anomalous trichromacy. In total, 8% of males and 0.5% of females suffer from color blindness

Anomalous trichromacy is a type of color blindness that results from a genetic mutation affecting one or more types of cone cells, causing them to respond differently than normal. This can result in a reduced ability to distinguish certain colors or a shift in the perceived color of an object. Anomalous trichromacy is the most common form of color blindness, typically occurring in red-green color blindness. This is caused by a shift in the response of M and/or L cones, resulting in a reduced range of trichromatic perception and variable effects on color vision.

Pure dichromacy is another type that results from the complete absence of one type of cone cells. The three types of cone cells are L (long-wave, red), M (mid-wave, green), and S (short-wave, blue). Protanopia is a type of pure dichromacy that results from the absence of L cones, which affects the ability to distinguish red from green. This type of color blindness occurs in approximately 1% of males and 0.01% of females. Deuteranopia is another type of pure dichromacy that results from the absence of M cones, which also affects the ability to distinguish red from green. This type of color blindness occurs in approximately 1.5% of males and 0.01% of females. Tritanopia is the third type of pure dichromacy, resulting from the absence of S cones. Individuals with tritanopia cannot distinguish blue from green and yellow from violet. This type of color blindness is rare, occurring in less than 0.01% of the population.

Size of color patches also affects the perception of color differences for color blind individuals. For very small color patches, human vision is unable to distinguish color differences for both colorblind and non-colorblind people.

(c) What should you take into account when making visualizations for color blind. Give examples of different cases and techniques.

Color selection: Red-green opponent colors is the most common blindness. Therefore, it is important to avoid using the red-green channel when designing a color scale that requires reading relative values. Instead, we can use the blue-yellow channel for the color scale because blue-yellow blindness is very rare. If there is no need for labeling nor reading values, it is safe to just use the greyscale, as it is immune to color-blindness problem

Contrast: Increase the contrast between different colors used in the visualization to make them easier to distinguish. This can be achieved by using darker or lighter shades of colors.

Labeling: when making nominal graphs using color channel, the label for the colors should be large enough to be distinguishable to avoid the problem of small field color blindness

Question 3: Graphics design

(a) Analyze the visualizations (a)...(g) in Figure 1. What Gestalt laws are effective in each case and how do they perceptually organize the graphical elements.

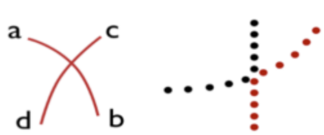
(b) In which cases above there are more than one relevant laws applicable? Do they agree on grouping the elements, and do they appear as integrable or separable features?

(a)

(b)

a) Proximity and similarity

b) Similarity

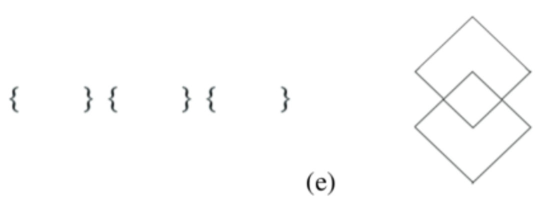


(c)

(d)

c) Continuation and similarity

d) Closure



(e)

e) Symmetry and continuation

(f)

(g)

f) figure-ground

g) Law of order and simplicity

Figure 1: Gestalt laws in action.

Gestalt laws of perceptual organization, also known as the Gestalt principles, are a set of principles that describe how humans tend to visually perceive objects in their environment as organized and unified whole. These principles were developed by the Gestalt School of Psychology in the early 20th century and have been influential in the fields of psychology, philosophy, and design.

The following are the eight main Gestalt principles:

Law of Similarity: This principle states that objects that share similar features, such as color, shape, or texture, tend to be perceived as a group or unit.

Law of Proximity: This principle states that objects that are close together tend to be perceived as a group or unit.

Law of Closure: This principle states that humans tend to perceive incomplete or fragmented objects as complete, filling in the missing information based on the context of the surrounding visual elements.

Law of Symmetry: This principle states that humans tend to perceive symmetrical objects as organized wholes.

Law of Continuity: This principle states that humans tend to perceive visual elements that follow a smooth, continuous path as a single object or group.

Law of Common Fate: This principle states that humans tend to perceive visual elements that move together in the same direction as a single object or group.

Law of Figure-Ground: This principle states that humans tend to perceive visual elements as either figures (objects of focus) or ground (background), and that these perceptions can alternate depending on context.

Law of Prägnanz: This principle, also known as the Law of Good Gestalt, states that humans tend to perceive visual stimuli in the simplest, most stable, and most complete form possible.

Question 4: Dimensionality reduction Consider the problem of embedding the 2-dimensional data set shown in Figure 2 into one dimension. The letters in the scatterplot are just for clarity and to make it easier to answer to this question: you can think them as class labels which do not affect how the embeddings and related quantities in items (a)–(c) are computed.

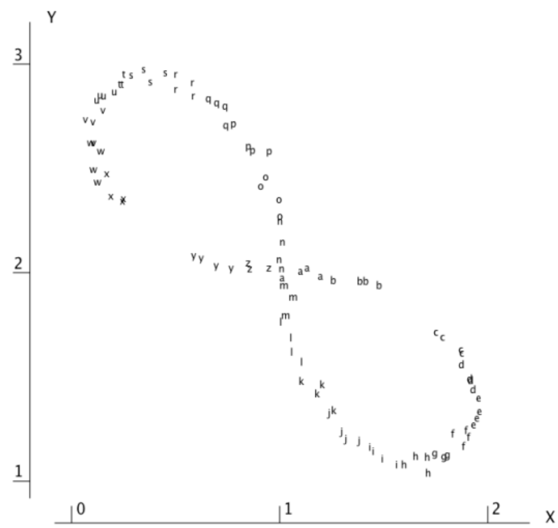
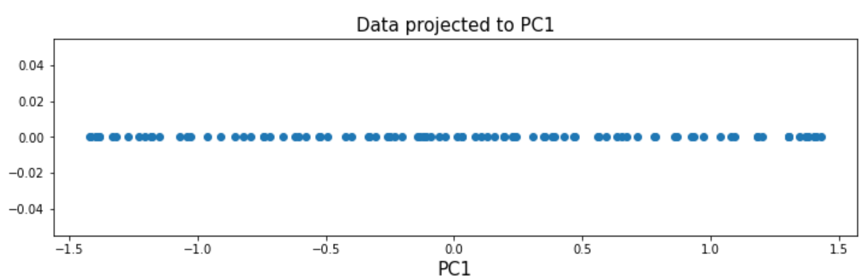
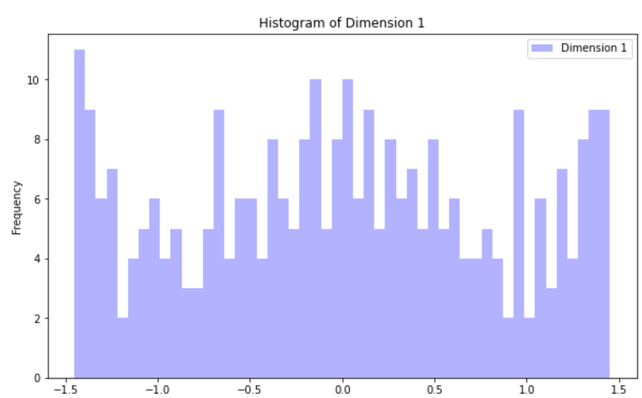
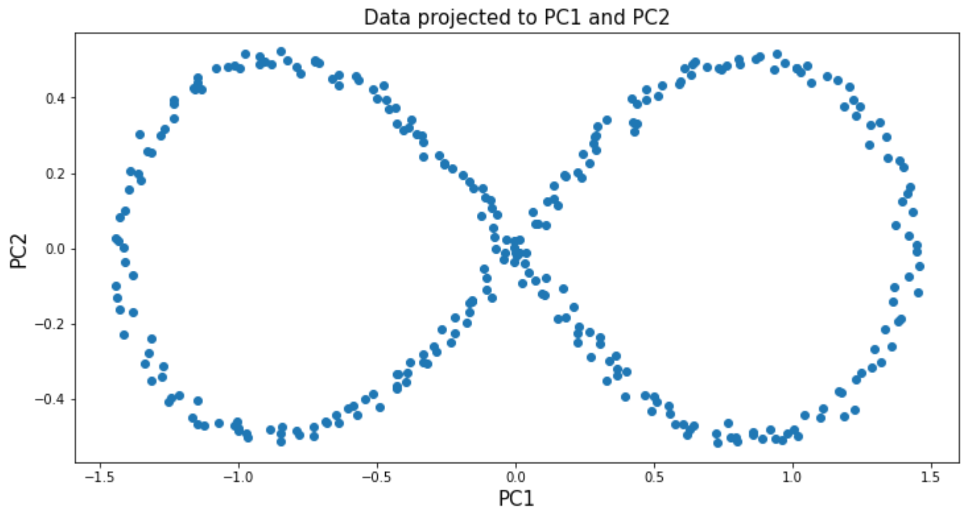


Figure 2: A 2D lemniscate data set.

(a) Make a visual sketch and explain briefly how the principal component analysis (PCA) would reduce the dimensionality of the dataset in Figure 2. What is the criterion for the PCA projection?





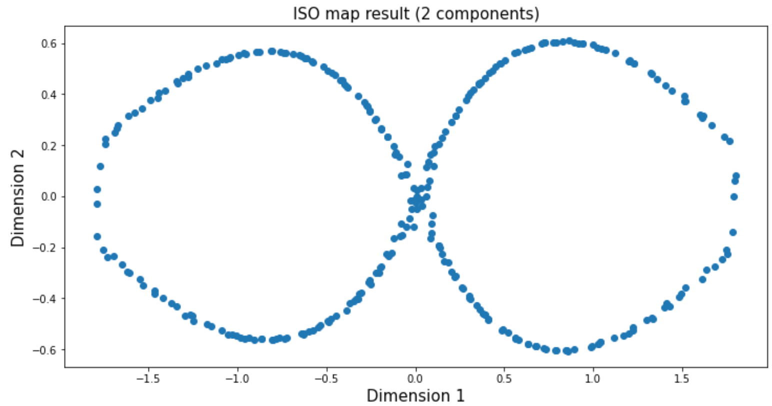


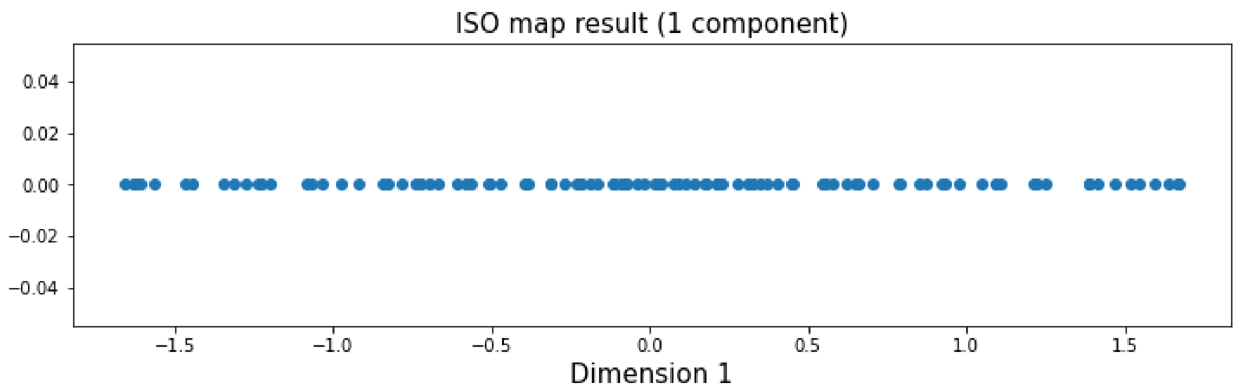
Principal Component Analysis (PCA) is a technique used to reduce the dimensionality of a dataset by transforming it into a new coordinate system that represents the original dataset in terms of orthogonal linear combinations of its variables, called principal components.

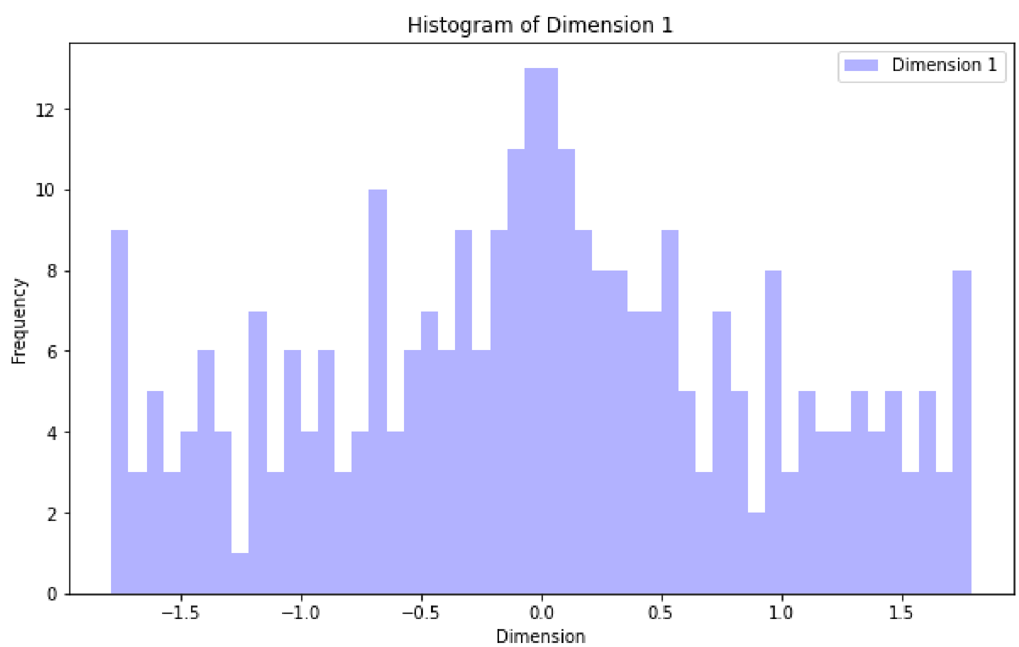
PCA reduces the dimensionality by identifying the directions of maximum variance in the data and projecting the data onto these directions, which are the principal components. The first principal component represents the direction of maximum variance in the data, the second principal component represents the direction of maximum variance orthogonal to the first principal component, and so on. By projecting the data onto the first few principal components, which capture most of the variance in the data, we can effectively reduce the dimensionality of the dataset.

The criterion for the PCA projection is to maximize the variance captured by each principal component, subject to the constraint that each principal component is orthogonal to the others. In other words, the first principal component is the direction of maximum variance in the data, the second principal component is the direction of maximum variance orthogonal to the first principal component, and so on, until we have as many principal components as there are variables in the original dataset.

(b) Make a visual sketch and explain briefly how the ISOMAP would reduce the dimensionality of the dataset in Figure 2. What is the principle of ISOMAP and how the ISOMAP embedding differs from the PCA embedding?







ISOMAP (Isometric Feature Mapping) is a non-linear dimensionality reduction technique that aims to preserve the intrinsic geometric structure of a dataset by embedding it into a lower-dimensional space while preserving pairwise distances between points.

In Figure 2, if we were to apply ISOMAP to reduce the dimensionality of the dataset, it would first construct a graph connecting each data point to its k nearest neighbors (k is a hyperparameter). Then, it would compute the geodesic distance (shortest path) between each pair of points along the graph edges. Finally, it would use these distances to embed the data into a lower-dimensional space while preserving the pairwise distances as much as possible.

The principle of ISOMAP is based on the assumption that the data lies on a low-dimensional manifold that is embedded in a high-dimensional space. By computing the geodesic distances along this manifold, ISOMAP is able to capture the underlying structure of the data and represent it in a lower-dimensional space.

Compared to PCA, which is a linear dimensionality reduction technique, ISOMAP can capture non-linear relationships between the data points. This means that ISOMAP is better suited for datasets that have complex non-linear structures, such as the "Swiss roll" dataset.

The ISOMAP embedding differs from the PCA embedding in that it can capture the non-linear structure of the data, whereas PCA can only capture linear relationships between the data points. Additionally, the ISOMAP embedding preserves the pairwise distances between the data points, whereas PCA maximizes the variance in the data along the principal components. As a result, the ISOMAP embedding is more suitable for visualization purposes, as it can preserve the local and global structure of the data while reducing its dimensionality.

(c) Define *stress*, *precision*, and *recall* (as used in dimensionality reduction). How would these three measures compare for the embeddings obtained in items (a) and (b) above. Explain how these measures would be calculated (but you do not have to compute numeric values here).

- Formally, an MDS algorithm is given as input *) the original distances p_{ij} (called *proximities*) between data points *i* and *j*
- MDS algorithm then tries to find a *k*-dimensional (usually *k*=2 or *k*=3) representation *X* for the points that minimizes the error function (called *stress*, by convention)

$$\sigma_r = \sum_{i<j} \left(f(p_{ij}) - d_{ij}(X)\right)^2$$

- ...where $d_{ij}(X)$ is the Euclidean distance between the data points *i* and *j* in representation *X* and *f* is a function that defines the MDS model (next slide).

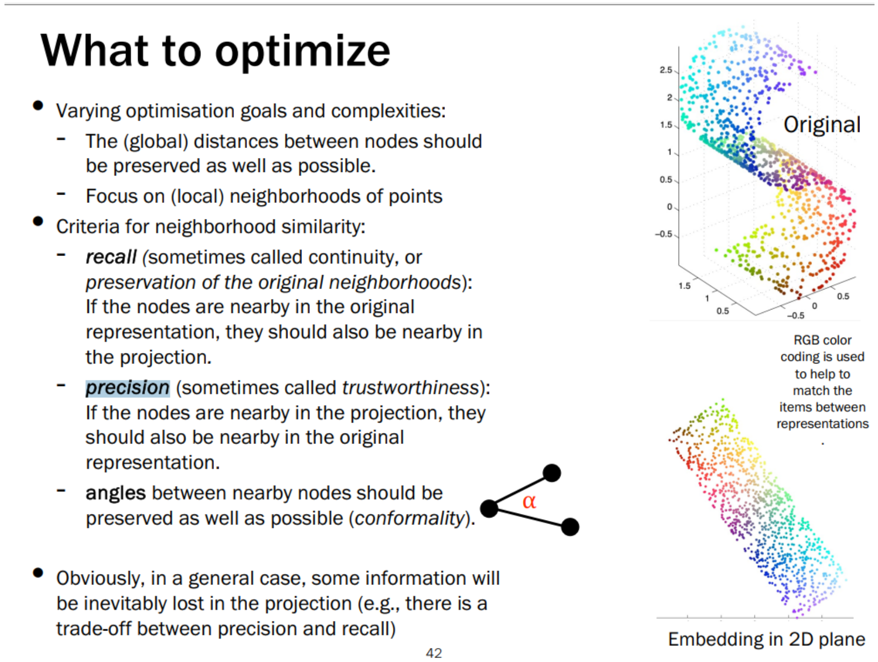
Stress is a measure of the discrepancy between the pairwise distances in the original high-dimensional space and the pairwise distances in the lower-dimensional embedding. The goal is to minimize the stress, which indicates how well the embedding preserves the pairwise distances in the original data. The stress measure is typically computed as the squared difference between the original pairwise distance and the distance in the embedding, summed over all pairs of points.

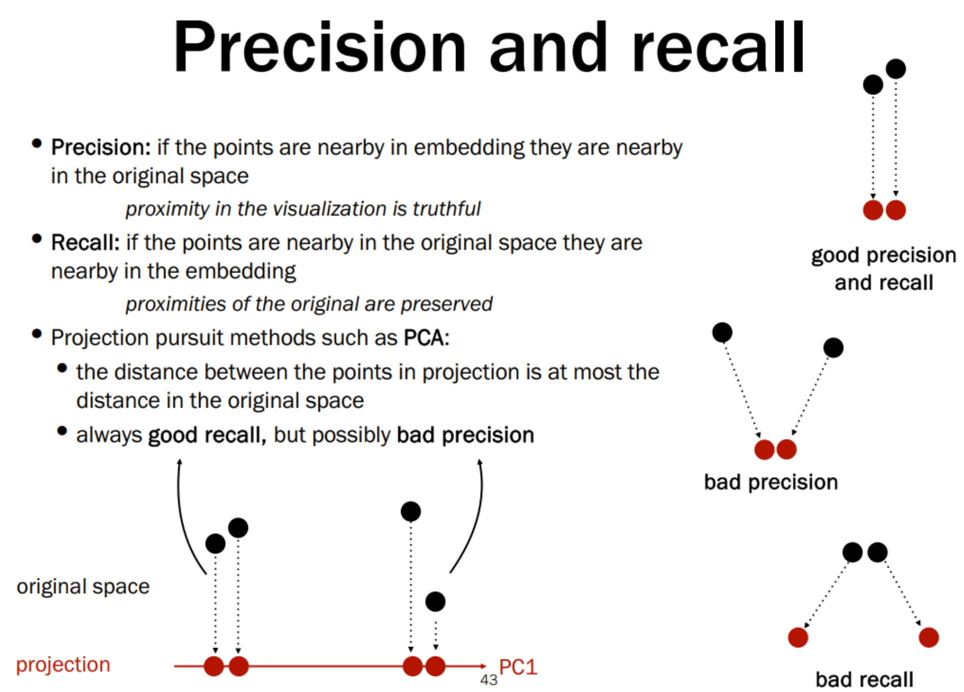
In the context of dimensionality reduction, precision refers to the fraction of true nearest neighbors in the original high-dimensional space that are also nearest neighbors in the lower-dimensional embedding. Recall refers to the fraction of true nearest neighbors in the original space that are identified as nearest neighbors in the embedding. The goal is to maximize both precision and recall, which indicate how well the embedding preserves the local structure of the data.

The three measures can be used together to evaluate the quality of a dimensionality reduction technique. A good embedding should have low stress, high precision, and high recall. However, in practice, there is often a trade-off between stress and precision/recall, as minimizing stress can lead to a loss of local structure in the embedding.

To calculate stress, one would first compute the pairwise distances between all points in the original high-dimensional space. Then, the dimensionality reduction technique would be applied to obtain an embedding in a lower-dimensional space, and the pairwise distances between the points in the embedding would be computed. The stress measure would then be calculated as the squared difference between the original pairwise distances and the distances in the embedding, summed over all pairs of points.

To calculate precision and recall, one would first identify the true nearest neighbors of each point in the original high-dimensional space. Then, the dimensionality reduction technique would be applied to obtain an embedding in a lower-dimensional space, and the nearest neighbors of each point in the embedding would be identified. Precision would be calculated as the fraction of true nearest neighbors in the high-dimensional space that are also nearest neighbors in the embedding, while recall would be calculated as the fraction of true nearest neighbors in the high-dimensional space that are identified as nearest neighbors in the embedding.





To calculate precision and recall for PCA and ISOMAP, we would follow the general procedure outlined in my previous answer, but with some additional steps specific to each technique.

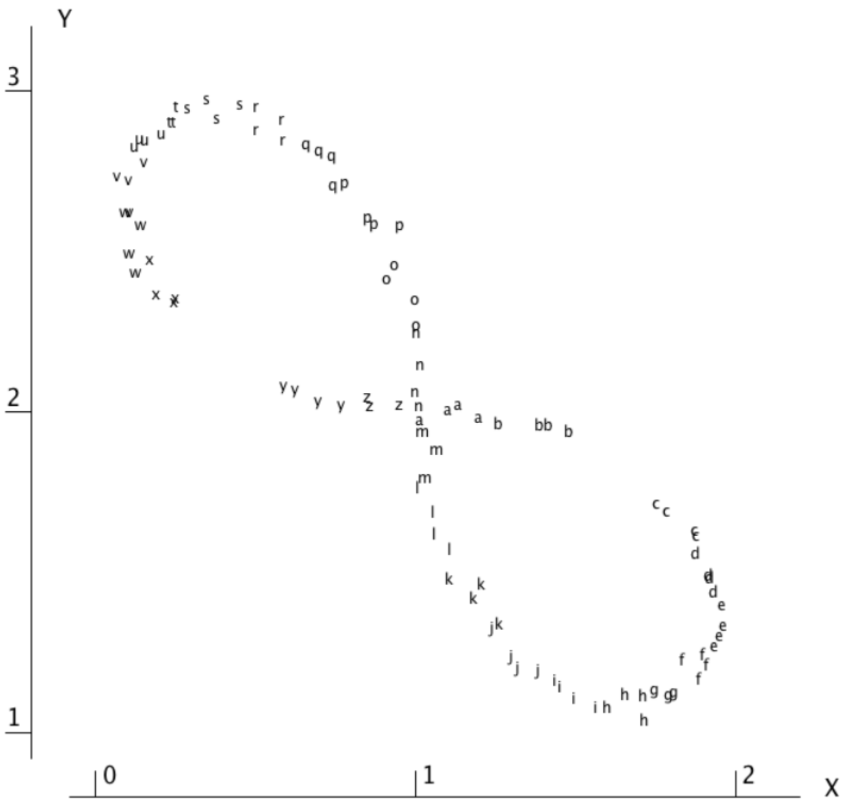
For PCA, we would first compute the principal components of the original high-dimensional space and use them to obtain an embedding in a lower-dimensional space. Then, we would compute the pairwise distances between the points in the embedding and identify the nearest neighbors of each point. To calculate precision and recall, we would compare the nearest neighbors in the embedding to the true nearest neighbors in the original high-dimensional space. Specifically, precision would be calculated as the fraction of true nearest neighbors in the high-dimensional space that are also nearest neighbors in the PCA embedding. Recall would be calculated as the fraction of true nearest neighbors in the high-dimensional space that are identified as nearest neighbors in the PCA embedding.

For ISOMAP, we would first construct a graph connecting each data point to its nearest neighbors, compute the geodesic distances between each pair of points along the graph edges, and use them to obtain an embedding in a lower-dimensional space. Then, we would compute the pairwise distances between the points in the embedding and identify the nearest neighbors of each point. To calculate precision and recall, we would compare the nearest neighbors in the embedding to the true nearest neighbors in the original high-dimensional space, just as we did for PCA.
In both cases, precision and recall would be calculated as fractions, with values between 0 and 1. Higher values of precision and recall indicate better preservation of the local structure of the data in the embedding.
PCA always good recall, but possibly bad precision
ISOMAP always good precision and recall => ISOMAP is better than PCA for this case

Question 5: Essay

Write an essay on topic “Techniques for presenting both context and details in a visualization.”.

Instructions for question 5. Write in full sentences. Structure your answer into paragraphs. Explain all of the technical terms that are used in your essay. The essay should be written in a manner understandable to your fellow student—who would have the necessary prerequisite information to take this course, but has not taken it—and who has asked to tell him or her about the topic of the essay.



Exam 2019

1. Explain terms
    a) Gibson's affordance theory
    b) CIEXYZ and CIELUV
    c) box plot
    d) Semiotics of graphics
    e) galmut
    f) Reference region

<Same as 2021. Referenced region also included in answer above>

2. Acuities

a) name and explain two acuities and super-acuities

b) How humans react to Contrast sensitivity? How this relates to acuities in a). How it changes with age?

c) If there is tv 57cm away how clearly you can see? What if it is 114cm away? What will change?

2. Acuities

a) name and explain simple acuities and superacuities

• Visual acuities are measurements of our ability to see detail, indicating limits on the information densities we can perceive. Acuity is at maximum at the center of the fovea
and acuity outside of the fovea drops rapidly. For example, we can only resolve about 1/10 of the details at 10° from the fovea.

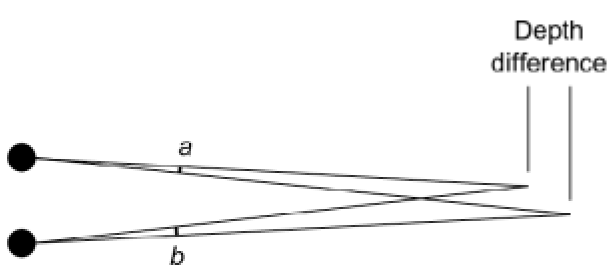
• Simple acuities are restricted by (and correspond to) the spacing of the receptor cells at the center of the fovea (angular size of cone cell ≈ ca. 20"). There are 3 types of simple acuities

point acuity (1')
the ability to resolve two distinct point targets

grating acuity(1-2')
the ability to distinguish a pattern of bright and dark bars from a uniform gray patch

letter acuity (5')
the ability to resolve letters

• Superacuity is the ability to achieve better resolution by integrating information over space (or time). There two types of superacuities
stereo acuity (10") the ability to resolve depth
Vernier acuity (10") the ability to see if 2 line segments are collinear
We can perform vernier acuity tasks with great accuracy at 10", that is to about 1/10 of a pixel



Visual acuities

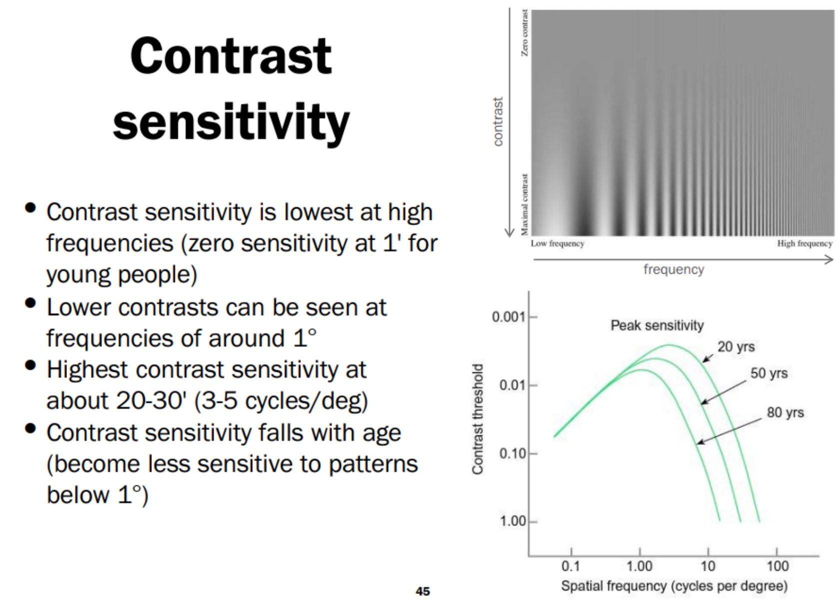
- The unit of acuity is minutes or seconds of arc
- full circle = 360 degrees = 360°
- 1° = 60 minutes of arc = 60'
- 1' = 60 seconds of arc = 60"
- For a viewing distance of 57 cm:
  - 1° = 60' = 3600" = 1 cm
  - 1' = 60" = 0.17 mm
  - 1" = 0.00028 mm

b) How do humans react to contrast sensitivity? How this relates to acuities in a). How do they changes with age?
•Eye has a lens (obeys laws of physics, no flexibility left at age of ~ 60) and the retina is like a film
Acuity and contrast sensitivity:
• Simple acuity (maximal at the fovea, ~ 1')
• super-acuities (achieved by integrating the output of several retinal receptors, 10")
• contrast sensitivity

Contrast sensitivity refers to the ability of the visual system to detect differences in luminance between adjacent areas. Humans are very sensitive to contrast and can detect differences in luminance as small as 1-2%. This ability is critical for visual perception and is involved in many tasks such as reading, driving, and navigating.

Simple acuity refers to the ability to detect the presence of a stimulus, while spatial acuity, also known as resolution acuity, refers to the ability to distinguish between two stimuli that are close together. Superacuity, or hyperacuity, is the ability to perceive details beyond the limits of resolution acuity, such as the ability to detect small deviations from a straight line or small differences in spacing.

As humans age, their contrast sensitivity tends to decrease, particularly at high spatial frequencies. This can be due to changes in the lens and other structures of the eye, as well as changes in the visual cortex. This can make it more difficult to perform tasks that require high contrast sensitivity, such as reading small print or driving at night.



c) If there is tv 57cm away how clearly you can see? What if it is 114cm away? What will change?

•The unit of acuity is minutes or seconds of arc

•full circle = 360 degrees = 360°

•1° = 60 minutes of arc = 60'

• 1' = 60 seconds of arc = 60"

For a viewing distance of 57 cm:

• 1° = 60' = 3600" = 1 cm

• 1' = 60" = 0.17 mm = 1cm/60

• 1" = 0.00028 mm

For a viewing distance of 57 cm, 1 degree (1°) of visual angle corresponds to 1 cm on the retina. Therefore, if the TV is 57 cm away, to see details with a visual angle of 1', the details would have to be at least 0.17 mm in size.

If the TV is placed twice as far, at a distance of 114 cm, the visual angle for the same details would be half, i.e. 0.5', and the size of the details would have to be at least 0.34 mm in size to be visible. This means that details would need to be larger to be resolved at a farther distance.

3. Gestalt laws
   a) What are gestalt laws and how used in information visualization.
   b) Name and briefly explain at least 6 laws.

a) What are Gestalt laws and how are they related to information visualization

Gestalt laws are principles in psychology that describe how humans perceive and organize visual information in 2D images. The word "Gestalt" comes from the German word for "shape" or "form," and these laws describe how people perceive shapes, patterns, and objects as whole entities rather than as a collection of individual parts. These laws are based on the idea that the whole is greater than the sum of its parts, and they help explain why people perceive certain patterns and arrangements in visual information.

In information visualization, Gestalt laws are important because they help designers create visualizations that are easy to understand and interpret. By understanding how humans perceive visual information, designers can create visualizations that are more intuitive and require less cognitive effort to interpret

b) List at least 6 Gestalt laws and explain them

Similarity: This law states that elements that **share similar visual properties such as color, size, shape, or texture are perceived as a group**.

Proximity: This law states that elements that are **close to each other are perceived as a group.**

Continuation: This law states that people tend to **perceive continuous, smooth curves or lines instead of discontinuous, jagged lines.**

Closure: This law states that when presented with a set of individual elements, people tend to **perceive a complete, enclosed shape or object, even if some parts of it are missing**.

Common Fate: This law states that elements that **move together** in the same direction and at the same speed are **perceived as a group.**

Figure/Ground: This law states that people naturally **perceive objects as either the foreground (figure) or the background (ground)** in a visual scene.

Symmetry: This law states that people tend to perceive **symmetric shapes** and forms as more **visually appealing and memorable than asymmetric** ones.

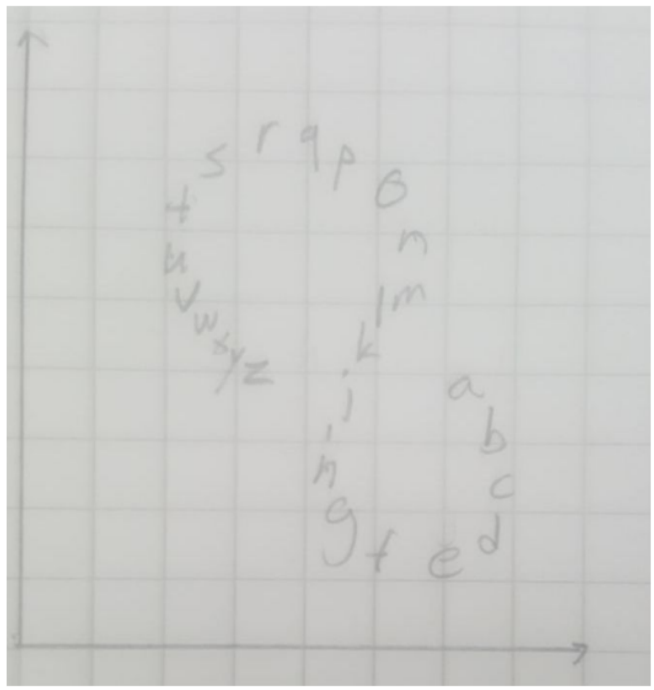
Simplicity/Prägnanz: states that people tend to **perceive visual elements in the simplest way possible in complete shapes**, with the fewest possible assumptions.

Causality describes how humans tend to **perceive cause-and-effect relationships in visual stimuli**. People tend to see one object as causing another object to move or change in some way. This perception occurs **even if there is no physical connection** between the objects or if the change is simply **an illusion** created by the way the objects are presented.
Example: x-y relationship with linear relationship, or converging time series.

4. Dimension reduction.
   a) PCA. How pca operates and what would it produce 1d picture from figure 1.
   b) How ISOMAP operates and how it would produce 1d picture from figure 1. How ISOMAP differs from PCA?
   c) Explain Stress, Precission and Recall. Witch is better for a) and b)?

5. Essay
   a) History of data graphics
   b) Color in information visualization. Guidelines and rules.

Example of Figure 1. The letters are simply data points meant to help with demonstration of the 1d transformation.



Info viz exam 21.5.2018

These are from my memory, the exam paper had to be returned

Question 1.

Explain briefly:

a) preattentive features

b) data-ink

c) ???

d) CIE XYZ and CIELUV

e) visual attention

f) reference region (visualization technique)

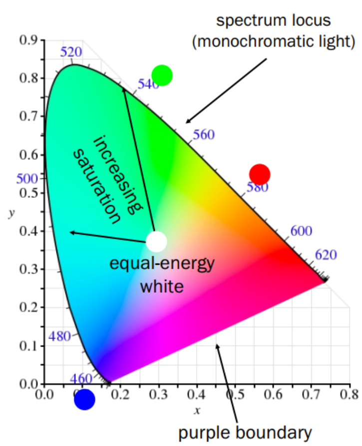
a) Preattentive features are visual properties that can be perceived instantly and effortlessly, without the need for focused attention. These include attributes such as color, size, orientation, and shape, among others. They are important in information visualization because they can be used to encode different types of data and facilitate their interpretation.

b) Data-ink is a term coined by Edward Tufte to describe the ink used in a visual representation that directly corresponds to the data being presented. This means that any ink used in a visualization that does not convey information should be avoided, as it takes up space and may distract from the relevant information.

c) CIE XYZ and CIELUV are color spaces used in color science to describe and quantify colors. CIE XYZ is based on three imaginary color primaries and is used to define all other color spaces. CIELUV is a modification of XYZ that takes into account human perception of color and includes a lightness component.

CIE xyY model: chromaticity diagram

- Colour is 3-dimensional: luminance (Y,1d) + **chromaticity (xy, 2d)**
- It can be used to present all visible colors as a combination of 3 primary colors at (x,y) coordinates (0,0), (0,1), (1,0).
- A *standard observer* is a hypothetical person whose color sensitivity is held to be that of a typical person (measurements are from prior 1931)
- **Problem 1:** primary colors (xyY) are non-physical & no combination of 3 physical colors could present all perceivable colors
- **Problem 2:** colors are perceptually non-uniform



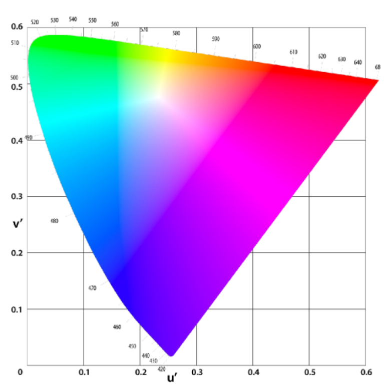
3

Perceptually more uniform CIELUV

- Derived from the CIE XYZ tristimulus model
  - CIE XYZ reference white at (X_n,Y_n,Z_n)
  - CIE xyY equations are
    - x = X/(X+Y+Z)
    - y = Y/(X+Y+Z)
  - CIELUV equations are
    - $L^* = 116(Y/Y_n)^{1/3}-16$
    - $u^* = 13L^*(u'-u_n')$
    - $v^* = 13L^*(v'-v_n')$
    - where u'=4X/(X+15Y+3Z) and v'=9Y/(X+15Y+3Z)
- CIELUV is perceptually more uniform, i.e., the perceptual difference of colours is about

$$\Delta E^2_{uv} = \sqrt{(\Delta L^*)^2 + (\Delta u^*)^2 + (\Delta v^*)^2}$$

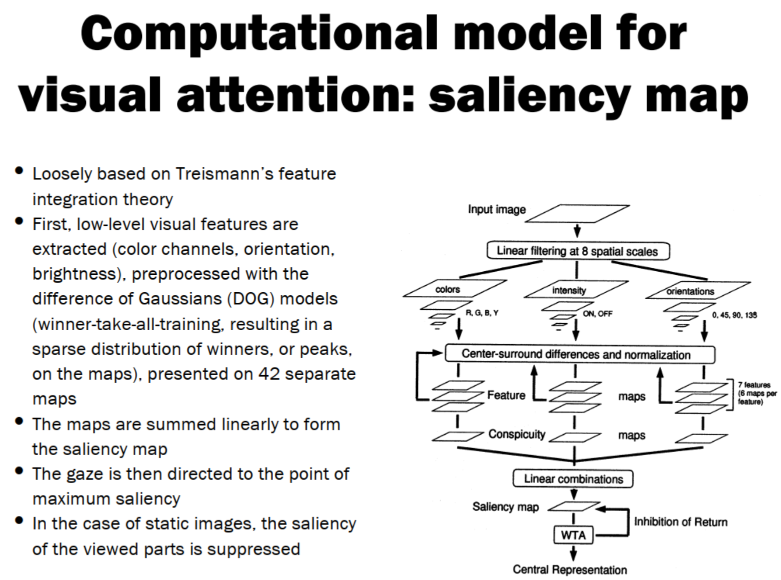
where 1 = approximately just noticeable difference



https://en.wikipedia.org/wiki/CIELUV#/media/File:CIE_1976_UCS.png

4

d) Visual attention refers to the cognitive process by which humans selectively focus their perception and processing resources on specific aspects of their visual environment. It is important in information visualization because it can affect how users perceive and interpret visual representations of data. Visual attention refers to the ability to prepare for, select, and maintain awareness of specific locations, objects, or attributes of the visual scene (or an imagined scene)

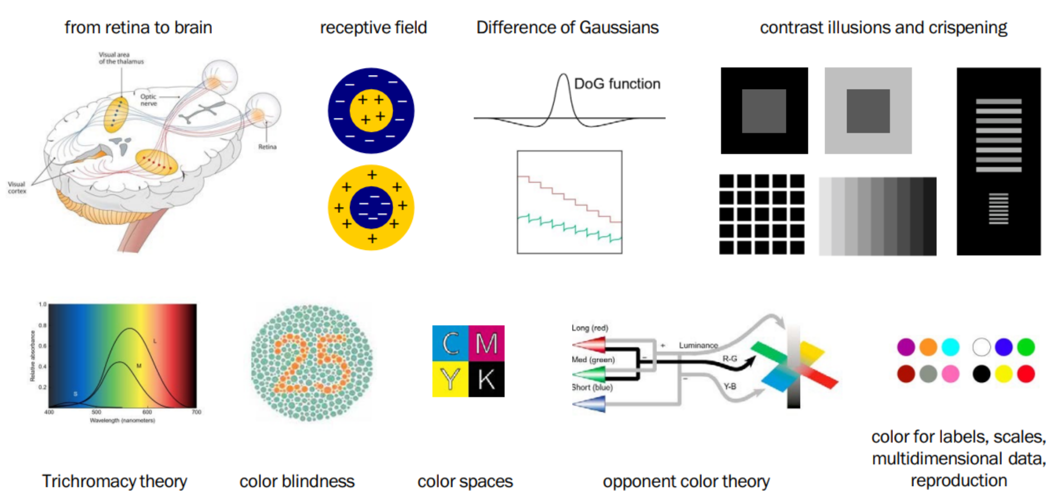


e) A reference region is a visualization technique that involves using a small, highlighted area of a larger visual field to draw attention to specific data or features. This can be useful when there is a large amount of information to be conveyed and it is important to focus attention on specific parts of the data.

Question 2.

a) Explain opponent colors theory <explained above>

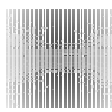
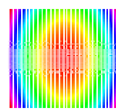
b) How can different coloring schemes be used in information visualization? Do you have to take opponent colors somehow into account?



c) Explaining pros and cons of both spectral scheme and grayscale.

- Spectrum (rainbow) scale
  - perceptually very non-uniform and not ordered
  - can create “false contours”
  - good for reading values back from the a scale
  - should not be used if the shape of the data is important

- Grayscale
  - not good for reading back values
  - shows detail and shape of the data well

	 grayscale	 spectrum
Shows detail	+++	---
Perceptually constant steps	++	---
Reading values from a scale	---	+
Show true shape	+++	---
Ordering is shown well	++	--
Good for labeling	---	++
Color-blind safe	+++	-
Shows zero point	---	--
...	?	?

Question 3 <ABOVE>

a) What are Gestalt laws and how are they related to information visualization

b) List at least 6 Gestalt laws and explain them

Question 4.

Time Series of 6 years of average day temperatures in Otaniemi. How would you visualize (give also sketches in addition to explaining in writing)

a) How would you visualize the data using superimposition

Superimposition is a technique where multiple data series are plotted on the same axis, making it easy to compare trends across them. To visualize the data of 6 years of average day temperatures in Otaniemi using superimposition, we would plot the average temperature for each day of the year on the y-axis, and the date on the x-axis. Each year would be represented by a different colored line on the same plot.

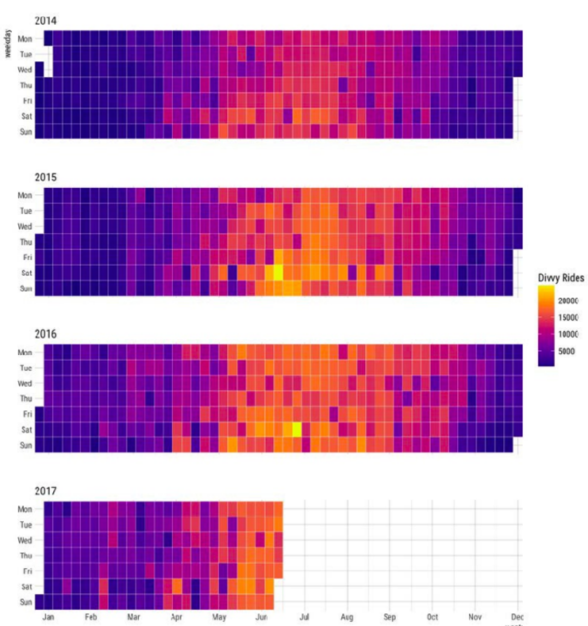
b) How would you visualize the data using small multiples

Small multiples is a technique where multiple plots of the same size and scale are used to show different parts of the data. To visualize the data of 6 years of average day temperatures in Otaniemi using small multiples, we would create six separate plots, each representing one year of data. The plots would be arranged in a grid, with each plot having the same scales.

c) Compare the pros and cons of these two techniques

The advantage of using superimposition is that it allows for easy and smooth comparison between the temperatures of each year. However, when there are too many lines in the plot, superimposition can become cluttered and difficult to read, or we can run out of distinctive colors. On the other hand, the advantage of using small multiples is that it allows for a clearer visualization of each year's data and trends without worries of clutter nor running out of colors. However, it can be more difficult to compare the data across years without flipping back and forth between plots. Additionally, small multiples require more space, which can squish the y-axis, rendering the y-axis ticks undecipherable.

• A heatmap shows many time-series, if superimposition creates too cluttered picture
• y-axis is individual time series, x-axis is time, colour shows the value
• similar arrangement (but different encoding) than with small multiples



Question 5.
Essay, choose either a or b.
a) History of data graphics
b) Data Dimensionality techniques and how they are used, pros and cons, and how are they validated.

<In Infoviz_Essay>