University of BRISTOL

Visual Analytics: Visual Queries

Ian Nabney

ian.nabney@bristol.ac.uk

bristol.ac.uk

University of BRISTOL

Overview

- Reading: Chapter 1 of Ware (e-book that can be downloaded from UoB library website)
- Understand the basics of seeing, attention, and cognition
- Able to relate these issues to design of information visualisation systems

Happy Chinese New Year!

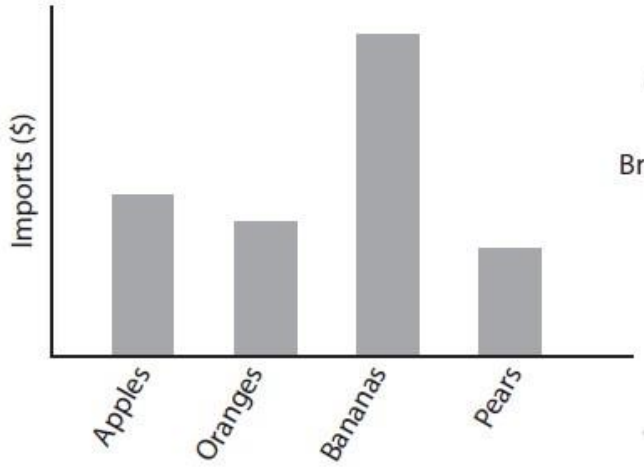
01/02/2022

Visual thinking

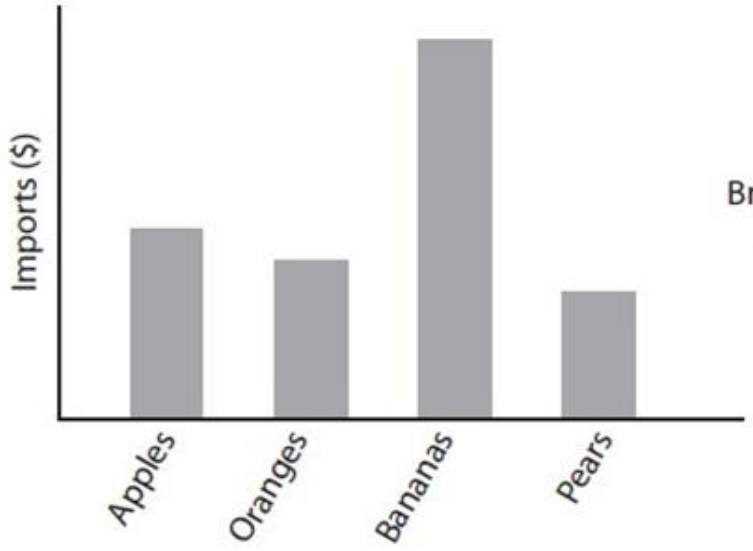
- We have the impression that we see the world vividly, completely and in detail
- This impression is completely wrong
- At any given instant, we apprehend only a tiny amount of the information in our surroundings, but it is usually just the right information to carry us through the task of the moment
- Keeping a copy of the world in our brains would be a huge waste of cognitive resources: it is much more efficient to see only what we attend to and only attend to what we need
- Our illusory impression that we are constantly aware of everything happens because our brains arrange for eye movements to occur and relevant information picked up just as we turn our attention to something we need
- This has led to a profoundly different model of perception

Graphic design: a new perspective

- Visual thinking consists of a series of acts of attention, driving eye movements and tuning our pattern-finding circuits
- These acts of attention are called **visual queries**, and understanding how they work can make us better designers
- Which kind of fruit import is the largest by dollar value? What is the fastest route from Calais to Toulouse?
- Write down how one answers these questions from the diagrams.



Solution



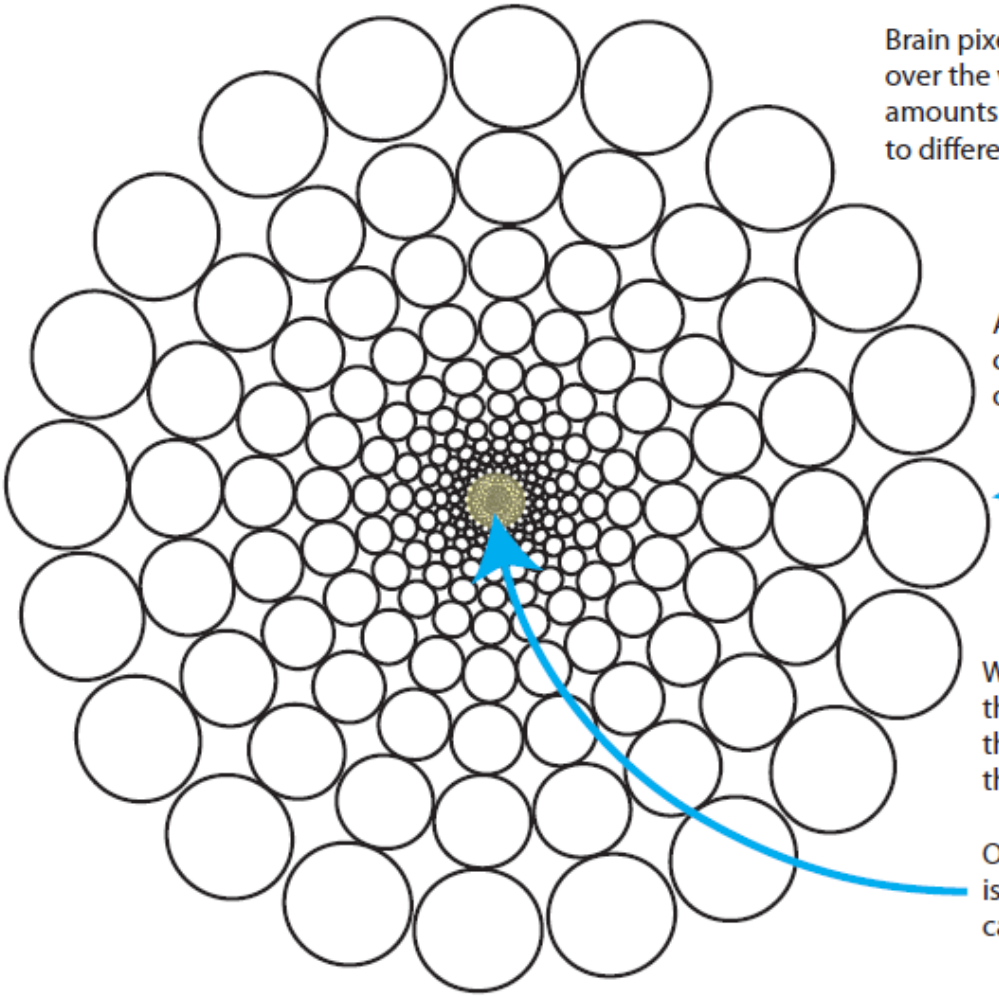
To find out which kind of fruit import is the largest by dollar value we make visual queries to find the tallest bar, then find and read the label beneath.

To find a fast route, we first make visual queries to find the starting and ending cities, then we make queries to find a connected red line, indicative of fast roads, between those points.

Apparatus and process of seeing

- The eyes are like little digital cameras
- Lenses focus an upside-down image on the eyeball
- Pixels are an array of light-sensitive **cones** recording three different colours (leaving aside **rods**)
- Brain pixels are concentrated in a central region called the **fovea**, whereas camera pixels are arranged in a uniform grid.
- Brain pixels function as little image-processing computers, not just passive recorders
- In the fovea, we can resolve c. 100 points on the head of a pin held at arm's length, but the region is only about the size of our thumbnail held at arm's length
- At the edge of the visual field, vision is terrible; we can just resolve something the size of a human head

Brain pixels



Brain pixels vary enormously in size over the visual field. This reflects differing amounts of neural processing power devoted to different regions of visual space.

At the edge of the visual field we can only barely see something the size of a fist at arm's length.

We can resolve about 100 points on the head of a pin held at arm's length in the very center of the visual field called the fovea.

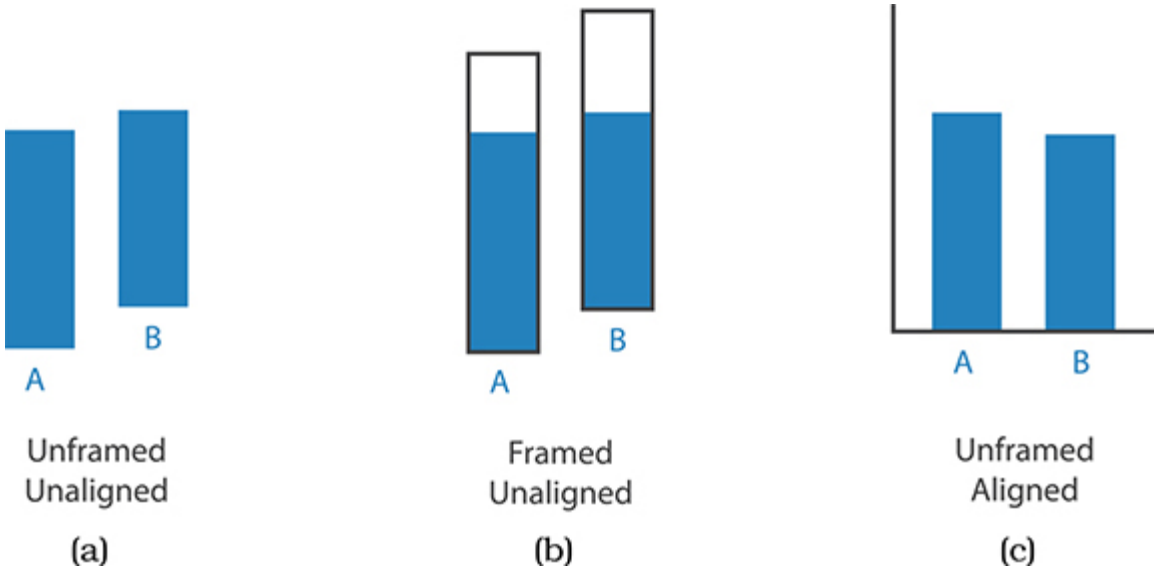
Over half of our visual processing power is concentrated in a slightly larger area called the parafovea.

Eye movements

- Half our visual brain power is directed to processing less than 5 percent of the visual world This is why we have to move our eyes; it is the only way we can direct our brain power where it is most useful
- Strong eye muscles attached to each eyeball rotate it rapidly so that different parts of the visual world become imaged on the central high-resolution fovea
- The muscles accelerate the eyeball to an angular velocity up to 900 degrees per second, then stop it, all in less than one-tenth of a second
- During a **saccadic** eye movement, vision is suppressed
- Controlling these eye movements is a key part of the skill of seeing

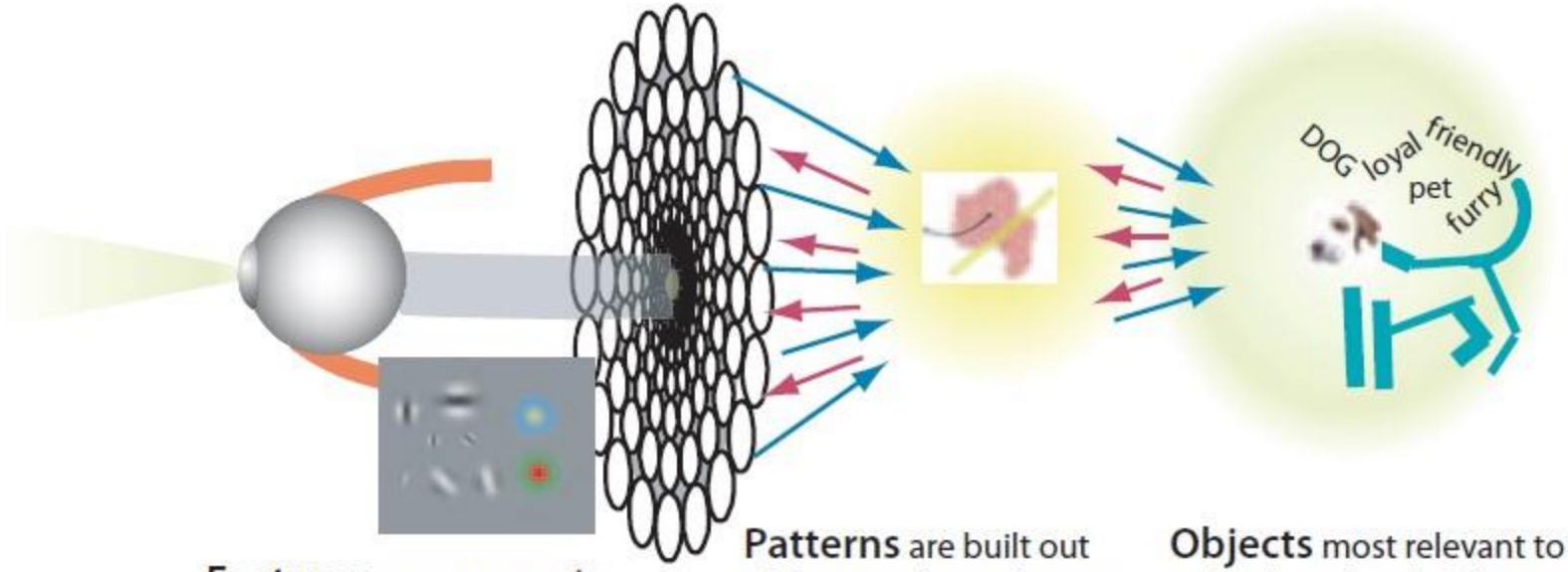
Recap: relative and absolute judgement

- The human perceptual system is fundamentally based on relative judgements, not absolute ones; **Weber's Law**
- For instance, the amount of length difference we can detect is a percentage of the object's length
- This principle holds true for all sensory modalities: our senses work through relative rather than absolute judgements



How do you think this relates to what you have just learned about eye movements and the fovea?

Act of perception



Features are processed in parallel from every part of the visual field. Millions of features are processed simultaneously.

Patterns are built out of features depending on attentional demands. Attentional tuning reinforces those most relevant.

Objects most relevant to the task at hand are held in Visual Working Memory. Only between one and three are held at any instant. Objects have both non-visual and visual attributes.

Bottom-up information drives pattern building

Top-down attentional processes reinforce relevant information

Implications for design

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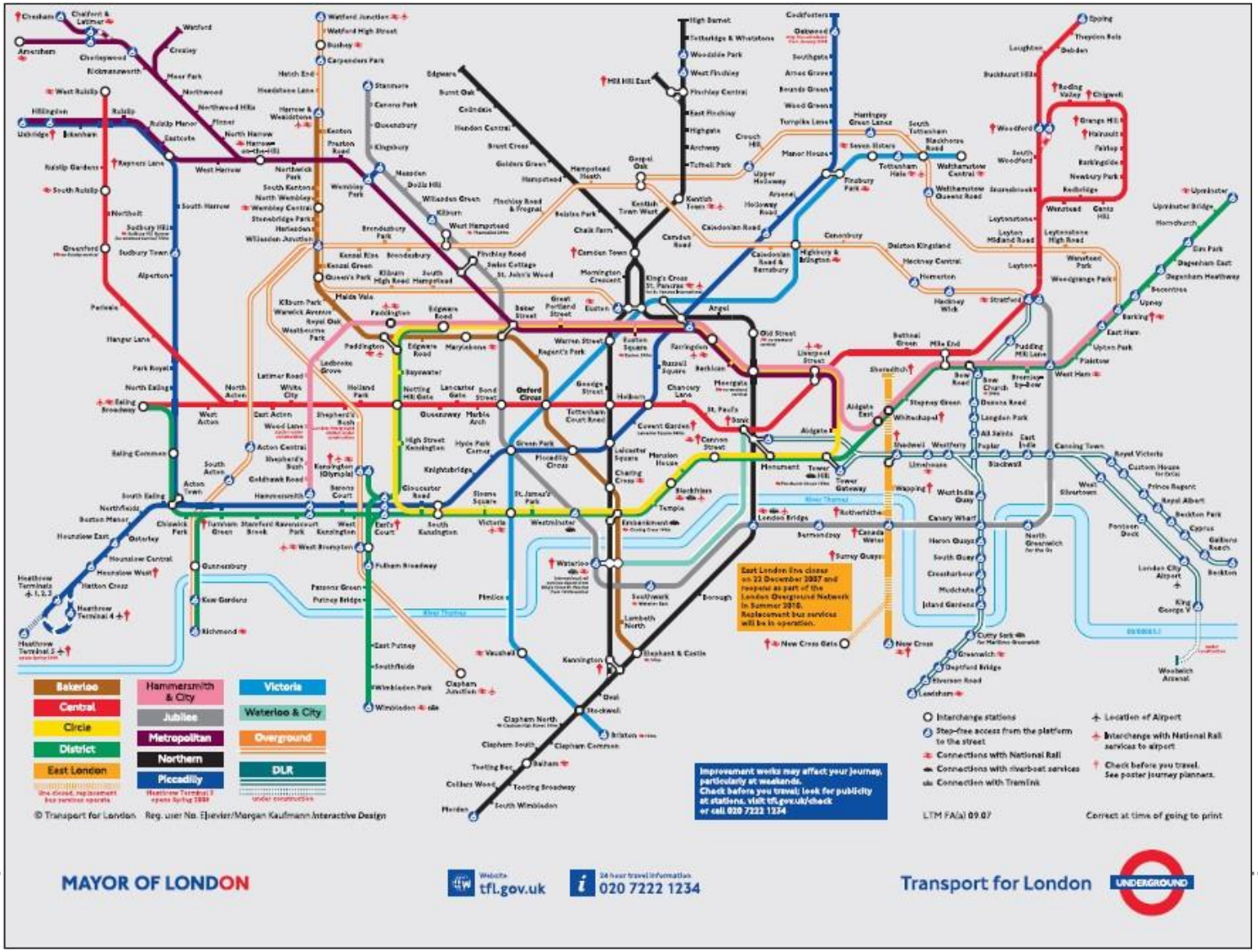

Original design by Harry Beck, 1933

Task analysis

- Suppose we are in a hotel near Ealing in West London, and we wish to go to a pub near Clapham Common where we will meet a friend

1. Which combination of lines will get us to the pub?
2. If there is more than one potential route, which is the shortest?
3. What are the names of stations where train changes are needed?
4. How long will the trip take?
5. What is the distance between the hotel and its nearest underground station?
6. What is the distance between the pub and its nearest underground station?
7. How much will it cost?

Exercise: write down a **cognitive plan** for solving this problem (consider the first three elements) – I suggest 4 steps. Think through how you solve the problem yourself

A solution

STEP ONE is to construct a visual query to locate the station nearest our hotel. Assuming we have the name of a station, this may take quite a protracted visual search since there are more than two hundred stations on the map; if, as is likely, we already have a rough idea where in London our hotel is located, this will narrow the search space.

STEP TWO is to visually locate a station near the pub, and this particular task is also not well supported. The famous map does support the station-finding task by spacing the labels for clear reading, but unlike other maps it does not give an index or a spatial reference grid.

STEP THREE is to find the route connecting our start station and our destination station. This visual query is very well supported by the map. The lines are carefully laid out in a way that radically distorts geographical space, but this is done to maintain clarity so that the visual tracing of lines is easy. Colour coding also supports visual tracing, as well as providing labels that can be matched to the table of lines at the side.

STEP FOUR is a visual query to get a rough estimate of how many stations there are on the route. This is unlikely to involve actual counting; instead, it will be a judgment that will be used together with prior experience to produce an estimate of the journey duration. This will naturally lead to misjudgements because the lengths of lines on the map do not correspond to travel times.

Analysis

- The London Underground map supports the visual route-finding step well but almost completely fails to support other planning steps such as finding a tube station near to the pub and estimating journey time
- This is not to say that it is a bad design; the map is justifiably famous
- The designers sacrificed spatial accuracy in favour of clear labels and routes, and therefore the map is very poor for providing information about the distance covered on the ground
- Alternatives have been created
  - Walking map http://content.tfl.gov.uk/walking-tube-map.pdf
  - Geographic map https://www.whatdotheyknow.com/request/224813/response/560395/attach/3/London%20Connections%20Map.pdf

Conclusion

- Perception is a skilled active process
- Eye movements are executed to satisfy our need for information and can be thought of as a sequence of visual queries on the visual world
- Each time the eye briefly comes to rest, the pattern-processing machinery sorts out what is most likely to be relevant to our current cognitive task
- Almost everything else is either not seen at all or retained for only a fraction of a second
- A few fragments are held for a second or two, and a tiny percentage forms part of our long-term memory
- The special skill of designers is the talent to analyse a design in terms of its ability to support the visual queries of others