Perception

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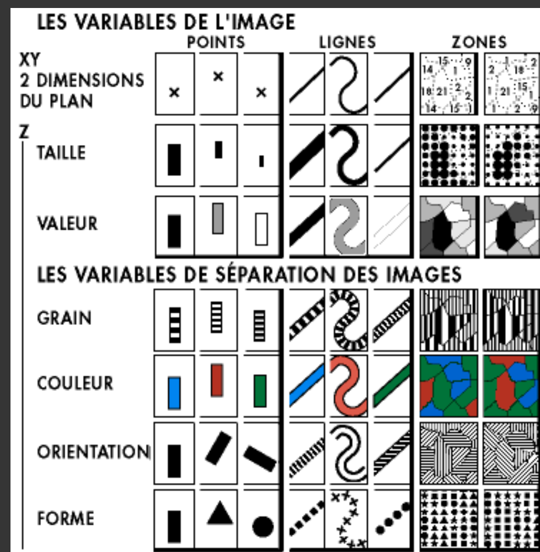
CS 294-10: Visualization
Fall 2013

Multidimensional Visualization

Visual Encoding Variables

Position
Length
Area
Volume
Value
Texture
Color
Orientation
Shape

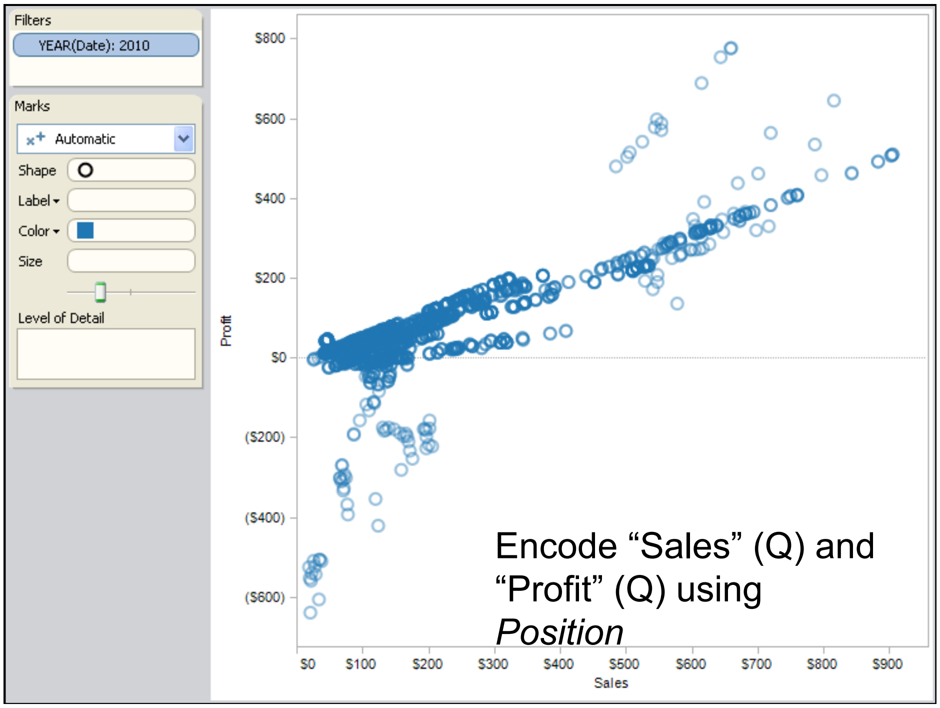
~8 dimensions?

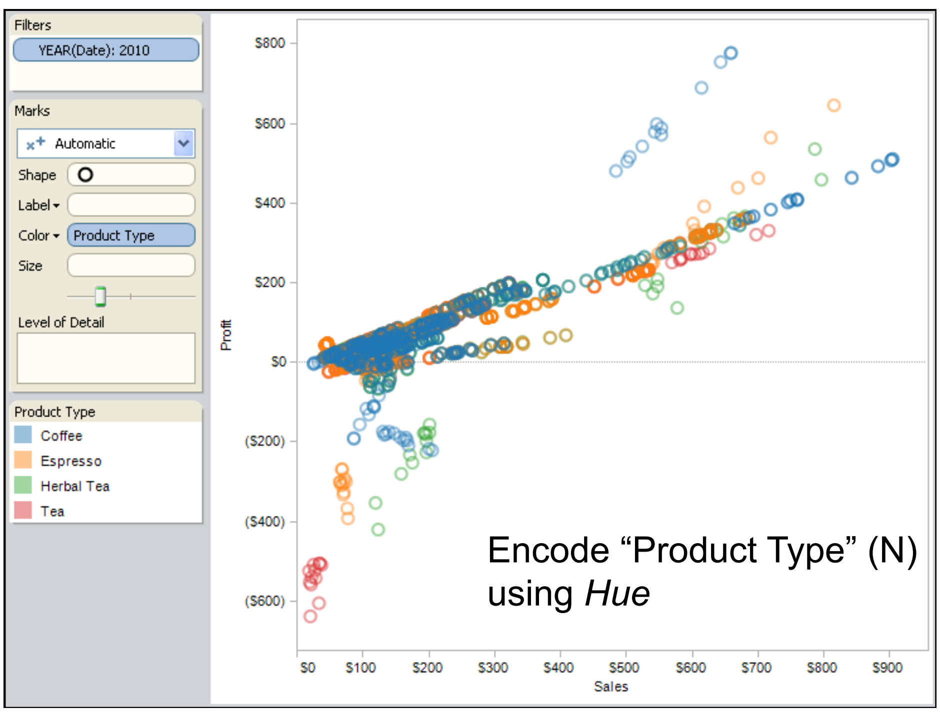


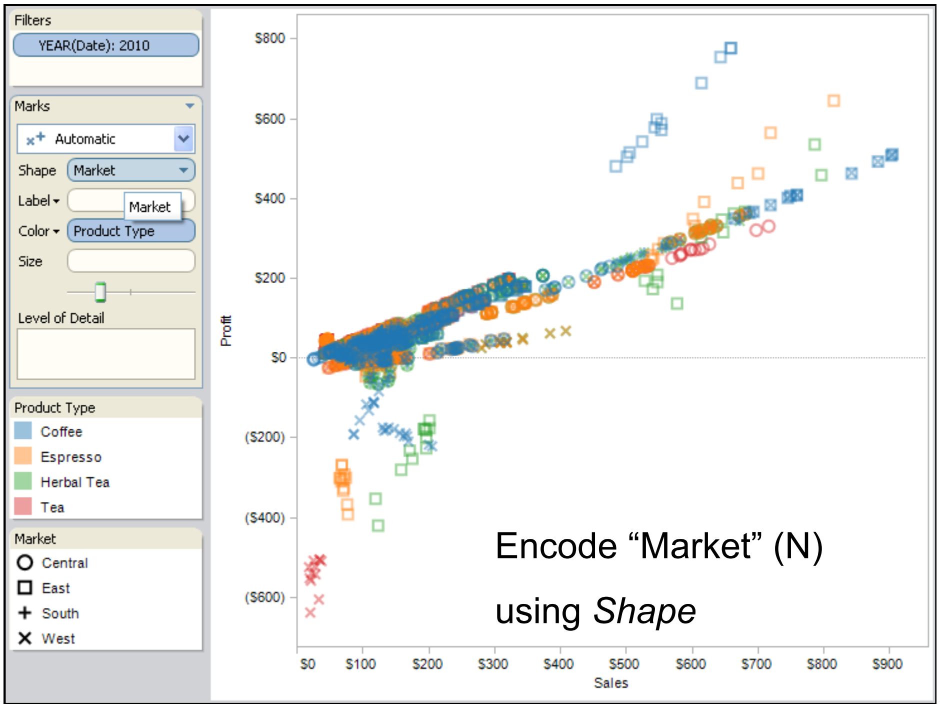
Example: Coffee Sales

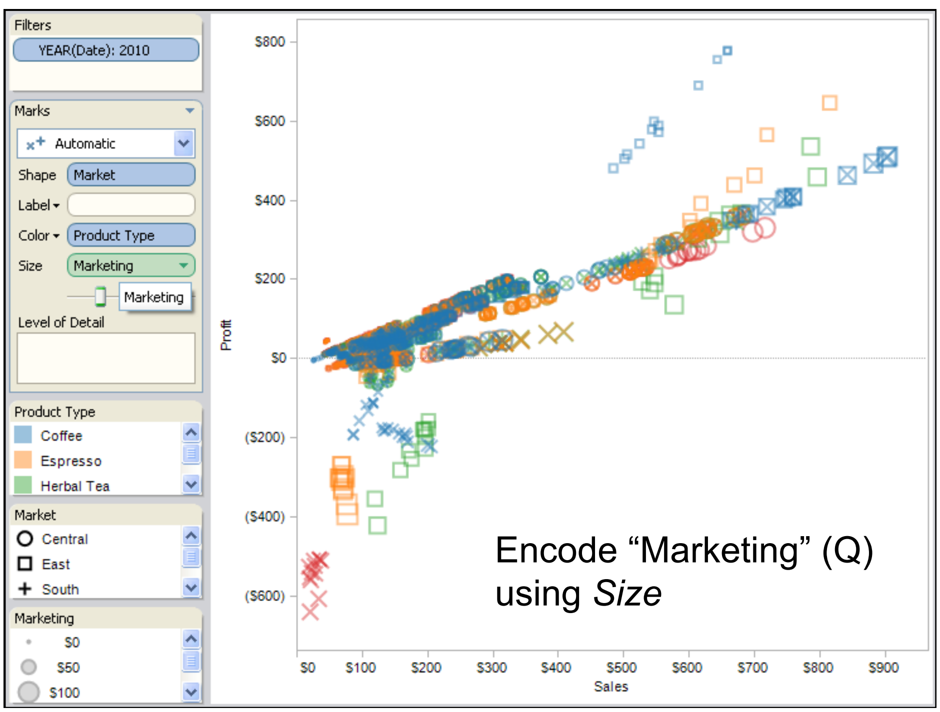
Sales figures for a fictional coffee chain:

Sales	Q-Ratio
Profit	Q-Ratio
Marketing	Q-Ratio
Product Type	N {Coffee, Espresso, Herbal Tea, Tea}
Market	N {Central, East, South, West}


Filters
YEAR(Date): 2010
Marks
Automatic
Shape
Label
Color
Size
Level of Detail
$800
$600
$400
$200
$0
($200)
($400)
($600)
Profit
$0
$100
$200
$300
$400
$500
$600
$700
$800
$900
Sales
Encode "Sales" (Q) and "Profit" (Q) using *Position*


Filters
YEAR(Date): 2010
Marks
Automatic
Shape
Label
Color
Product Type
Size
Level of Detail
Product Type
Coffee
Espresso
Herbal Tea
Tea
$800
$600
$400
$200
$0
($200)
($400)
($600)
Profit
$0
$100
$200
$300
$400
$500
$600
$700
$800
$900
Sales
Encode "Product Type" (N) using *Hue*


Filters
YEAR(Date): 2010
Marks
Automatic
Shape
Market
Label
Market
Color
Product Type
Size
Level of Detail
Product Type
Coffee
Espresso
Herbal Tea
Tea
Market
Central
East
South
West
Profit
Sales
Encode "Market" (N)
using *Shape*

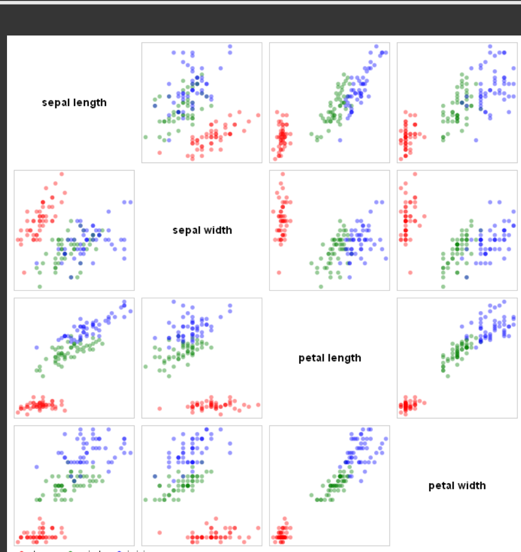

Filters
YEAR(Date): 2010
Marks
Automatic
Shape
Market
Label
Color
Product Type
Size
Marketing
Marketing
Level of Detail
Product Type
Coffee
Espresso
Herbal Tea
Market
Central
East
South
Marketing
$0
$50
$100
Profit
Sales
Encode "Marketing" (Q)
using *Size*

Trellis Plots

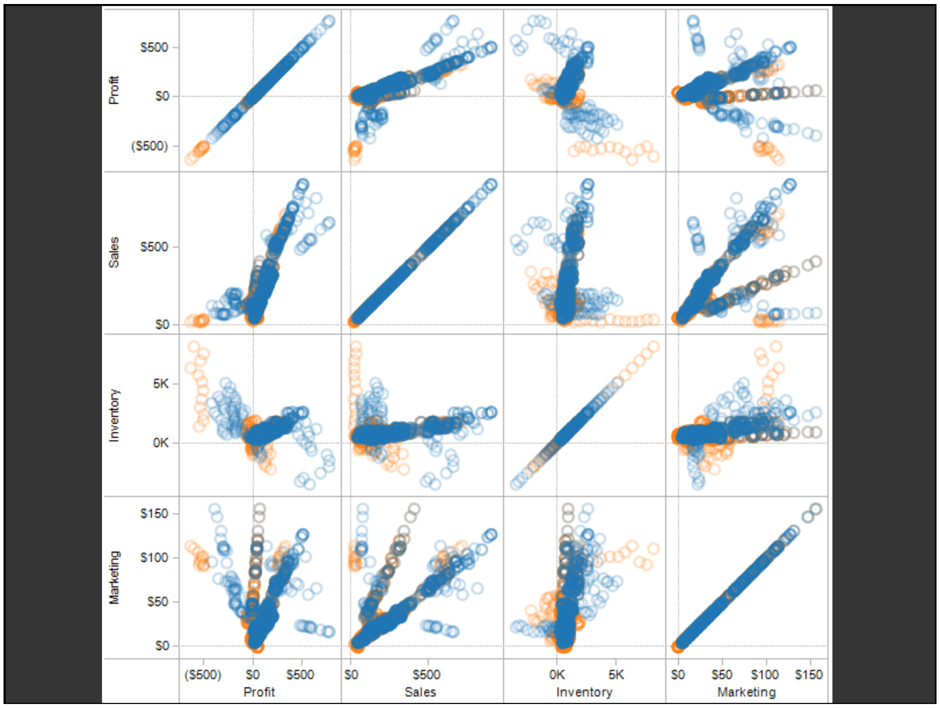
A ***trellis plot*** subdivides space to enable comparison across multiple plots

Typically nominal or ordinal variables are used as dimensions for subdivision

Scatterplot Matrix (SPLOM)



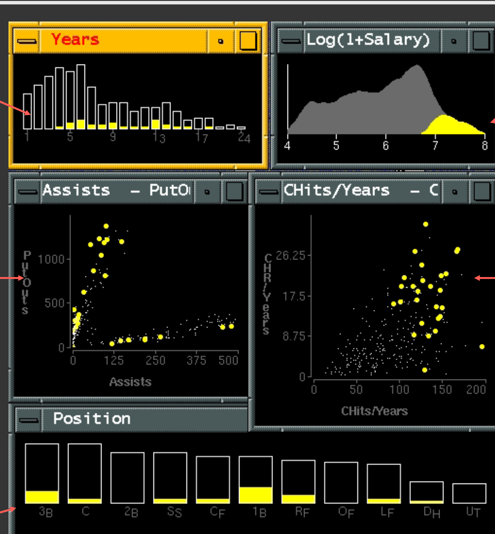
Scatter plots enabling pair-wise comparison of each data dimension



Small Multiples [from Wills 95]

how long in majors

select high salaries

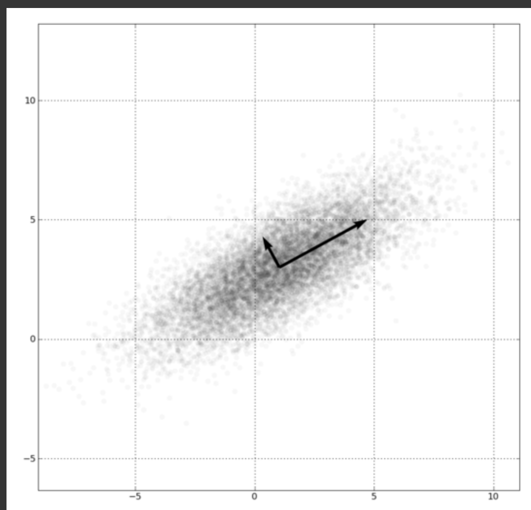


avg assists vs avg putouts (fielding ability)

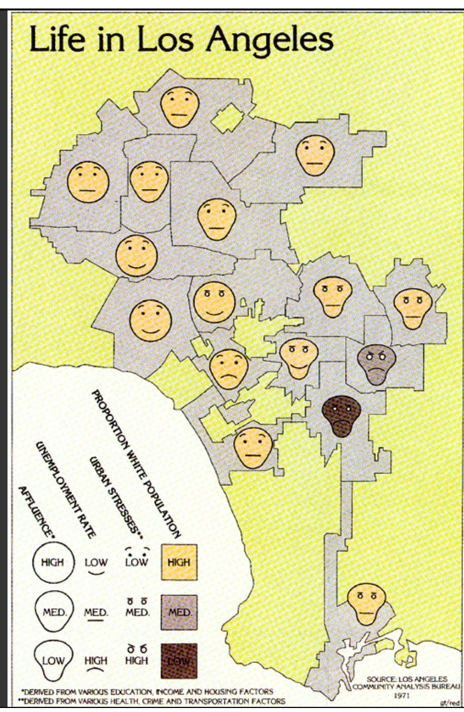
avg career HRs vs avg career hits (batting ability)

distribution of positions played

Principal Component Analysis



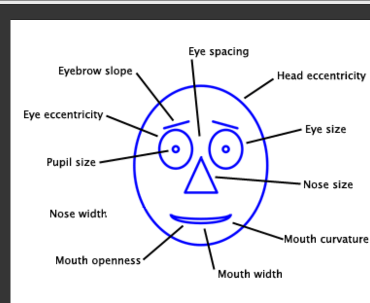
1. Mean-center the data
2. Find ⊥ basis vectors that maximize the data variance
3. Plot the data using the top vectors



Chernoff Faces (1973)

Insight: We have evolved a sophisticated ability to interpret facial expression

Idea: Map data variables to facial features

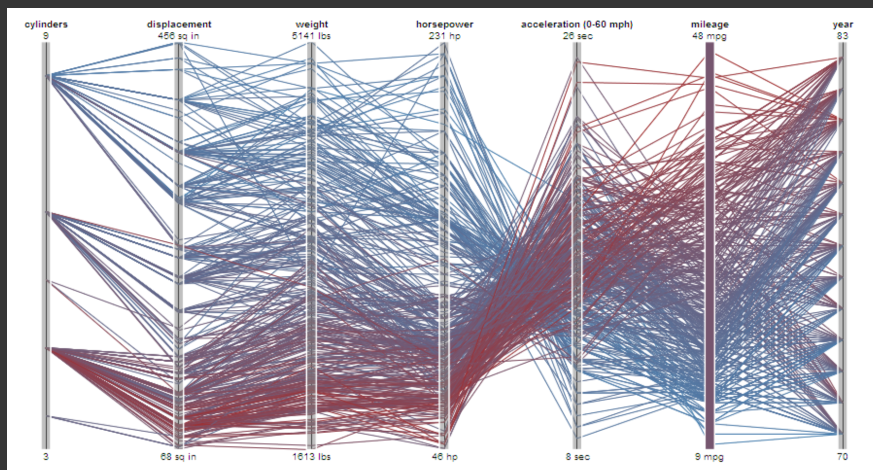


Question: Do we process facial features in an uncorrelated way? (i.e., are they *separable*?)

This is just one example of nD "glyphs"

Parallel Coordinates

Parallel Coordinates [Inselberg]



The Multidimensional Detective

The Dataset:
Production data for 473 batches of a VLSI chip
16 process parameters:

X1:	**The yield: % of produced chips that are useful**
X2:	**The quality of the produced chips (speed)**
X3 … X12:	**10 types of defects (zero defects shown at top)**
X13 … X16:	**4 physical parameters**

The Objective:
Raise the yield (X1) and maintain high quality (X2)

A. Inselberg, Multidimensional Detective, Proceedings of IEEE Symposium on Information Visualization (InfoVis '97), 1997

Parallel Coordinates

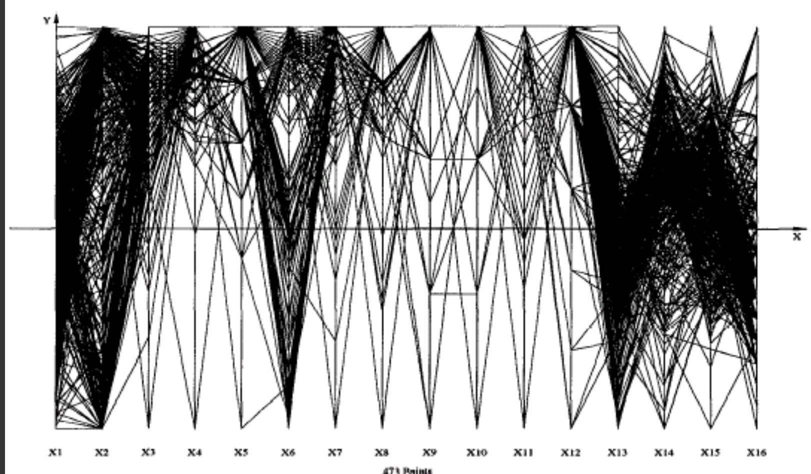


Figure 1: The full dataset consisting of 473 batches

Inselberg's Principles

1. Do not let the picture scare you
2. Understand your objectives
   - Use them to obtain visual cues
3. Carefully scrutinize the picture
4. Test your assumptions, especially the "I am really sure of's"
5. You can't be unlucky all the time!

Each line represents a tuple (e.g., VLSI batch)
Filtered below for high values of X1 and X2

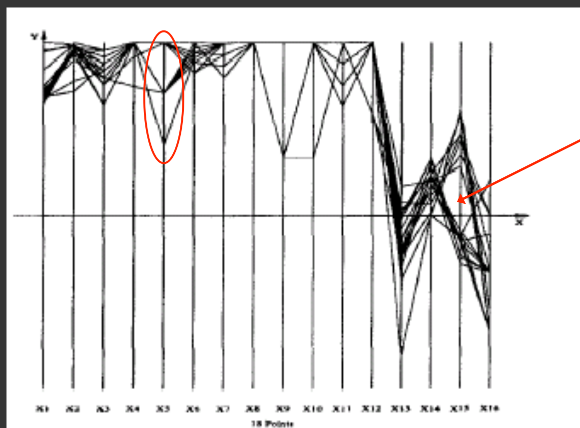
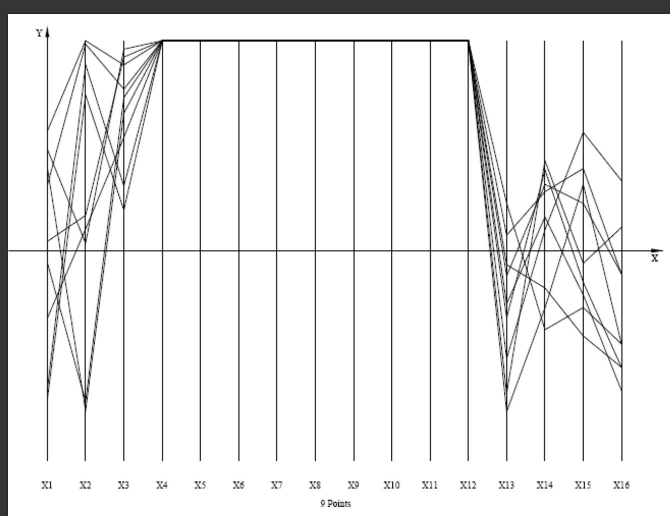


Figure 2: The batches high in Yield, $X1$, and Quality, $X2$.

Look for batches with *nearly* zero defects
Most of these have low yields → defects OK



Notice that X6 behaves differently.

Allow 2 defects, including X6 → best batches

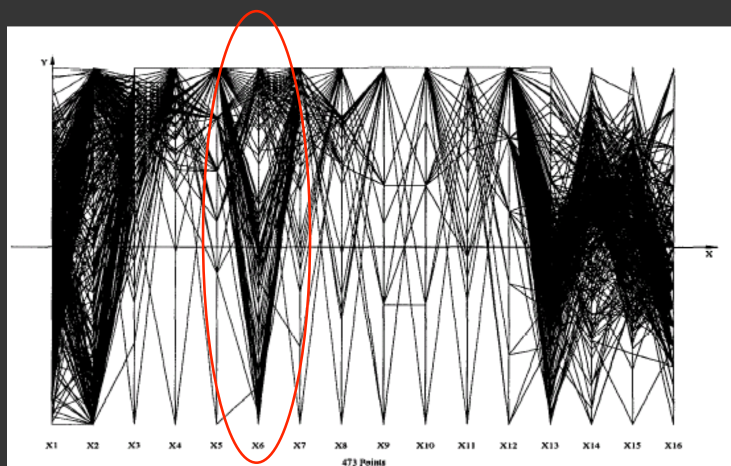
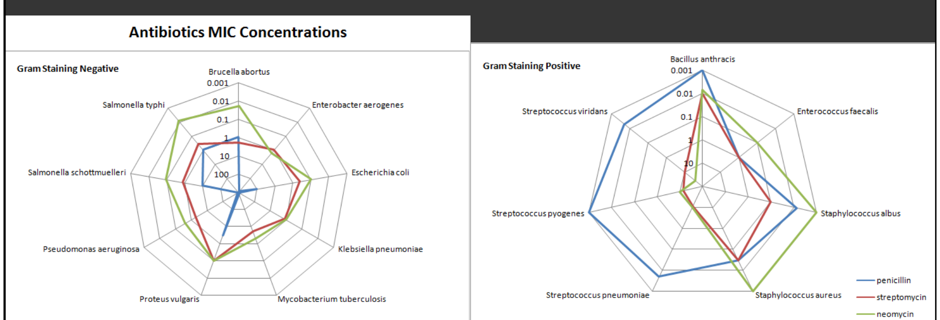


Figure 1: The full dataset consisting of 473 batches

Radar Plot / Star Graph



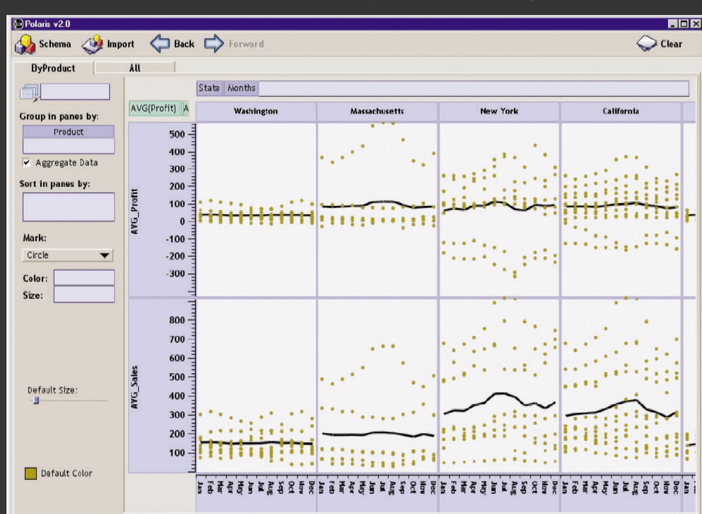
"Parallel" dimensions in polar coordinate space

Best if same units apply to each axis

Tableau / Polaris

Tableau

Research at Stanford: “Polaris” by Stolte, Tang & Hanrahan



Tableau

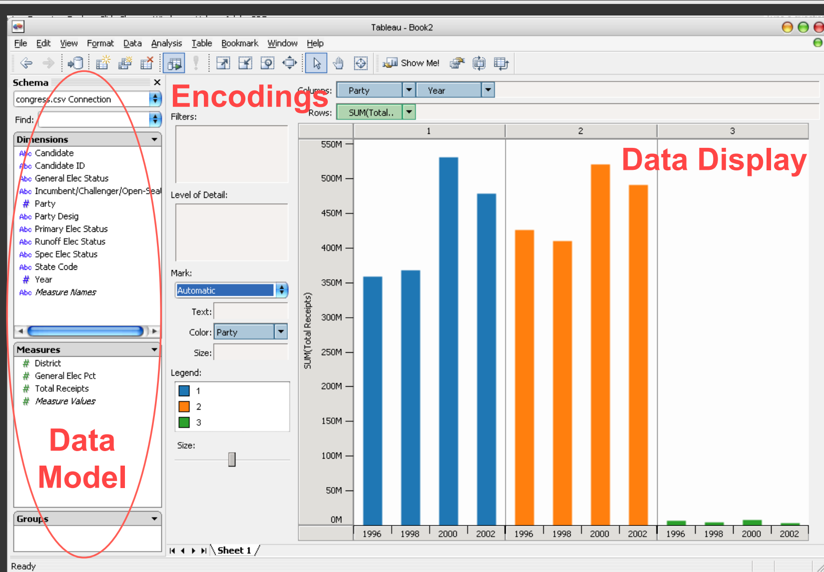


Tableau demo

The dataset:

- Federal Elections Commission Receipts
- Every Congressional Candidate from 1996 to 2002
- 4 Election Cycles
- 9216 Candidacies

Data Set Schema

- Year (Qi)
- Candidate Code (N)
- Candidate Name (N)
- Incumbent / Challenger / Open-Seat (N)
- Party Code (N) [1=Dem,2=Rep,3=Other]
- Party Name (N)
- Total Receipts (Qr)
- State (N)
- District (N)

- This is a subset of the larger data set available from the FEC, but should be sufficient for the demo

Hypotheses?

What might we learn from this data?

Hypotheses?

What might we learn from this data?

- Has spending increased over time?
- Do democrats or republicans spend more money?
- Candidates from which state spend the most money?

Tableau Demo

Polaris/Tableau Approach

Insight: simultaneously specify both database queries and visualization

Choose data, then visualization, not vice versa

Use smart defaults for visual encodings

Recently: automate visualization design (ShowMe – Like APT)

Specifying Table Configurations

Operands are names of database fields

Each operand interpreted as a set {…}

Quantitative and Ordinal fields treated differently

Three operators:

- concatenation (+)
- cross product (x)
- nest (/)

Table Algebra: Operands

Ordinal fields: interpret domain as a set that partitions table into rows and columns

Quarter = {(Qtr1),(Qtr2),(Qtr3),(Qtr4)} →

Qtr1	Qtr2	Qtr3	Qtr4
95892	101760	105282	98225

Quantitative fields: treat domain as single element set and encode spatially as axes

Profit = {(Profit[-410,650])} →

Concatenation (+) Operator

Ordered union of set interpretations

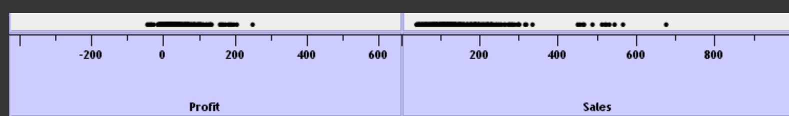
Quarter + Product Type

= {(Qtr1),(Qtr2),(Qtr3),(Qtr4)} + {(Coffee), (Espresso)}

= {(Qtr1),(Qtr2),(Qtr3),(Qtr4),(Coffee),(Espresso)}

Qtr1	Qtr2	Qtr3	Qtr4	Coffee	Espresso
48	59	57	53	151	21

Profit + Sales = {(Profit[-310,620]),(Sales[0,1000])}



Cross (x) Operator

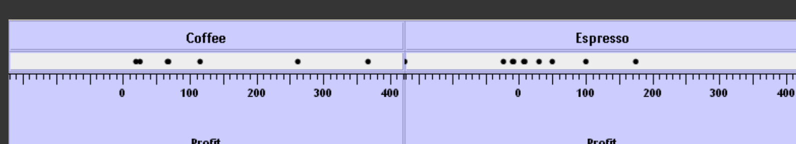
Cross-product of set interpretations

Quarter x Product Type

= {(Qtr1,Coffee), (Qtr1, Tea), (Qtr2, Coffee), (Qtr2, Tea),
(Qtr3, Coffee), (Qtr3, Tea), (Qtr4, Coffee), (Qtr4,Tea)}

Qtr1		Qtr2		Qtr3		Qtr4	
Coffee	Espresso	Coffee	Espresso	Coffee	Espresso	Coffee	Espresso
131	19	160	20	178	12	134	33

Product Type x Profit =



Nest (/) Operator

Cross-product filtered by existing records

Quarter x Month

- creates twelve entries for each quarter. i.e., (Qtr1, December)

Quarter / Month

- creates three entries per quarter based on tuples in database (not semantics)

Polaris/Tableau Table Algebra

The operators (+, x, /) and operands (O, Q) provide an *algebra* for tabular visualization.

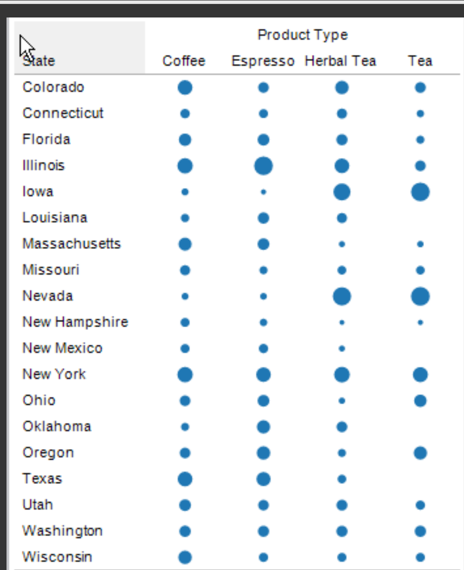
Algebraic statements are then mapped to:

- Visualizations - trellis plot partitions, visual encodings
- Queries - selection, projection, group-by aggregation

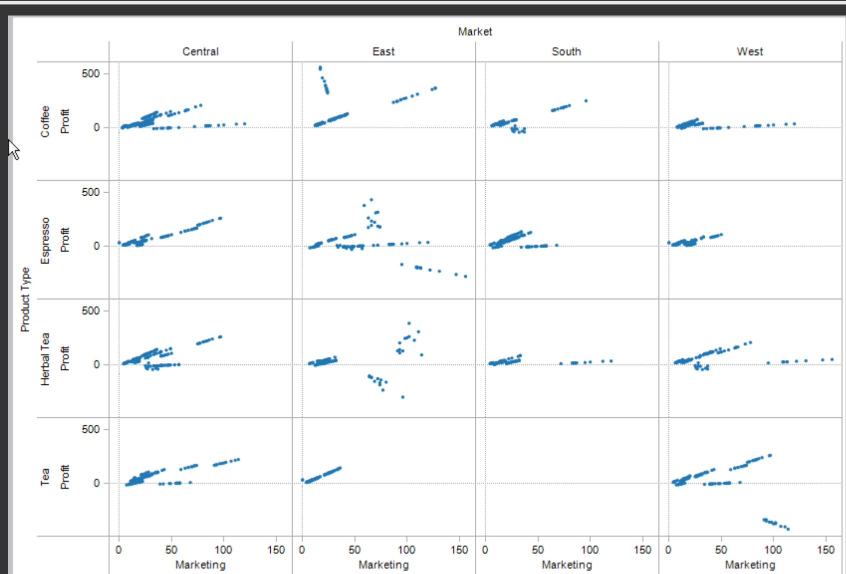
In Tableau, users make statements via drag-and-drop

- Note that this specifies operands NOT operators!
- Operators are inferred by data type (O, Q)

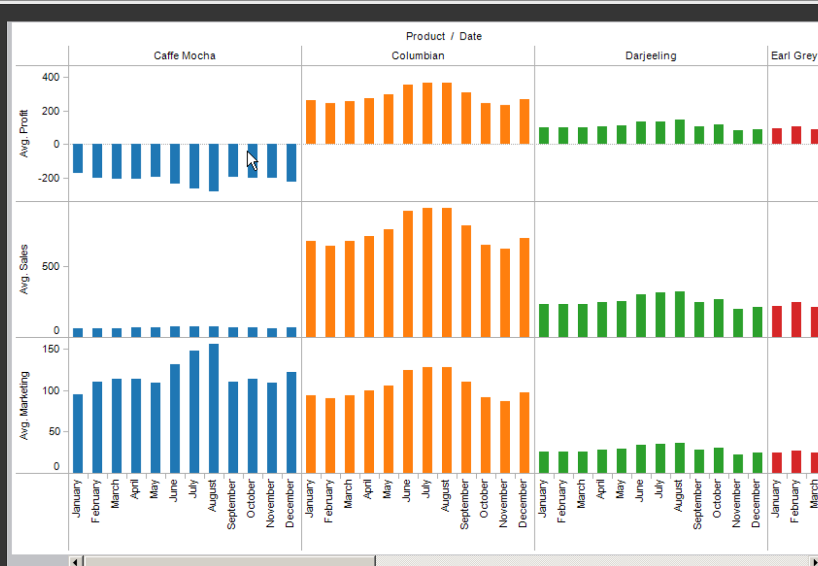
Ordinal - Ordinal



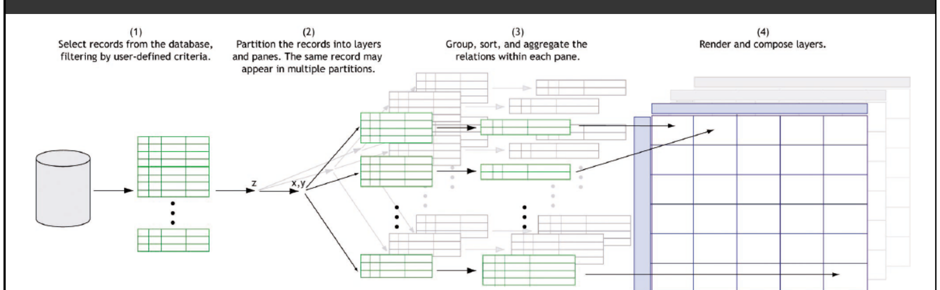
Quantitative - Quantitative



Ordinal - Quantitative



Querying the Database



Summary

Visualizing Multiple Dimensions

- Start by visualizing individual dimensions
- Avoid “over-encoding”
- Use space and small multiples intelligently
- Use interaction to generate *relevant* views

There is rarely a single visualization that answers all questions. Instead, the ability to generate appropriate visualizations quickly is key.

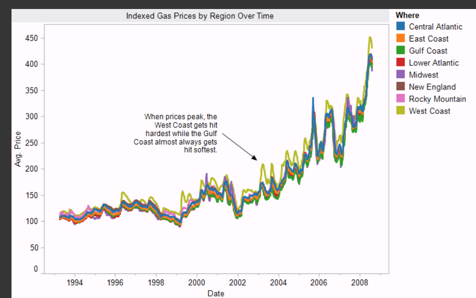
Announcements

Assignment 2: Exploratory Data Analysis

Use Tableau to formulate & answer questions

First steps
- Step 1: Pick a domain
- Step 2: Pose questions
- Step 3: Find data
- Iterate

Create visualizations
- Interact with data
- Question will evolve
- Tableau



Make wiki notebook
- Keep record of all steps you took to answer the questions

Due before class on Sep 30, 2013

Perception

Mackinlay's ranking of encodings

QUANTITATIVE	ORDINAL	NOMINAL
Position	Position	Position
Length	Density (Val)	Color Hue
Angle	Color Sat	Texture
Slope	Color Hue	Connection
Area (Size)	Texture	Containment
Volume	Connection	Density (Val)
Density (Val)	Containment	Color Sat
Color Sat	Length	Shape
Color Hue	Angle	Length
Texture	Slope	Angle
Connection	Area (Size)	Slope
Containment	Volume	Area
Shape	Shape	Volume

Topics

Signal Detection

Magnitude Estimation

Pre-Attentive Visual Processing

Using Multiple Visual Encodings

Gestalt Grouping

Change Blindness

Detection

Detecting brightness

Which is brighter?

Detecting brightness

(128, 128, 128) (133, 133, 133)

Which is brighter?

Just noticeable difference

JND (Weber's Law)

$$\Delta S = k\frac{\Delta I}{I}$$

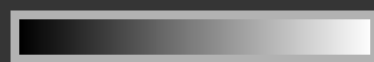
- Ratios more important than magnitude
- Most continuous variations in stimuli are perceived in discrete steps

Information in color and value

Value is perceived as ordered

∴ Encode ordinal variables (O)

∴ Encode continuous variables (Q) [not as well]



Hue is normally perceived as unordered

∴ Encode nominal variables (N) using color

Steps in font size

Sizes standardized in 16^{th} century

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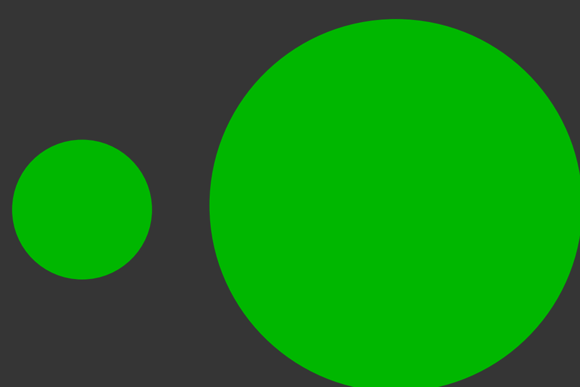
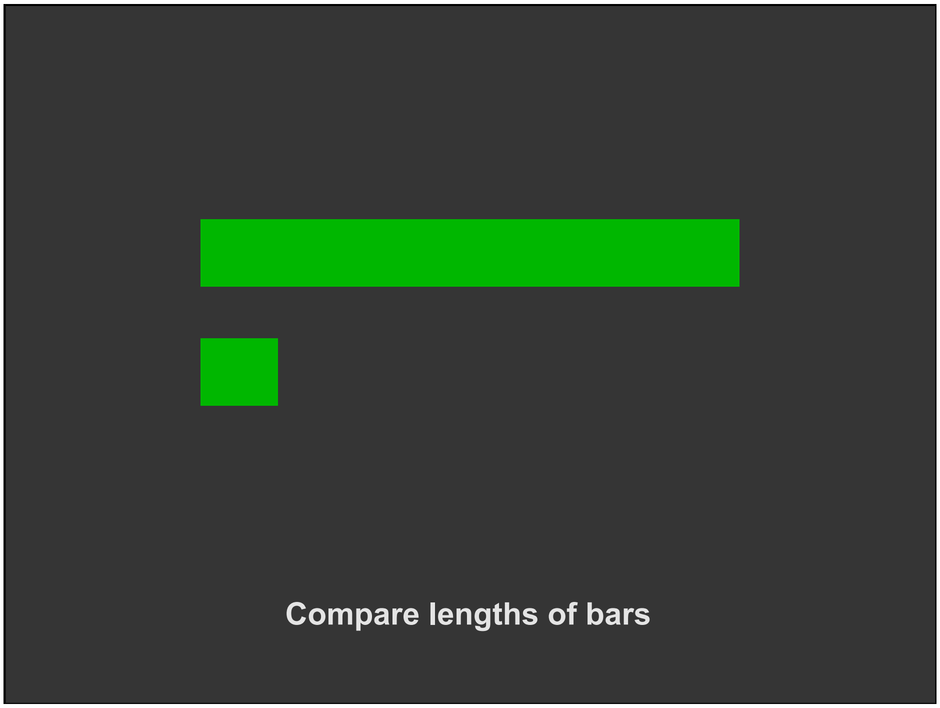
6 7 8 9 10 11 12 14 16 18 21 24 36 48 60 72

Estimating Magnitude



Compare areas of circles


Compare lengths of bars