02

Data Foundations

Notice

- **Author**
  - **João Moura Pires (jmp@fct.unl.pt)**

Bibliography

- **Many examples are extracted and adapted from**
  - **Interactive Data Visualization: Foundations, Techniques, and Applications,**

    Matthew O. Ward, Georges Grinstein, Daniel Keim, 2015

  - **Visualization Analysis & Design,**

    Tamara Munzner, 2015

Table of Contents

- **Introduction**
- **Data by Matthew O. Ward, et all**
- **Data by Tamara Munzner**
- **Structure within and between records**
- **Data Preprocessing**

Some practical Information

Evaluation rules

- **Two mid-term written individual tests (25% each)**
- **One project (for team of 3 students), with several phases:**
  - **Specification**
  - **Paper (20%)**
  - **Code/implementation (30%)**
  - **(*) an oral discussion will be required to validate the project components**

- **Course approval requires the following minimal grades:**
  - **(mean (Test1; Test2) >= 10) AND (Test1 >= 8) AND (Test2 >= 8)**
  - **(mean(Paper;Code&Implementation) >= 10) AND**
- **Final exam may replace mean (Test1; Test2) if project is approved.**

Important dates

- **Team registration - Mars 20th**

- **Select datasets for your project - Mars 25 th - April 24th**
  - **Discuss in the lab sessions the viability**
  - **Evaluate de selected datasets**
  - **Define and get an approval of your research questions**
  - **Make a state of the art**

- **Paper - May 15th**

Team Registration

- **Access the <u>shared google sheet</u>**

	Register you team by indicating in the first available Group-ID the student ID for each student (exactly 3 students)					
	Please fill in your number in the yellow columns					
Group ID	**ID-1**	**Name-1**	**ID-2**	**Name-2**	**ID-3**	**Name-3**
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  - **And with the teacher**

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- You will receive (later) an invite for the Tableau online

Recap from previous lecture

What is the Goal of Data Visualization?

“Data visualization is not just about seeing data !

Is about UNDERSTANDING data,

and being able to make decisions based on the data”

by John C. Hart

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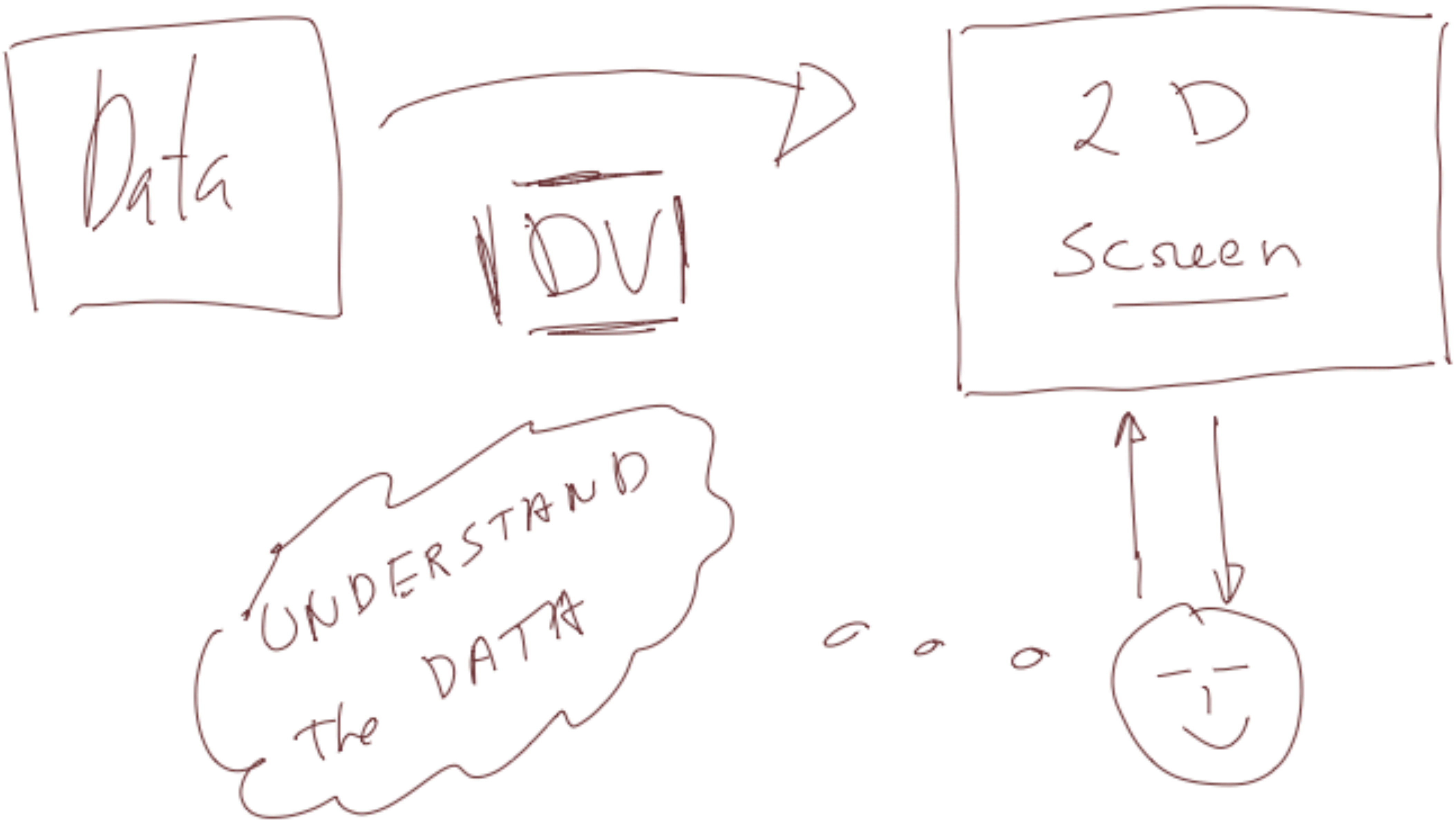
What is the core idea of Interactive Data Visualization?



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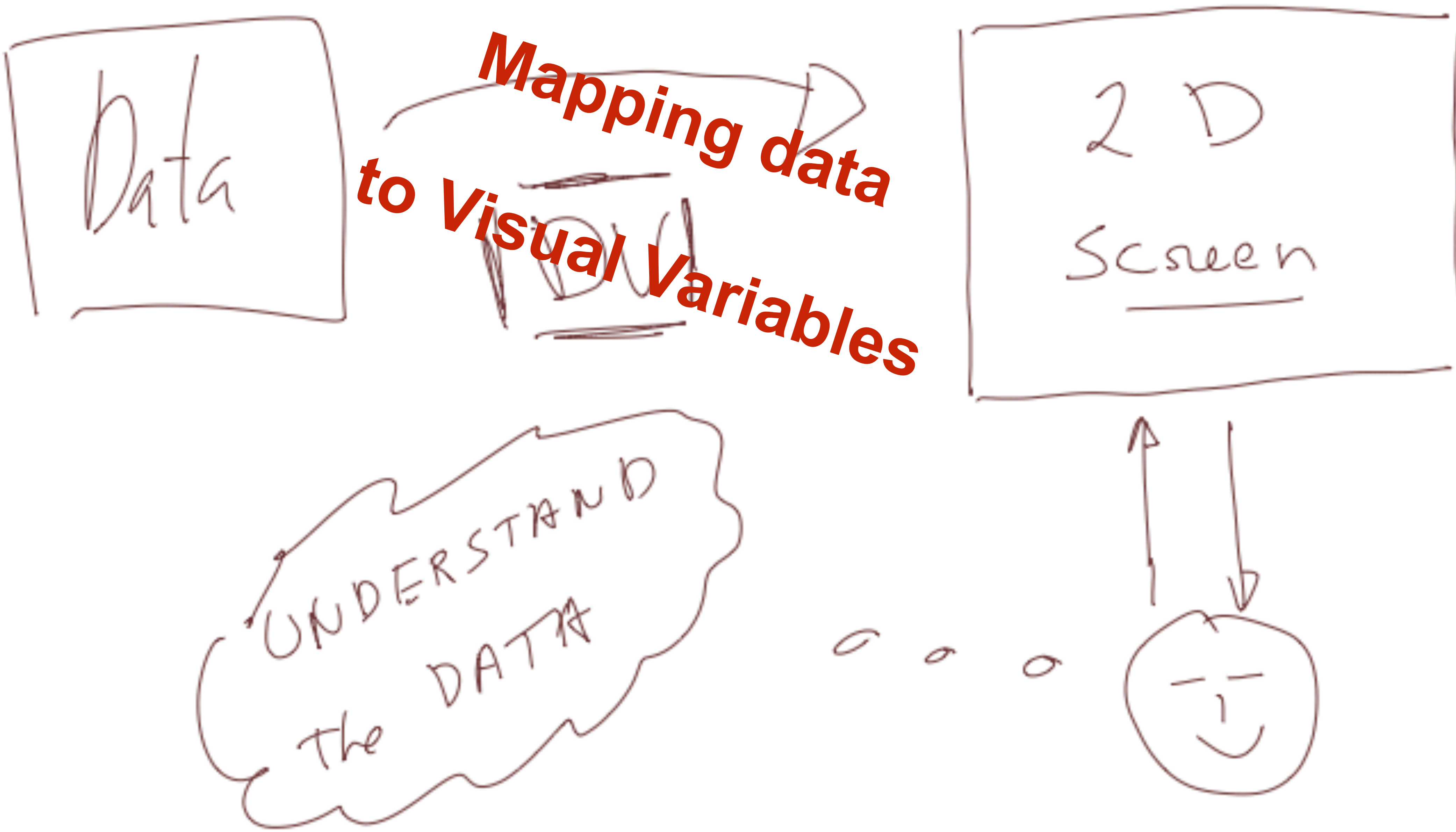

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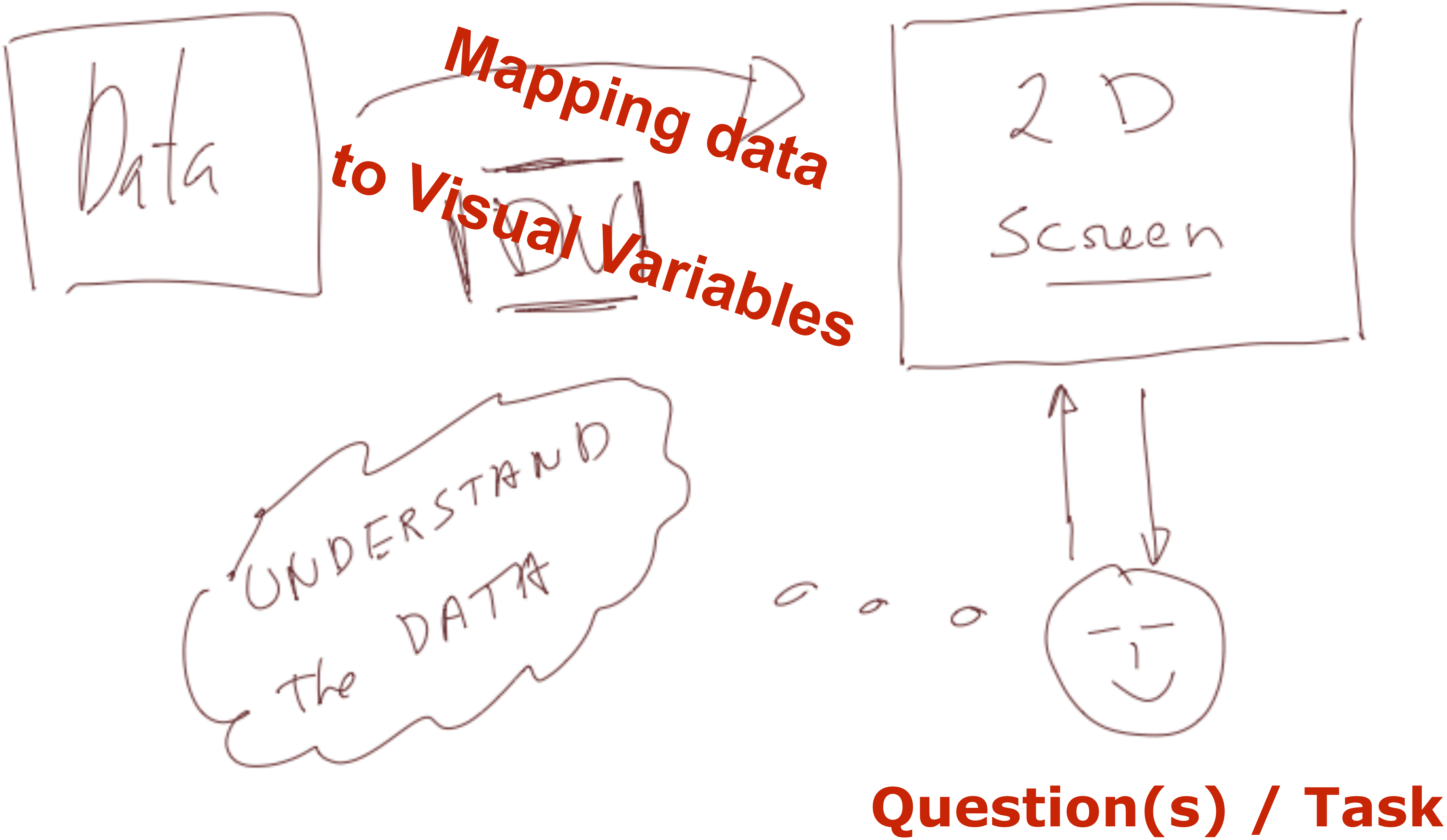

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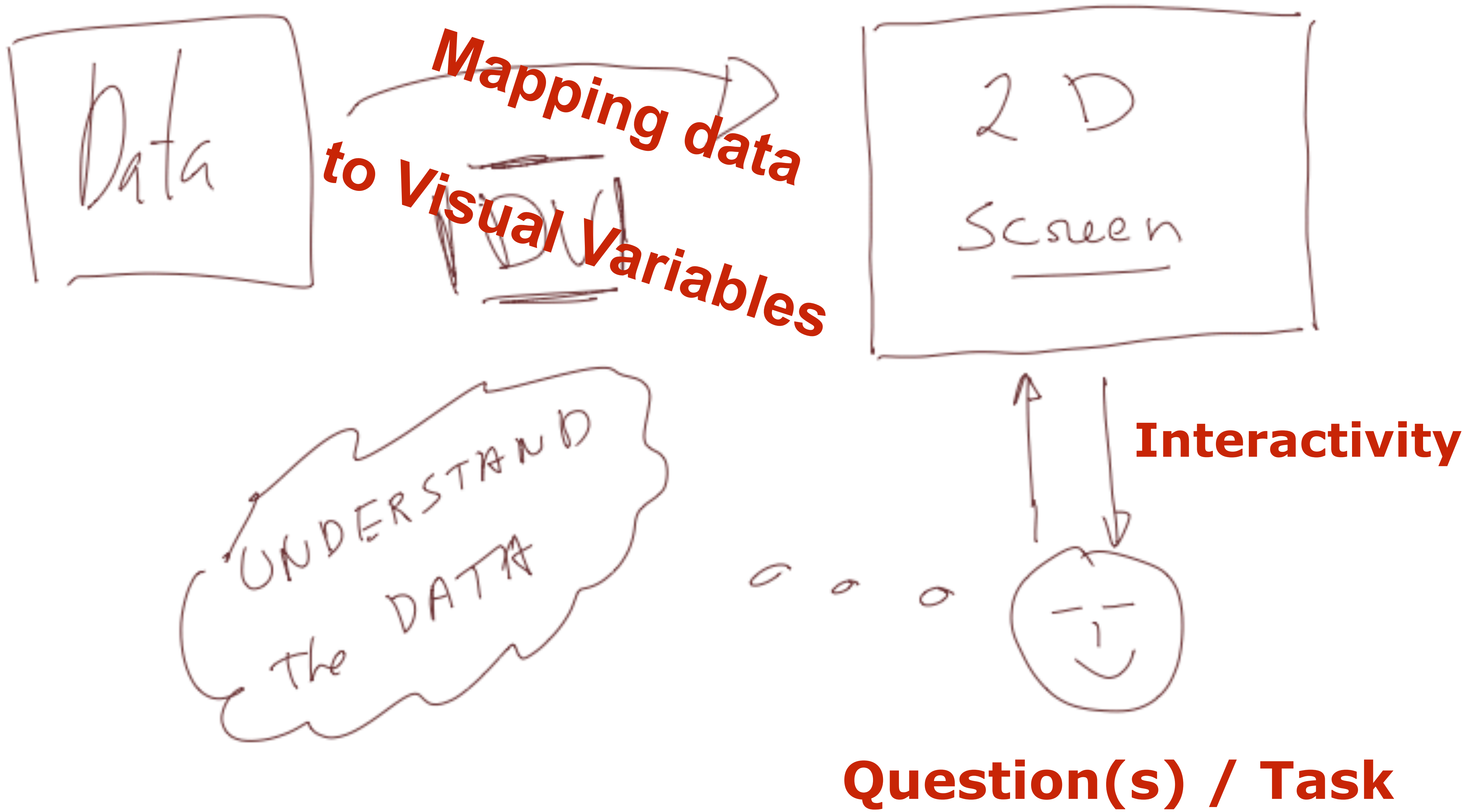

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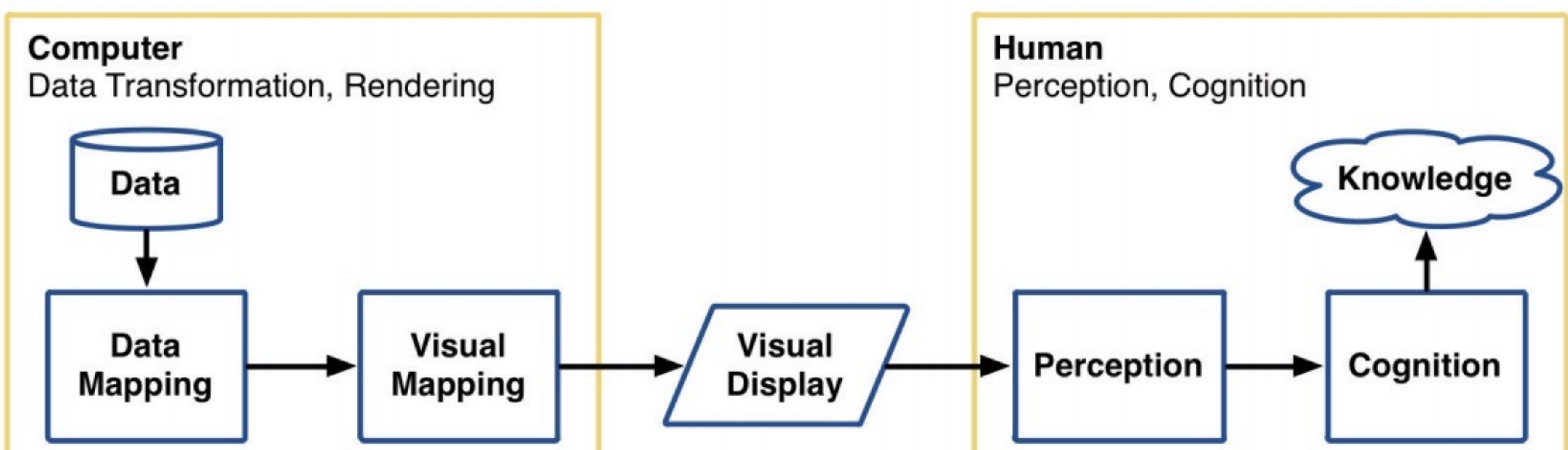
- **The role of Perception.**
  - The role and the importance of the user.

Introduction to Data Foundations

Visualization Process: visualization pipeline

- For visualization the stages are:
  - Modeling: the data to be visualized
  - Data Selection: similar to clipping
  - Data to visual mappings: the heart of the visualization is mapping data values to graphical entities or their attributes; may involve scaling, shifting, filtering, interpolating, or subsampling.
  - Scene parameter setting: (ex: color mapping)
  - Rendering or generation of the visualization



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- **Raw versus Processed data**
  - **Raw data (untreated)**
  - **Processed: smoothing, noise removal, scaling, interpolation, aggregation**

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  - **(r_1, r_2, …, r_n)**
  - **a record r_i consists in *m* (one or more) observations or variables**

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  - **A variable may be classified as:**
    - **independent: whose value is not controlled or affected by another variable**
    - **dependent: whose value is affected by the variation in one or more associated independent variables**

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- **A record *r* consists in *mi* independent variables and *md* dependent variables**

$$r = (iv_1, iv_2, \ldots, iv_{mi}, dv_1, dv_2, \ldots, dv_{md})$$

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  - **A data set can be seen as a function**

Domain of Independent variables $\xrightarrow{F}$ **Range of dependent variables**

Data

(Matthew O. Ward, et all)

Data Types

Types of data. Numeric versus Non-Numeric

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- **Numeric (ordinal):**
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- **Non Numeric (nominal):**
  - **categorial: finite (normally short) list of values (e.g., red, green, blue);**
  - **ranked: a categorial variable that has an implied order (e.g., small, medium, large);**
  - **arbitrary: potentially infinite range of values (e.g., names, addresses).**

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  - **A minimum value of zero. The scale has a true zero point, below which no values exist. When a scale has an absolute zero then it makes sense to apply all the mathematical operations (+, -, *, /).**

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  - **Discrete. e.g., Fahrenheit (or centigrade) scale to measure temperature**
- **Ratio Scale of Measurement**
  - **Satisfies identity, magnitude, equal intervals, and a minimum value of zero.**
  - **Continuous. e.g., weight, distance, etc. Can apply operations of / and *.**

Structure within and between records

Data sets structure

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More info about tensors -> https://www.youtube.com/watch?v=fu-eMNi_aag

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- **Vector: multiple variables in a single record can represent a single item**
  - **e.g.: Position coordinates (2D or 3D); Color using RGB(Red, Green, Blue) components, Phone number (Country code, area code and local number), etc.**
  - **each component (of the vector) can be considered individually but is most appropriate to treat the vector as a whole.**

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- **Tensor: a tensor is defined by its *rank* and its *dimensionality.* A scalar is a tensor of rank 0; a vector with *D* components is a tensor of rank 1 and D dimensionality. A tensor of rank 2 and 3 dimensions can be represented as a Matrix 3 x 3.**

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- Geometric structure is implied and it is assumed some form of grid. Successive data records are located at successive positions. It requires to set the starting point, the directions and the step size for each dimension.
  - Satellite images.

Other forms of structure

- **Time**
  - **Present in many data sets**
  - **Uniformly spaced versus non-uniformly spaced**
  - **Relative versus absolute**
  - **Local versus Universal time**
  - **Seen as linear versus as cyclic**

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- **Topology**
  - **How the records are connected.**
  - **Geometry and space (spatial neighbors)**
  - **Hierarchy and graphs**
  - **This form of structure can be explicitly included in the data record or as an auxiliary data structure**

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Examples

MRI (magnetic resonance imagery). Density (scalar), with three spatial attributes, 3D grid connectivity;

CFD (computational fluid dynamics). Three dimensions for displacement, with one temporal and three spatial attributes, 3D grid connectivity (uniform or nonuniform);

Financial. No geometric structure, n possibly independent components, nominal and ordinal, with a temporal attribute;

CAD (computer-aided design). Three spatial attributes with edge and polygon connections, and surface properties;

Remote sensing. Multiple channels, with two or three spatial attributes, one temporal attribute, and grid connectivity;

Census. Multiple fields of all types, spatial attributes (e.g., addresses), temporal attribute, and connectivity implied by similarities in fields;

Social Network. Nodes consisting of multiple fields of all types, with various connectivity attributes that could be spatial, temporal, or dependent

Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew O. Ward, Georges Grinstein, Daniel Keim, 2015

Data

(Tamara Munzner)

Data Types and Dataset Types

- **Data Types**

➔ **Data Types**				
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Data Types and Dataset Types

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- An **item** is an individual entity that is discrete, such as a row in a simple table or a node in a network

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- A **grid** specifies the strategy for sampling continuous data in terms of both geometric and topological relationships between its cells

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- A **dataset** is any collection of information that is the target of analysis.

Data and Dataset Types

Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
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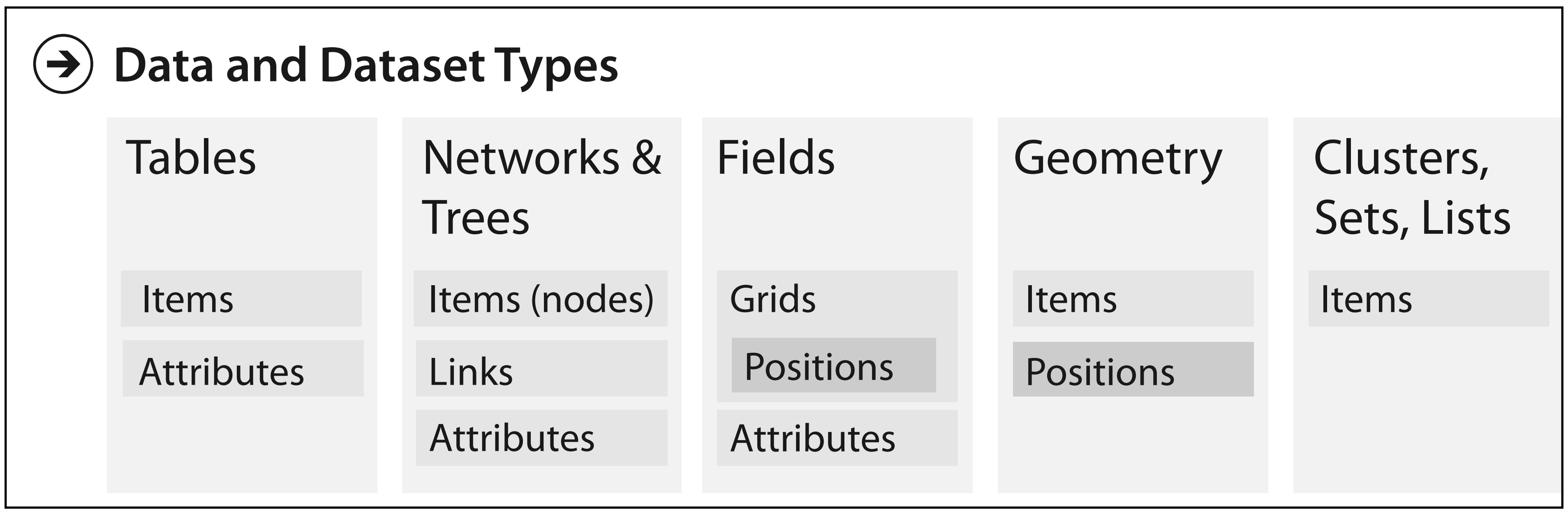

- **Other ways** to group items together include **clusters**, **sets**, and **lists**.
- In real-world situations, complex combinations of these basic types are common.

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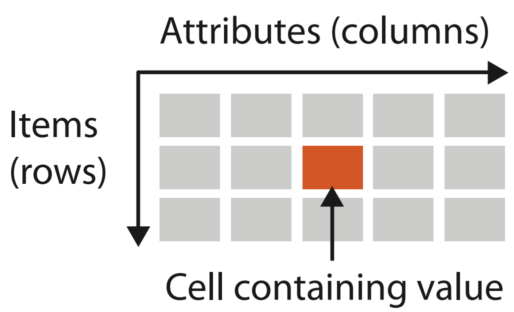
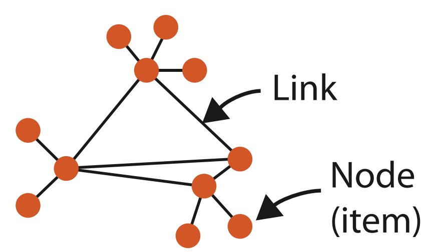
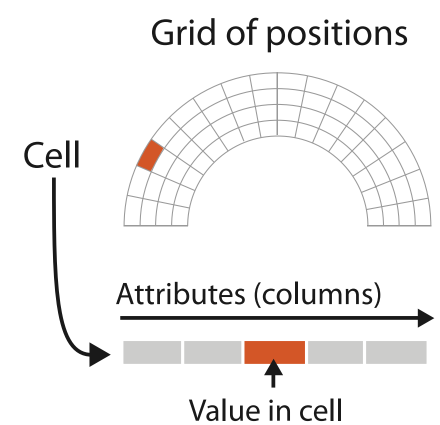
- **Tables**



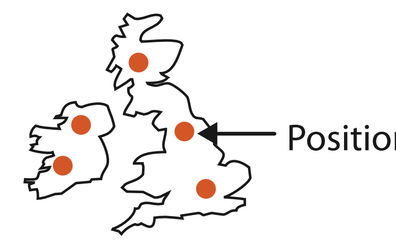
- **Networks**



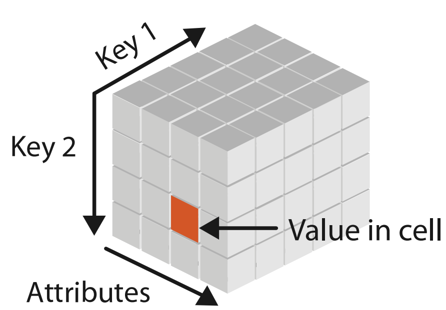
- **Fields** (Continuous)



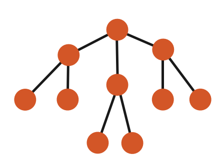
- **Geometry** (Spatial)



- *Multidimensional Table*

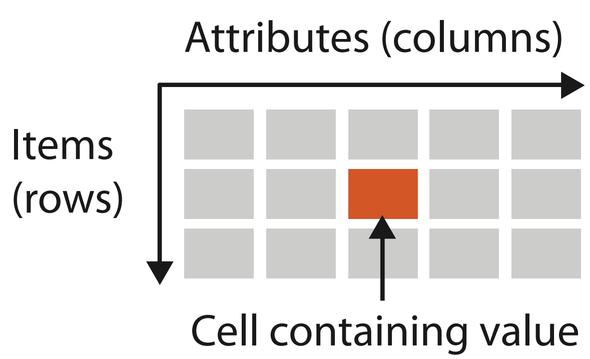


- *Trees*

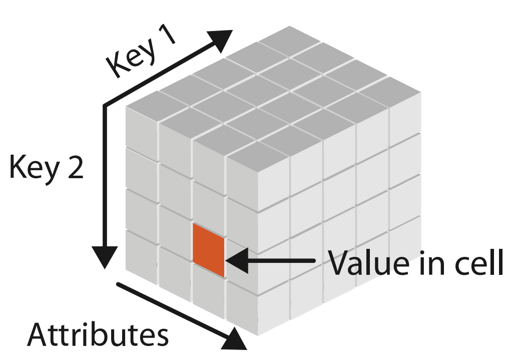


Dataset Types: **Table**

- ➔ Tables



- ➔ *Multidimensional Table*



A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	[illegible]	7/17/07
32	7/16/07	2-High	Medium Box	[illegible]	7/18/07
32	7/16/07	2-High	Medium Box	[illegible]	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	[illegible]	5-Low	Wrap Bag	0.56	1/20/05
69	[illegible]	4-Not Specified	Small Pack	0.44	6/6/05
69	[illegible]	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
96	4/17/05	2-High	Small Box	0.55	4/19/05
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

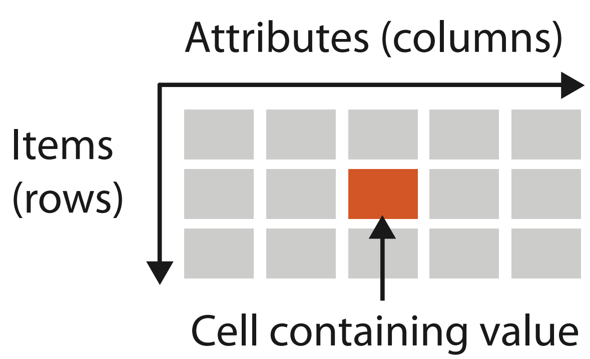
attribute

item

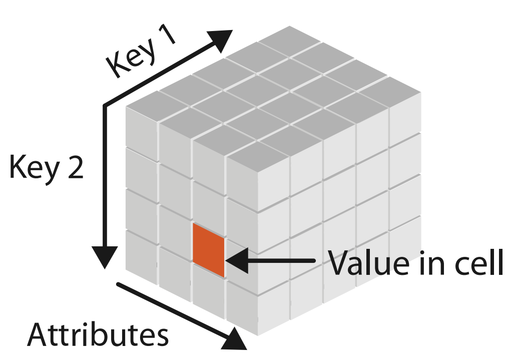
cell

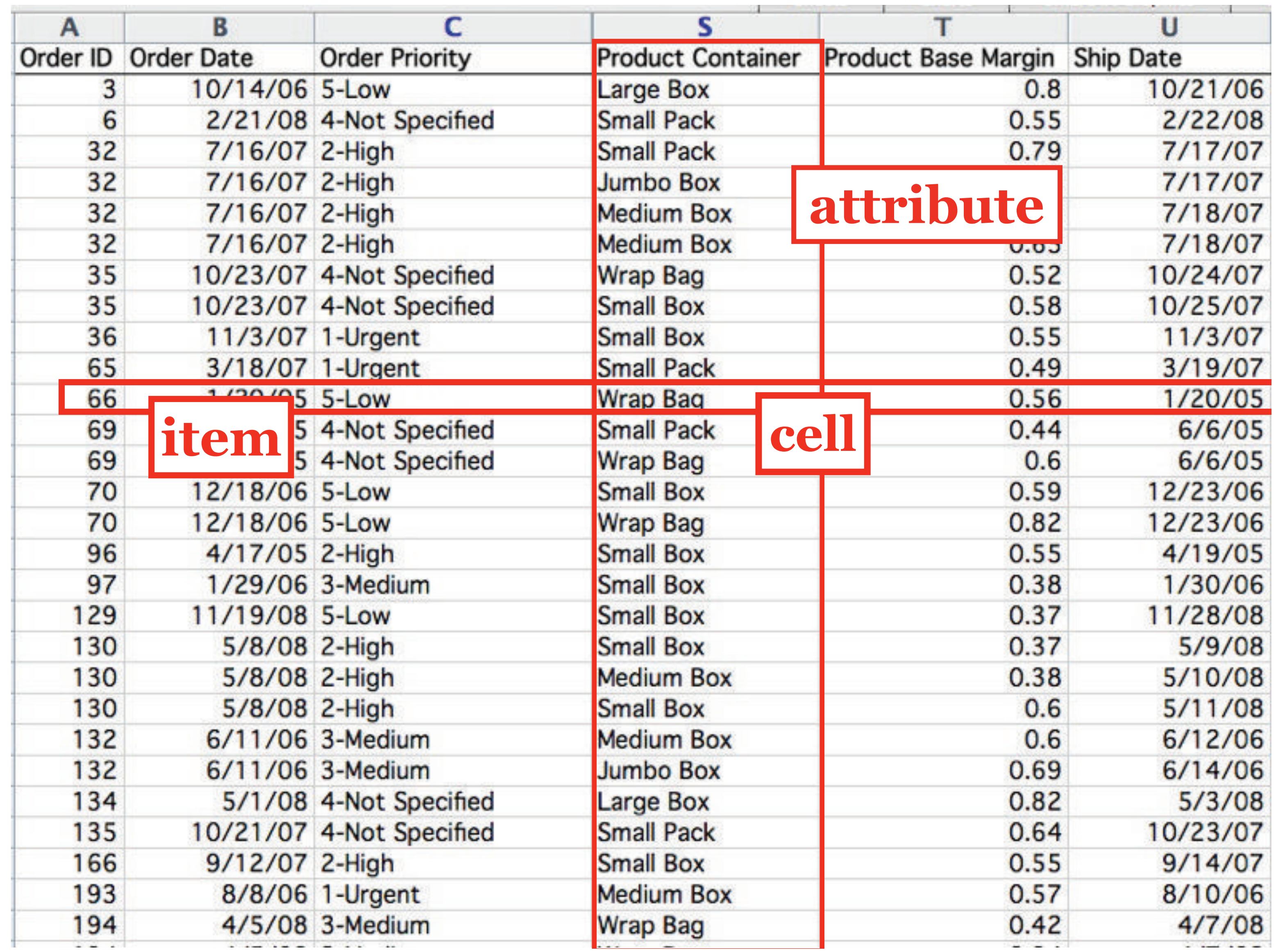
Dataset Types: **Table**

➔ Tables



➔ *Multidimensional Table*





A	B	C	S	T	U
Order ID	Order Date	Order Priority	Product Container	Product Base Margin	Ship Date
3	10/14/06	5-Low	Large Box	0.8	10/21/06
6	2/21/08	4-Not Specified	Small Pack	0.55	2/22/08
32	7/16/07	2-High	Small Pack	0.79	7/17/07
32	7/16/07	2-High	Jumbo Box	[illegible]	7/17/07
32	7/16/07	2-High	Medium Box	[illegible]	7/18/07
32	7/16/07	2-High	Medium Box	[illegible]	7/18/07
35	10/23/07	4-Not Specified	Wrap Bag	0.52	10/24/07
35	10/23/07	4-Not Specified	Small Box	0.58	10/25/07
36	11/3/07	1-Urgent	Small Box	0.55	11/3/07
65	3/18/07	1-Urgent	Small Pack	0.49	3/19/07
66	[illegible]	5-Low	Wrap Bag	0.56	1/20/05
69	[illegible]	4-Not Specified	Small Pack	0.44	6/6/05
69	[illegible]	4-Not Specified	Wrap Bag	0.6	6/6/05
70	12/18/06	5-Low	Small Box	0.59	12/23/06
70	12/18/06	5-Low	Wrap Bag	0.82	12/23/06
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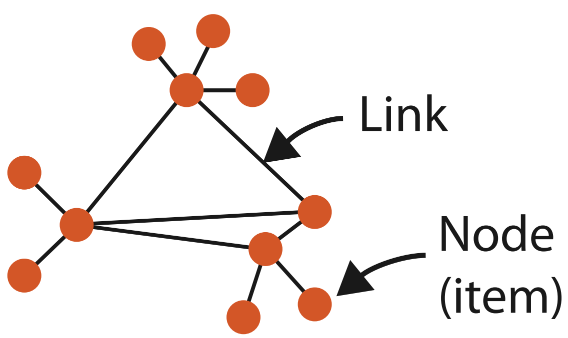
97	1/29/06	3-Medium	Small Box	0.38	1/30/06
129	11/19/08	5-Low	Small Box	0.37	11/28/08
130	5/8/08	2-High	Small Box	0.37	5/9/08
130	5/8/08	2-High	Medium Box	0.38	5/10/08
130	5/8/08	2-High	Small Box	0.6	5/11/08
132	6/11/06	3-Medium	Medium Box	0.6	6/12/06
132	6/11/06	3-Medium	Jumbo Box	0.69	6/14/06
134	5/1/08	4-Not Specified	Large Box	0.82	5/3/08
135	10/21/07	4-Not Specified	Small Pack	0.64	10/23/07
166	9/12/07	2-High	Small Box	0.55	9/14/07
193	8/8/06	1-Urgent	Medium Box	0.57	8/10/06
194	4/5/08	3-Medium	Wrap Bag	0.42	4/7/08

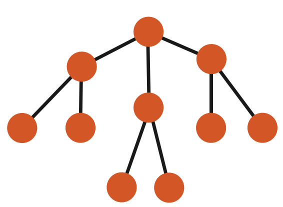
A **multidimensional table** has a more complex structure for indexing into a cell, with multiple keys.

Data Types and Dataset Types

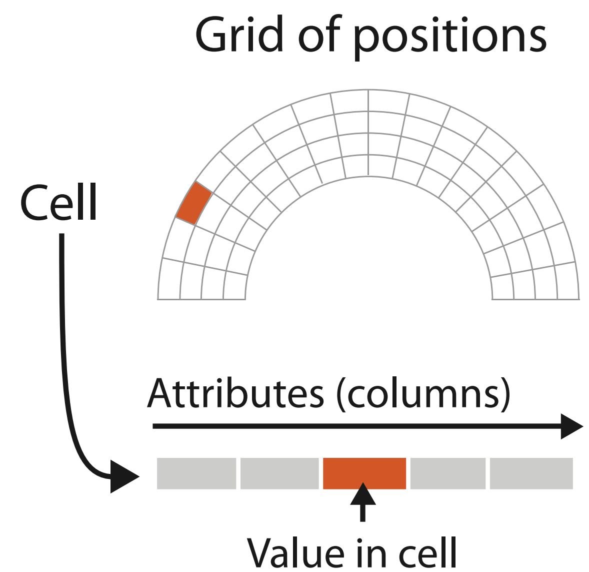
→ Networks



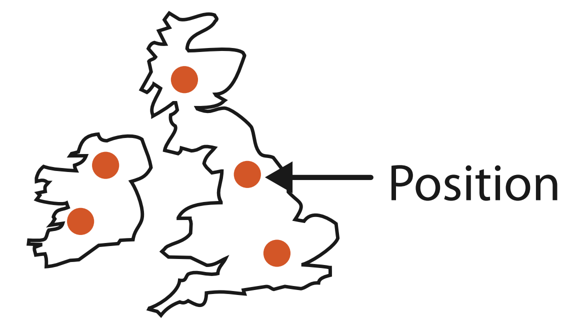
→ *Trees*



→ Fields (Continuous)

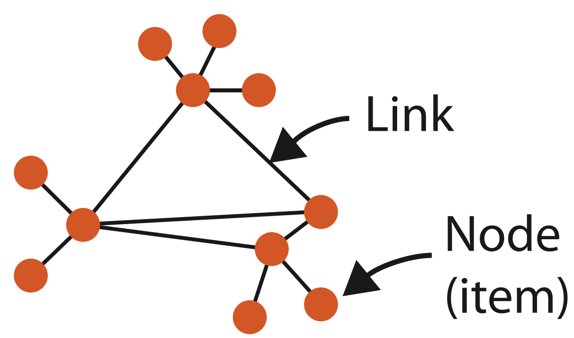


→ Geometry (Spatial)

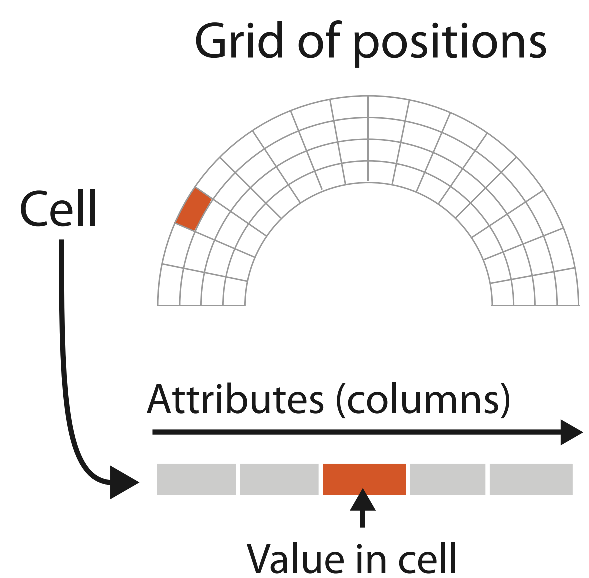


Data Types and Dataset Types

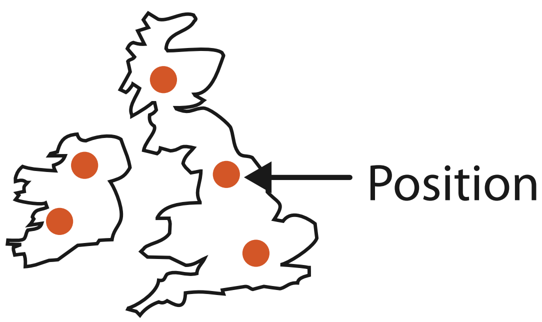
➔ Networks



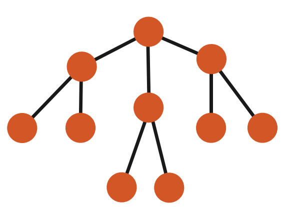
➔ Fields (Continuous)



➔ Geometry (Spatial)



➔ *Trees*



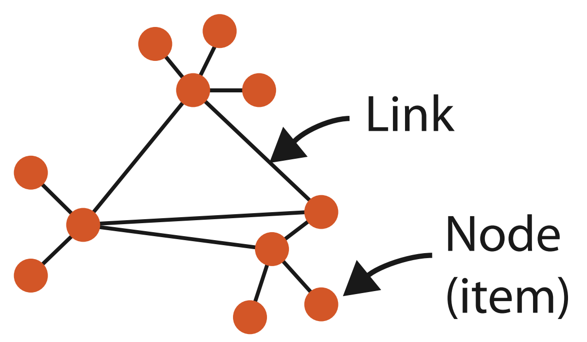
The **field** dataset type also contains attribute values associated with cells.

Each **cell** in a field contains measurements or calculations from a **continuous** domain

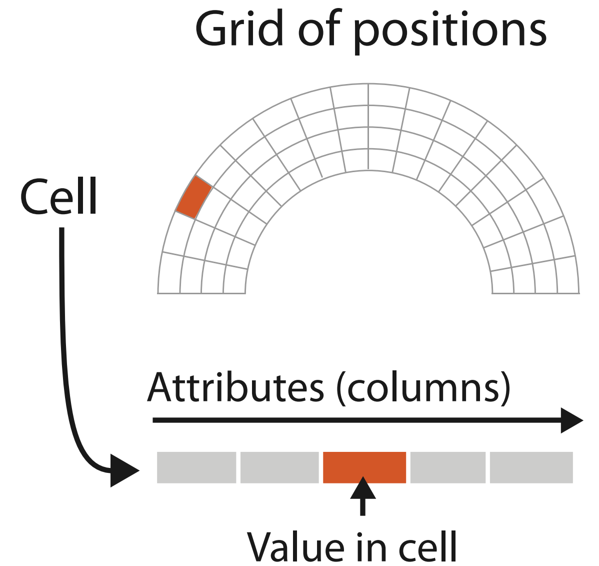
Continuous data requires careful treatment that takes into account the mathematical questions of **sampling** data **interpolation**

Data Types and Dataset Types

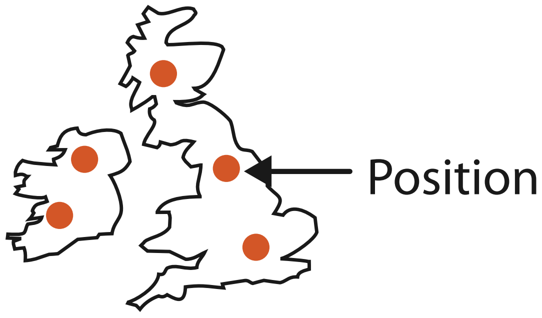
- ➔ Networks



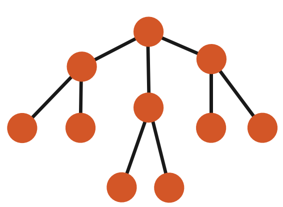
- ➔ Fields (Continuous)



- ➔ Geometry (Spatial)



- ➔ *Trees*



The **field** dataset type also contains attribute values associated with cells.

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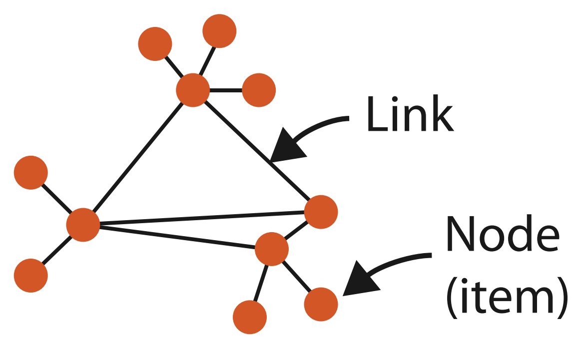
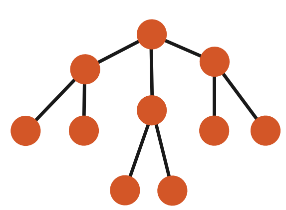
scientific visualization

Data Types and Dataset Types

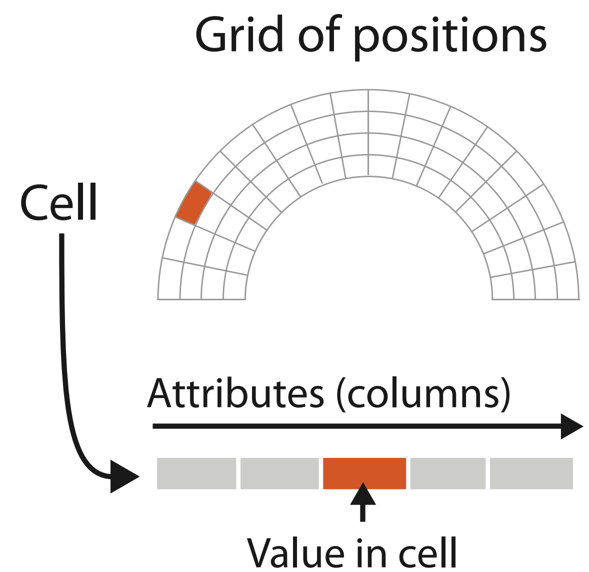
➔ Networks



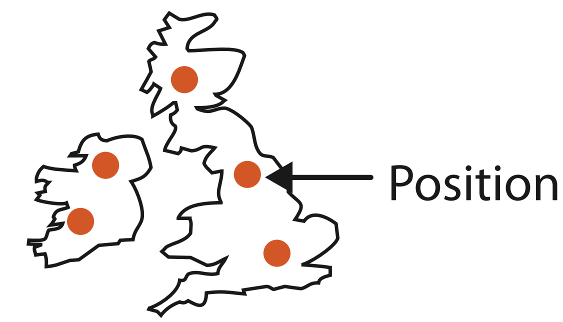
➔ *Trees*



➔ Fields (Continuous)



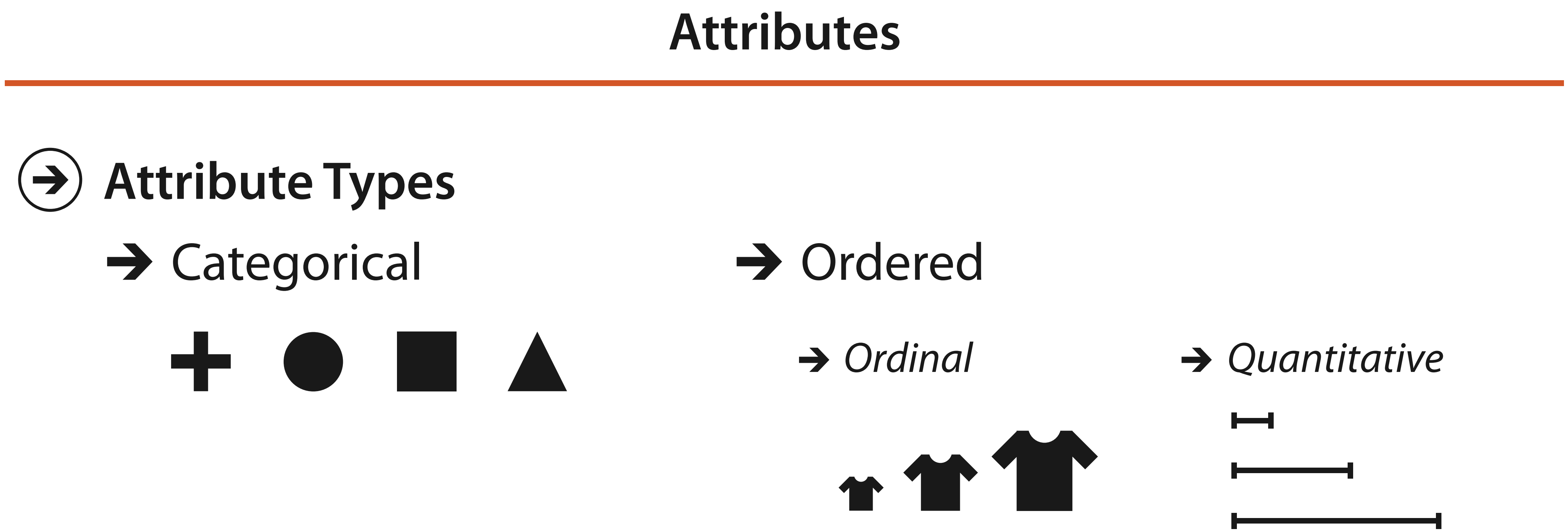
➔ Geometry (Spatial)



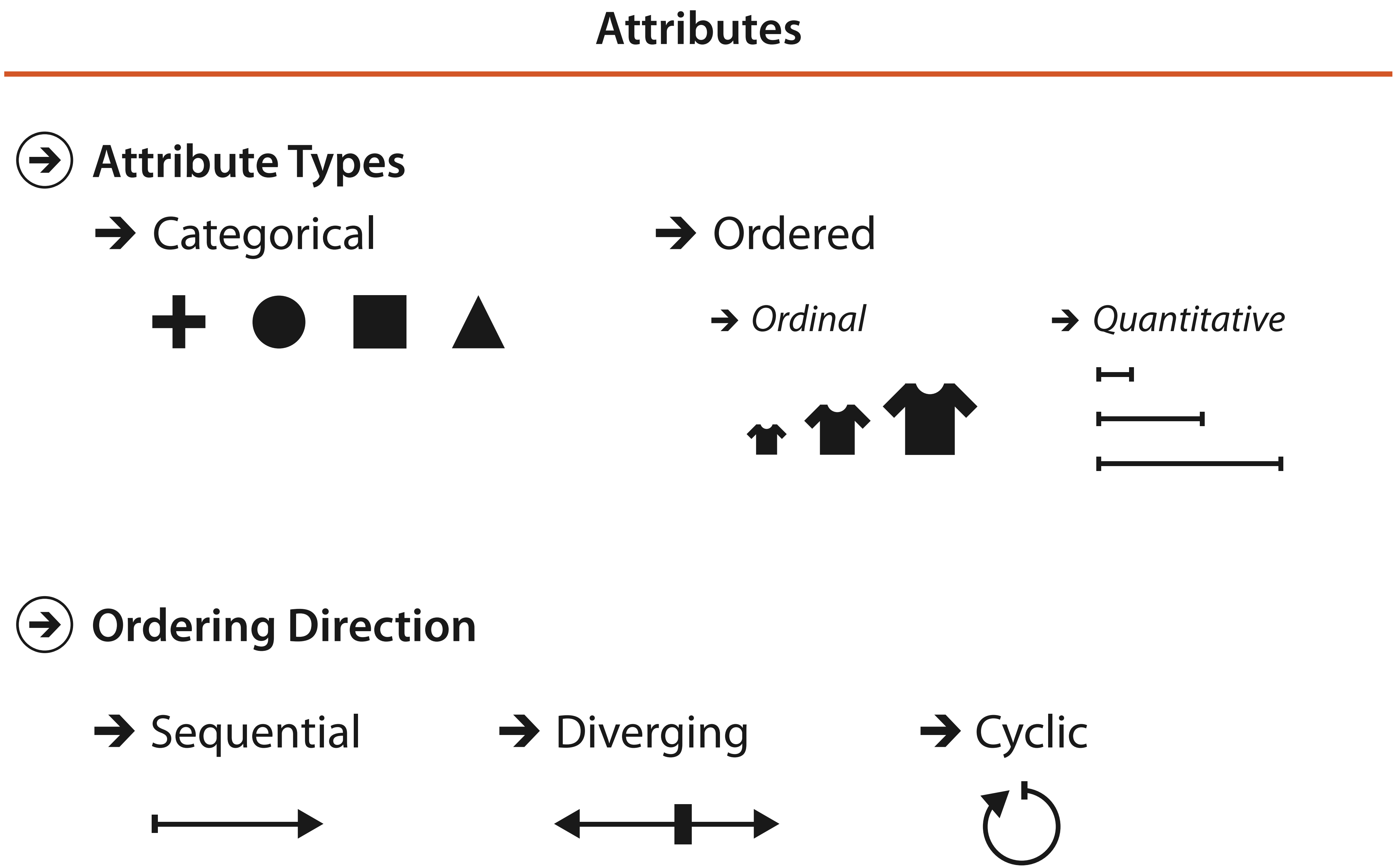
The problem of how to **create images from a geometric description** of a scene falls into another domain: **computer graphics**.

Simply showing a geometric dataset is not an interesting problem from the point of view of a vis designer.

Attribute Types



Attribute Types



What?

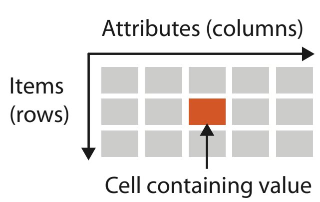
Datasets

Data Types
- Items
- Attributes
- Links
- Positions
- Grids

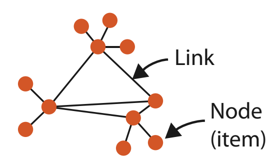
Data and Dataset Types

Tables	Networks & Trees	Fields	Geometry	Clusters, Sets, Lists
Items	Items (nodes)	Grids	Items	Items
Attributes	Links	Positions	Positions	
	Attributes	Attributes		

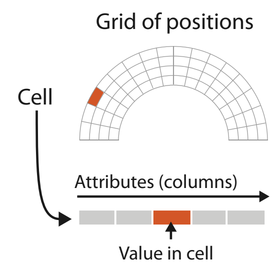
Dataset Types
- Tables



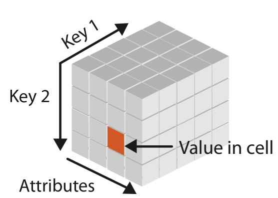
- Networks



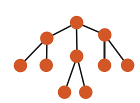
- Fields (Continuous)



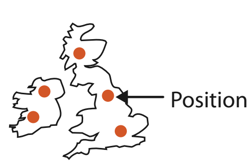
- *Multidimensional Table*



- *Trees*



- Geometry (Spatial)



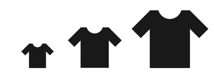
Dataset Availability
- Static

- Dynamic

Attributes

Attribute Types
- Categorical

- Ordered
  - *Ordinal*

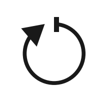


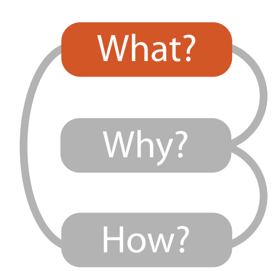
  - *Quantitative*

Ordering Direction
- Sequential

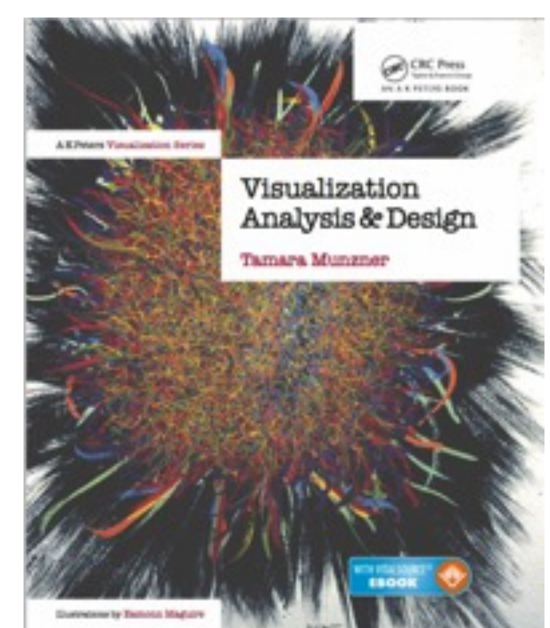
- Diverging

- Cyclic





Tamara Munzner



Data Preprocessing

Data Preprocessing

- **Metadata**

Data Preprocessing

- **Metadata**

- **Basic statistics about the (scalar) data**

Data Preprocessing

- **Metadata**
- **Basic statistics about the (scalar) data**
- **Missing Values and Data Cleansing**

Data Preprocessing

- **Metadata**
- **Basic statistics about the (scalar) data**
- **Missing Values and Data Cleansing**
- **Normalization**

Data Preprocessing

- **Metadata**
- **Basic statistics about the (scalar) data**
- **Missing Values and Data Cleansing**
- **Normalization**
- **Dimension reduction**

Data Preprocessing

- **Metadata**
- **Basic statistics about the (scalar) data**
- **Missing Values and Data Cleansing**
- **Normalization**
- **Dimension reduction**
- **Mapping Nominal Dimensions to Numbers**

Data Preprocessing

- **Metadata**
- **Basic statistics about the (scalar) data**
- **Missing Values and Data Cleansing**
- **Normalization**
- **Dimension reduction**
- **Mapping Nominal Dimensions to Numbers**
- **Other data processing topics**

Metadata

- **Sample from the cars data set**

Acura 3.5 RL 4dr	1	0	0	0	0	0	0	0	43755	39014	3,5	6	225	18	24	3880	115	197	72
Acura 3.5 RL w/Navigation 4dr	1	0	0	0	0	0	0	0	46100	41100	3,5	6	225	18	24	3893	115	197	72
Acura MDX	0	0	1	0	0	0	1	0	36945	33337	3,5	6	265	17	23	4451	106	189	77
Acura NSX coupe 2dr manual S	0	1	0	0	0	0	0	1	89765	79978	3,2	6	290	17	24	3153	100	174	71
Acura RSX Type S 2dr	1	0	0	0	0	0	0	0	23820	21761	2	4	200	24	31	2778	101	172	68
Acura TL 4dr	1	0	0	0	0	0	0	0	33195	30299	3,2	6	270	20	28	3575	108	186	72
Acura TSX 4dr	1	0	0	0	0	0	0	0	26990	24647	2,4	4	200	22	29	3230	105	183	69
Audi A4 1.8T 4dr	1	0	0	0	0	0	0	0	25940	23508	1,8	4	170	22	31	3252	104	179	70
Audi A4 3.0 4dr	1	0	0	0	0	0	0	0	31840	28846	3	6	220	20	28	3462	104	179	70
Audi A4 3.0 convertible 2dr	1	0	0	0	0	0	0	0	42490	38325	3	6	220	20	27	3814	105	180	70
Audi A4 3.0 Quattro 4dr auto	1	0	0	0	0	0	1	0	34480	31388	3	6	220	18	25	3627	104	179	70

Metadata

- **Sample from the cars data set**

Acura 3.5 RL 4dr	1	0	0	0	0	0	0	0	43755	39014	3,5	6	225	18	24	3880	115	197	72
Acura 3.5 RL w/Navigation 4dr	1	0	0	0	0	0	0	0	46100	41100	3,5	6	225	18	24	3893	115	197	72
Acura MDX	0	0	1	0	0	0	1	0	36945	33337	3,5	6	265	17	23	4451	106	189	77
Acura NSX coupe 2dr manual S	0	1	0	0	0	0	0	1	89765	79978	3,2	6	290	17	24	3153	100	174	71
Acura RSX Type S 2dr	1	0	0	0	0	0	0	0	23820	21761	2	4	200	24	31	2778	101	172	68
Acura TL 4dr	1	0	0	0	0	0	0	0	33195	30299	3,2	6	270	20	28	3575	108	186	72
Acura TSX 4dr	1	0	0	0	0	0	0	0	26990	24647	2,4	4	200	22	29	3230	105	183	69
Audi A4 1.8T 4dr	1	0	0	0	0	0	0	0	25940	23508	1,8	4	170	22	31	3252	104	179	70
Audi A4 3.0 4dr	1	0	0	0	0	0	0	0	31840	28846	3	6	220	20	28	3462	104	179	70
Audi A4 3.0 convertible 2dr	1	0	0	0	0	0	0	0	42490	38325	3	6	220	20	27	3814	105	180	70
Audi A4 3.0 Quattro 4dr auto	1	0	0	0	0	0	1	0	34480	31388	3	6	220	18	25	3627	104	179	70

- **With the exception of first column (Vehicle name) we need more information!**

Metadata

- **Sample from the cars data set**

Acura 3.5 RL 4dr	1	0	0	0	0	0	0	0	43755	39014	3,5	6	225	18	24	3880	115	197	72
Acura 3.5 RL w/Navigation 4dr	1	0	0	0	0	0	0	0	46100	41100	3,5	6	225	18	24	3893	115	197	72
Acura MDX	0	0	1	0	0	0	1	0	36945	33337	3,5	6	265	17	23	4451	106	189	77
Acura NSX coupe 2dr manual S	0	1	0	0	0	0	0	1	89765	79978	3,2	6	290	17	24	3153	100	174	71
Acura RSX Type S 2dr	1	0	0	0	0	0	0	0	23820	21761	2	4	200	24	31	2778	101	172	68
Acura TL 4dr	1	0	0	0	0	0	0	0	33195	30299	3,2	6	270	20	28	3575	108	186	72
Acura TSX 4dr	1	0	0	0	0	0	0	0	26990	24647	2,4	4	200	22	29	3230	105	183	69
Audi A4 1.8T 4dr	1	0	0	0	0	0	0	0	25940	23508	1,8	4	170	22	31	3252	104	179	70
Audi A4 3.0 4dr	1	0	0	0	0	0	0	0	31840	28846	3	6	220	20	28	3462	104	179	70
Audi A4 3.0 convertible 2dr	1	0	0	0	0	0	0	0	42490	38325	3	6	220	20	27	3814	105	180	70
Audi A4 3.0 Quattro 4dr auto	1	0	0	0	0	0	1	0	34480	31388	3	6	220	18	25	3627	104	179	70

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Vehicle Name	Small/Sporty/ Compact/Large Sedan	Sports Car	SUV	Wagon	Minivan	Pickup	AWD	RWD	Retail Price	Dealer Cost	Engine Size (l)	Cyl	HP	City MPG	Hwy MPG	Weight	Wheel Base	Len	Width
Acura 3.5 RL 4dr	1	0	0	0	0	0	0	0	43755	39014	3,5	6	225	18	24	3880	115	197	72
Acura 3.5 RL w/Navigation 4dr	1	0	0	0	0	0	0	0	46100	41100	3,5	6	225	18	24	3893	115	197	72
Acura MDX	0	0	1	0	0	0	1	0	36945	33337	3,5	6	265	17	23	4451	106	189	77
Acura NSX coupe 2dr manual S	0	1	0	0	0	0	0	1	89765	79978	3,2	6	290	17	24	3153	100	174	71
Acura RSX Type S 2dr	1	0	0	0	0	0	0	0	23820	21761	2	4	200	24	31	2778	101	172	68
Acura TL 4dr	1	0	0	0	0	0	0	0	33195	30299	3,2	6	270	20	28	3575	108	186	72
Acura TSX 4dr	1	0	0	0	0	0	0	0	26990	24647	2,4	4	200	22	29	3230	105	183	69
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- **With the column names it is much better but it is not enough !**

Metadata

Associated Metadata

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TYPE:  Sample
SIZE:  428 observations, 19 variables

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Specifications are given for 428 new vehicles for the 2004 year. The variables recorded include price, measurements
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SOURCE:
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the JSE Web site kindly granted by PARS International Corporation, 102 West 38th Street, New York, NY 10018)

VARIABLE DESCRIPTIONS:

Columns Variables
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+ **Special values**

+ **How to denote missing values**

Metadata

- **Metadata provides:**
  - **Source of data**
  - **Information that facilitates the interpretation of the data set**
  - **Units**
  - **Symbol to indicate a missing value**
  - **Reference point for some measurements**
  - **Resolution at which the measurements were acquired**

Basic statistics about the (scalar) data

- **For simple data types (scalars)**

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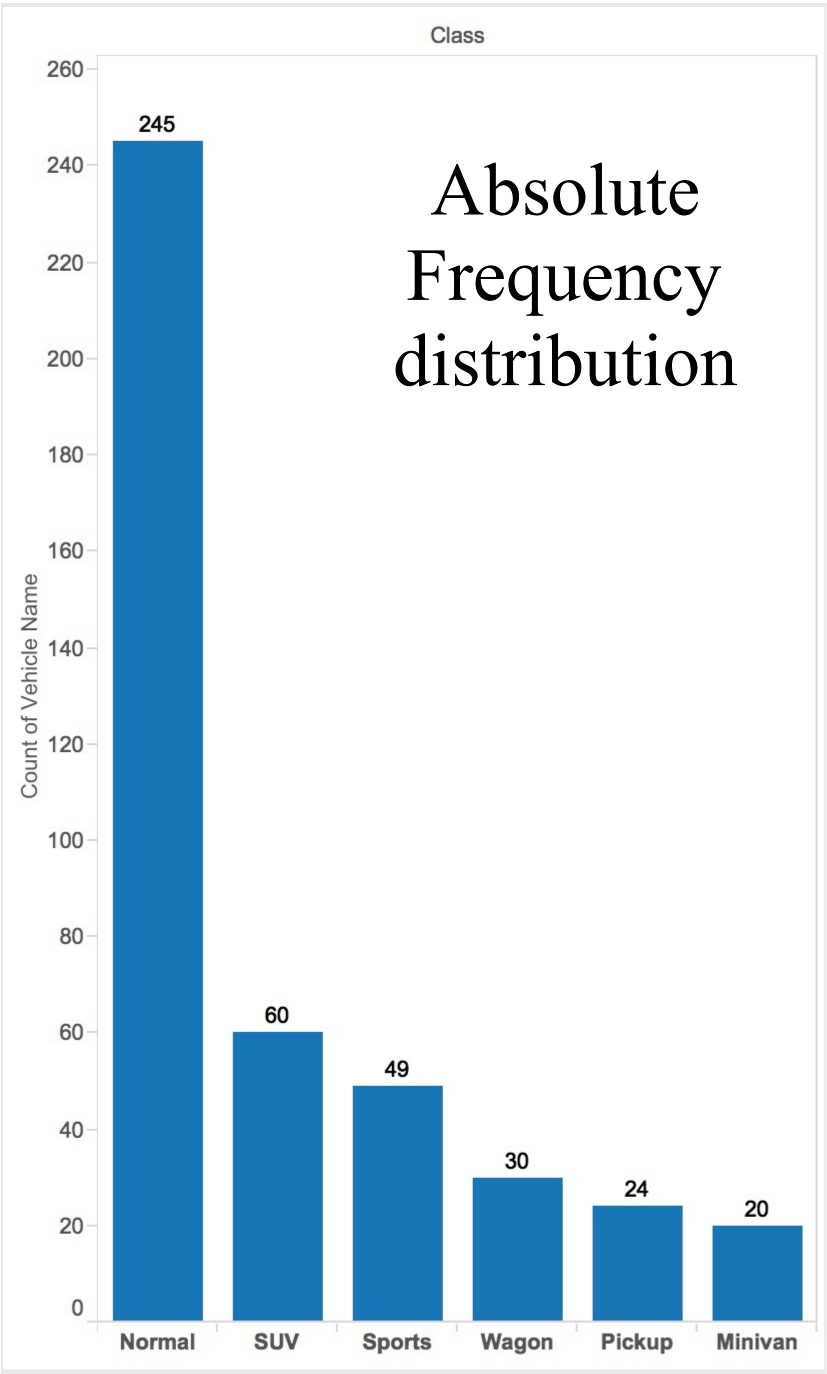
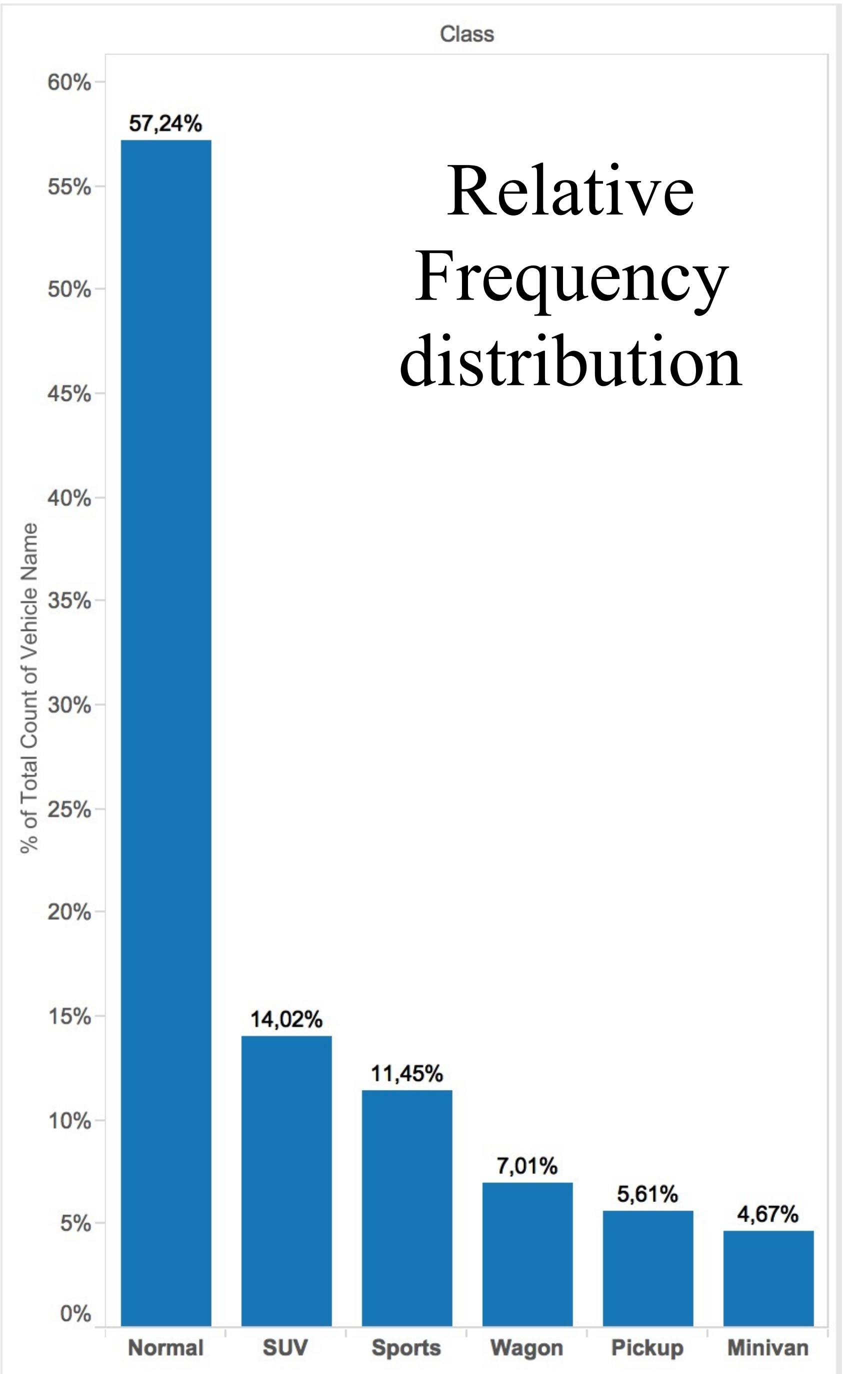
  - **Mean, Variance, etc.**

Basic statistics about the (scalar) data

- **Categorial variable (from Cars data set): Class**

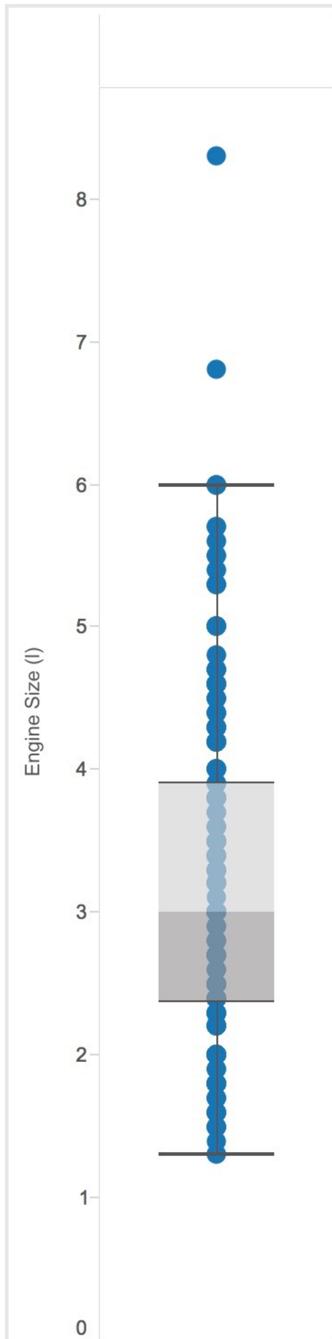




Stats:
- mode
- domain cardinality

Basic statistics about the (scalar) data

- **Numeric (continuous) variable (from Cars data set): Engine Size**



Summary

Count:	428
SUM(Engine Size (l))	
Average:	3.197
Minimum:	1.300
Maximum:	8.300
Median:	3.000
Standard Deviation:	1.109
First Quartile:	2.375
Third Quartile:	3.900
Skewness:	0.71
Excess Kurtosis:	0.52

Statistics techniques for getting additional insights

- **Outlier detection**
  - **“In statistics, an outlier is an observation point that is distant from other observations. An outlier may be due to variability in the measurement or it may indicate experimental error; the latter are sometimes excluded from the data set.!”**

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- **Correlation Analysis**
  - **can help users to eliminate variables (because are redundant or highlight)**

Statistics techniques for getting additional insights

Correlation Analysis

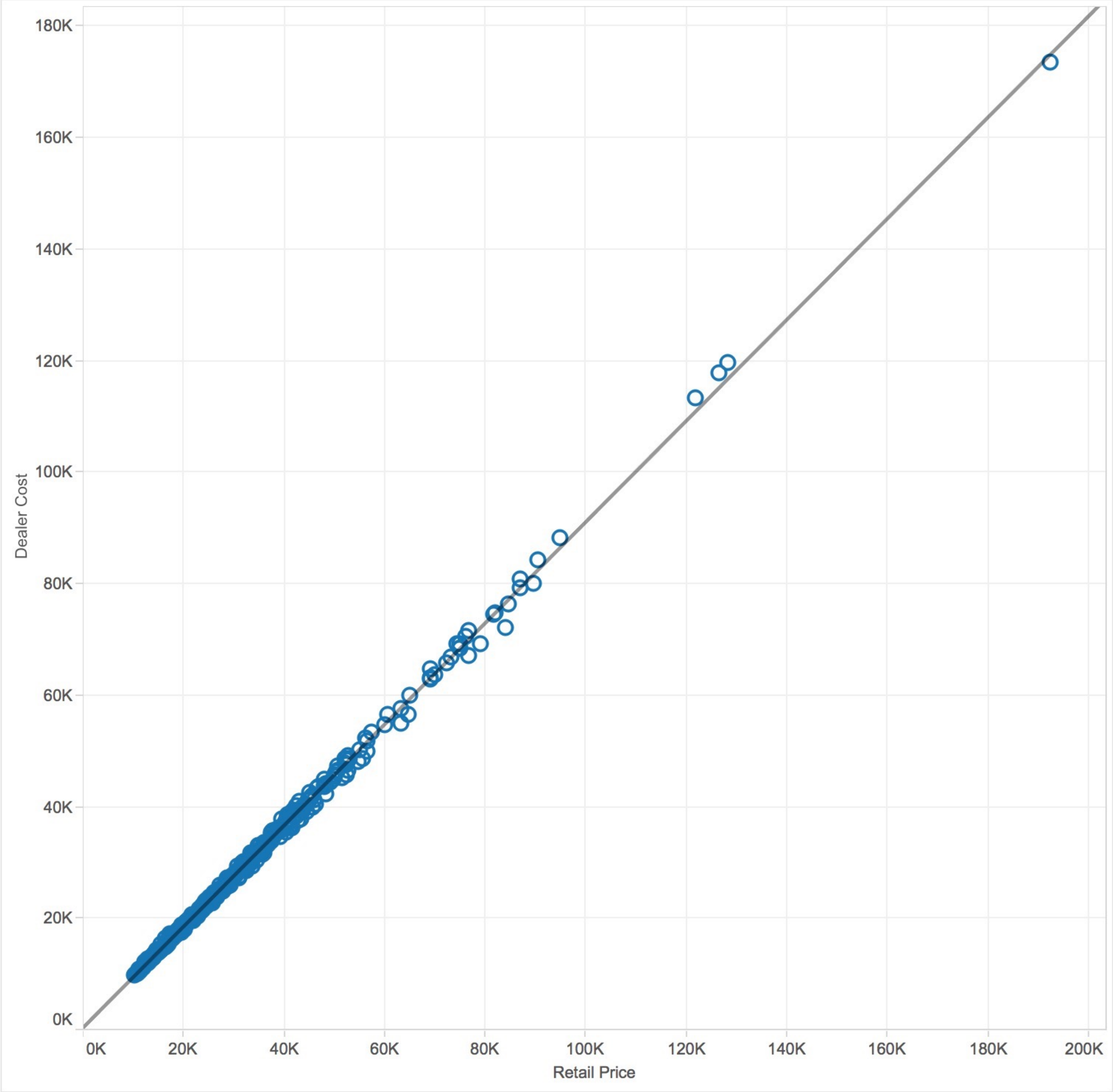
Trend Lines Model

A linear trend model is computed for Dealer Cost given Retail Price. The model may be significant at p <= 0,05.

Model formula:	(Retail Price + intercept)
Number of modeled observations:	428
Number of filtered observations:	0
Model degrees of freedom:	2
Residual degrees of freedom (DF):	426
SSE (sum squared error):	2,30717e+08
MSE (mean squared error):	541590
R-Squared:	0,998264
Standard error:	735,928
p-value (significance):	< 0,0001

Individual trend lines:

Panes		Line		Coefficients				
Row	Column	p-value	DF	Term	Value	StdErr	t-value	p-value
Dealer Cost	Retail Price	< 0,0001	426	Retail Price	0,907115	0,0018328	494,939	< 0,0001
				intercept	284,145	69,8118	4,07015	< 0,0001



Missing Values and Data Cleansing

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- **Erroneous data**
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  - **May be very hard to detect unless they are out of range values or obvious outlier.**

Missing Values

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  - **Is the most commonly applied; It implies a loss of information that should be evaluated. Sometimes the records with missing values are the most interesting to be analyzed.**

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- Assign a **sentinel value**
  - Assign a sentinel value for each variable when the real value is in question (missing or erroneous). This value should be carefully considered in the processing.
- Assign the **average** value
  - Average value for that variable; Minimally affects the statistics of that variable; The average may not be a good guess; It may mask outliers.

Missing Values and Data Cleansing

Missing Values and Data Cleansing

- **Assign value based on nearest neighbor**
  - **Try to find the (missing) value for one variable *i* for one particular record based on the value(s) for that variable based on the records that are the most similar to this particular record (based on the other variables). We are assuming that the variable *i* depends on all other variables and may not be the case.**
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  - **When we have connectivity information (spatial or geo-spatial data, graphs) the nearest neighbor may be considered based on the available connections.**
- **Compute a substitute value**
  - **All the previous methods are had hoc ! Some new statistical approaches propose methods and algorithms to make multiple imputations for the missing values**
  - **More info: ”Multiple imputation for multivariate missing-data problems: a data analyst’s perspective", by Joseph L. Schafer and Maren K. Olsen**

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- **Replacing *Min* and *Max* by ∂-*Quantile* and (1-∂)-*Quantile***

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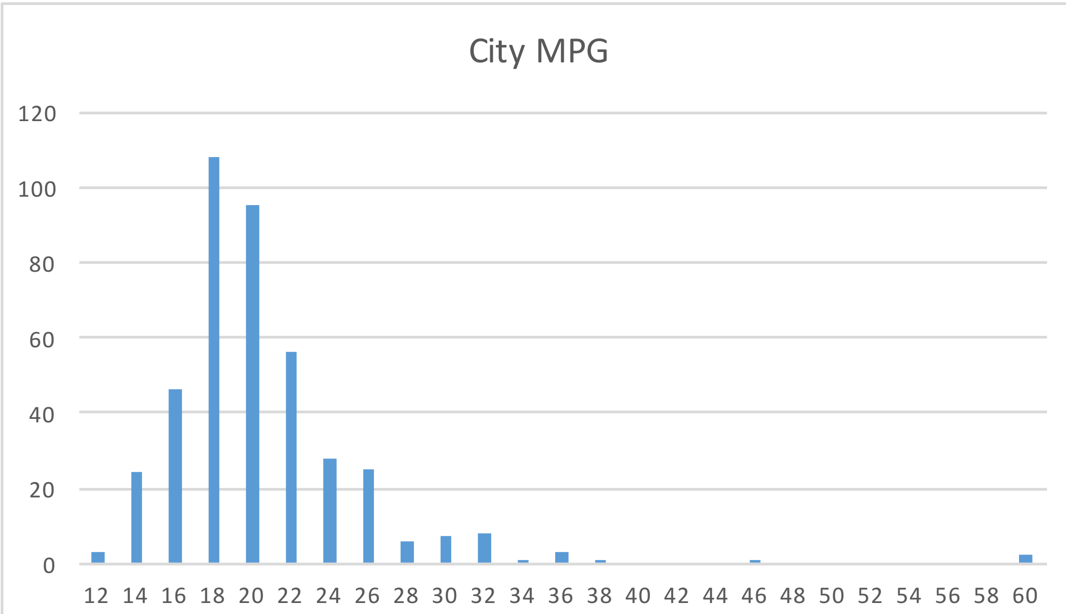

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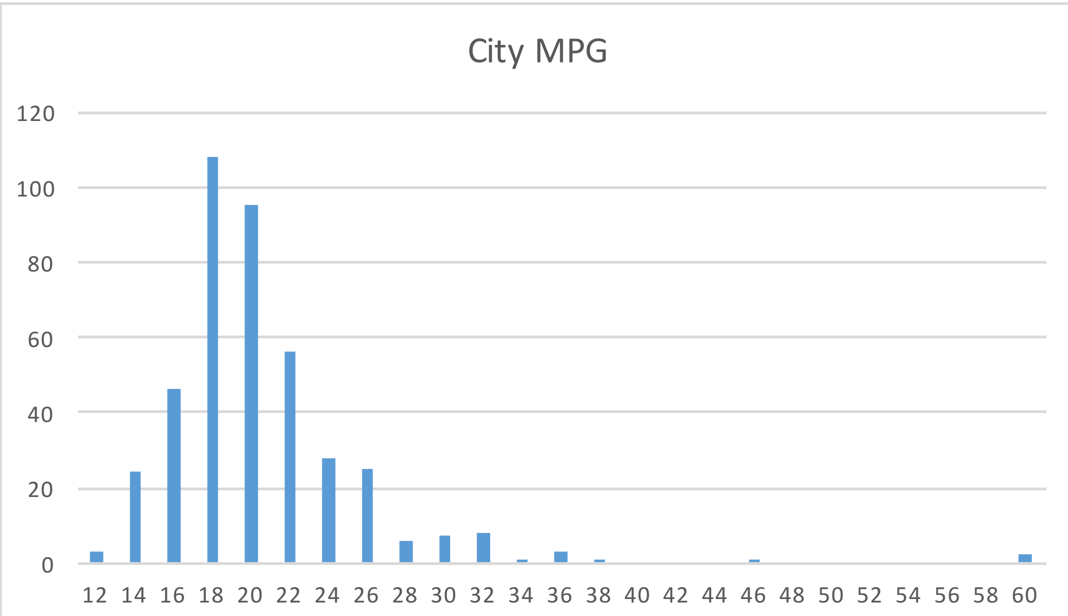

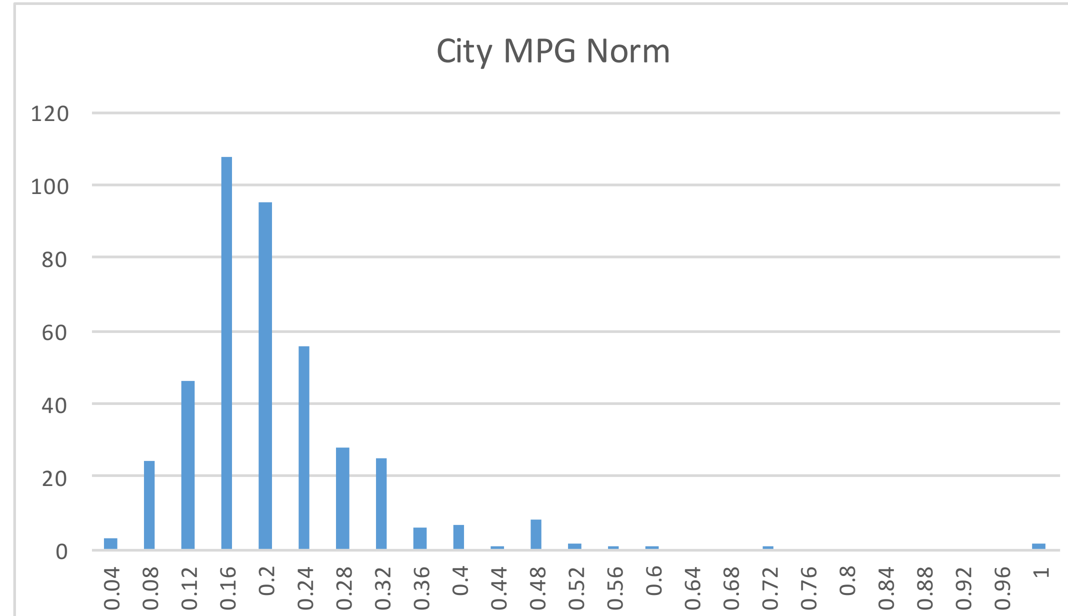

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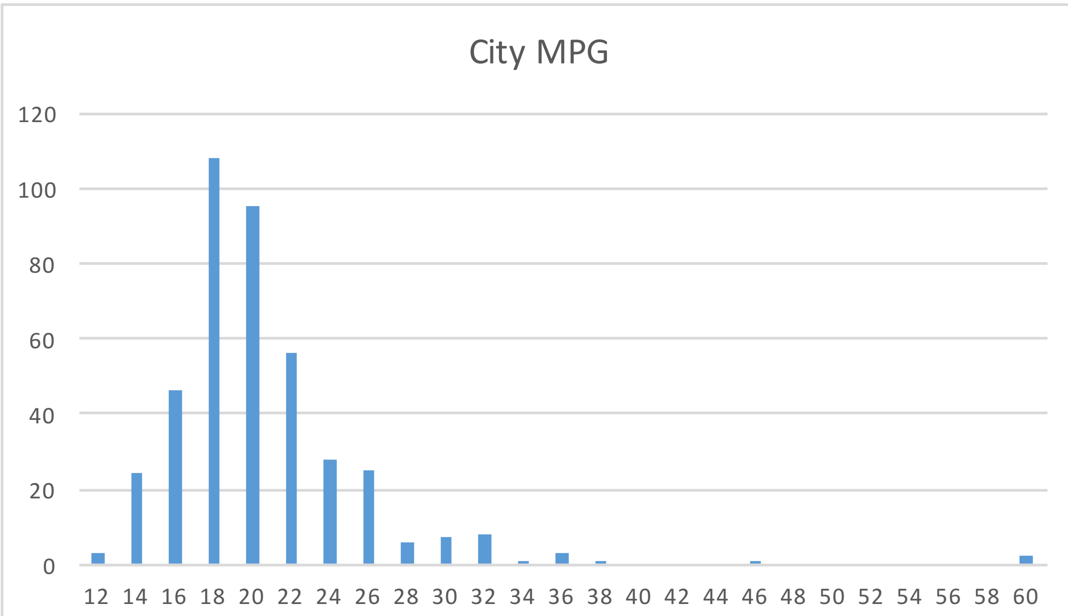

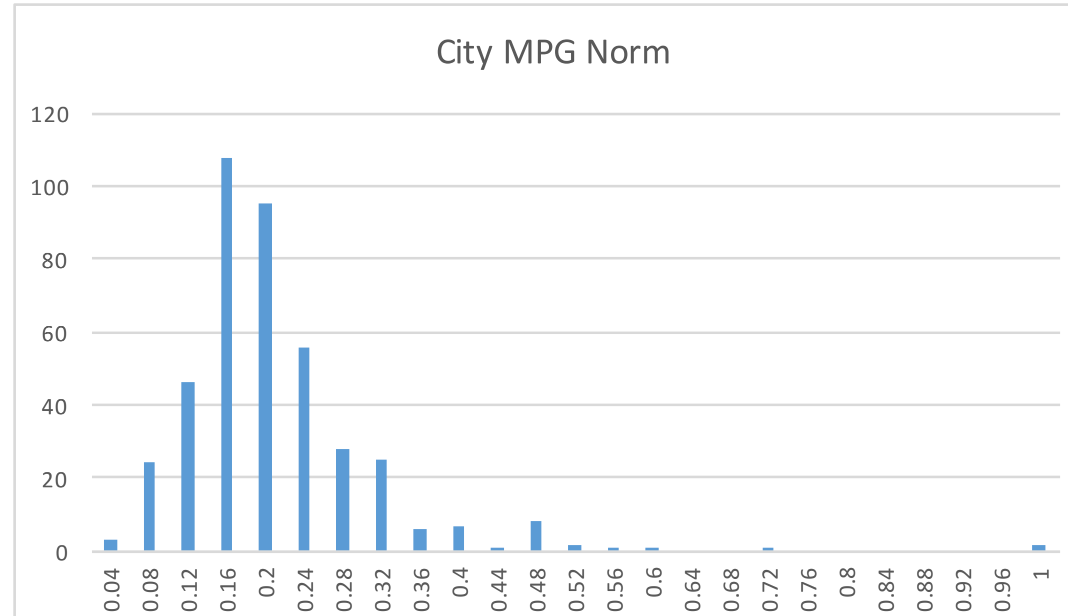

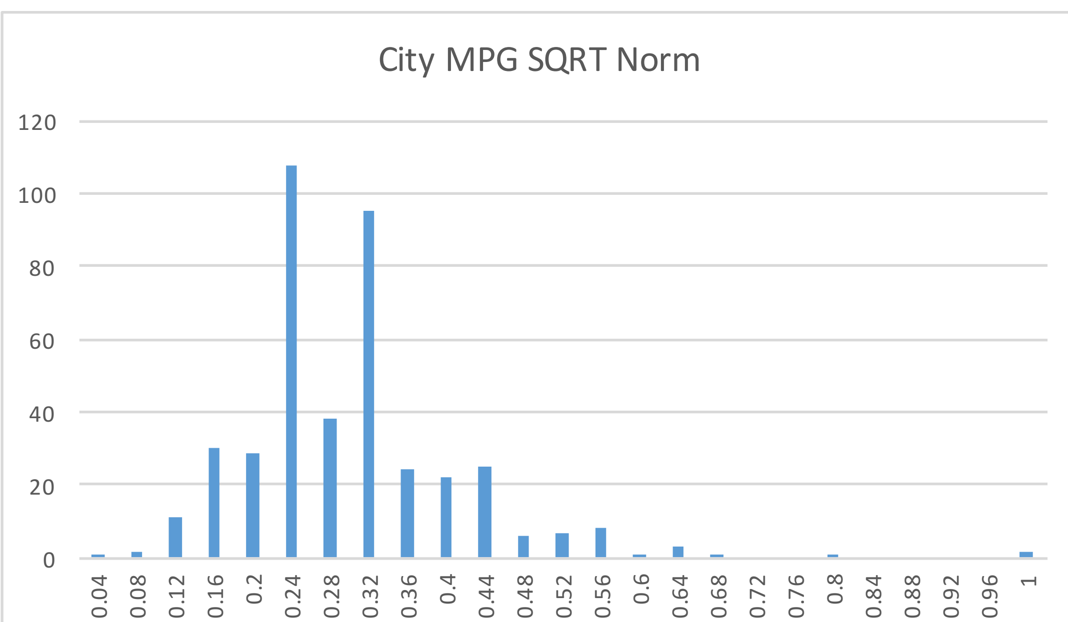

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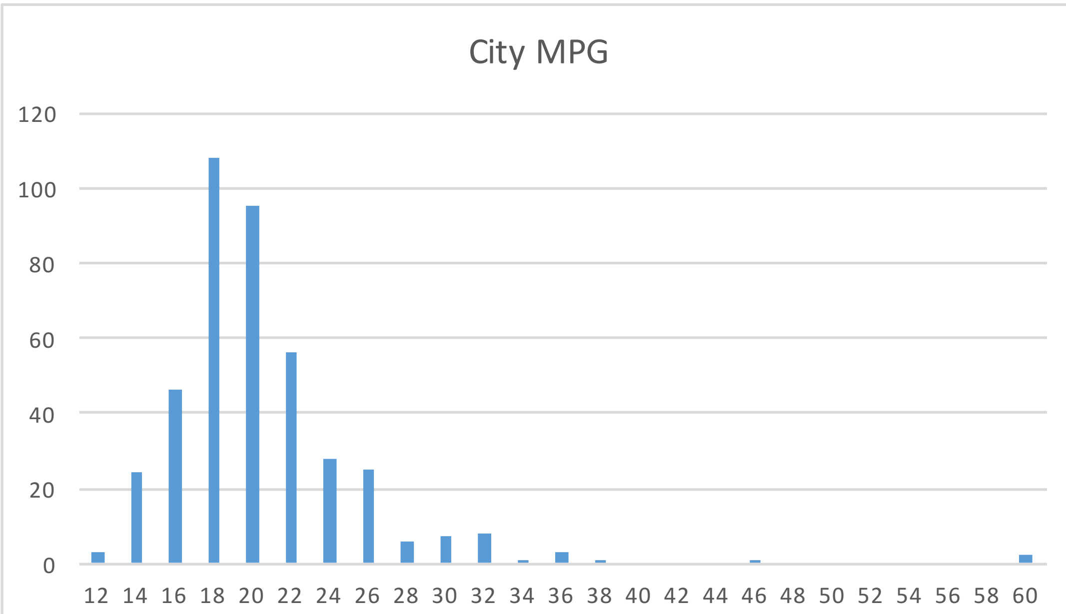

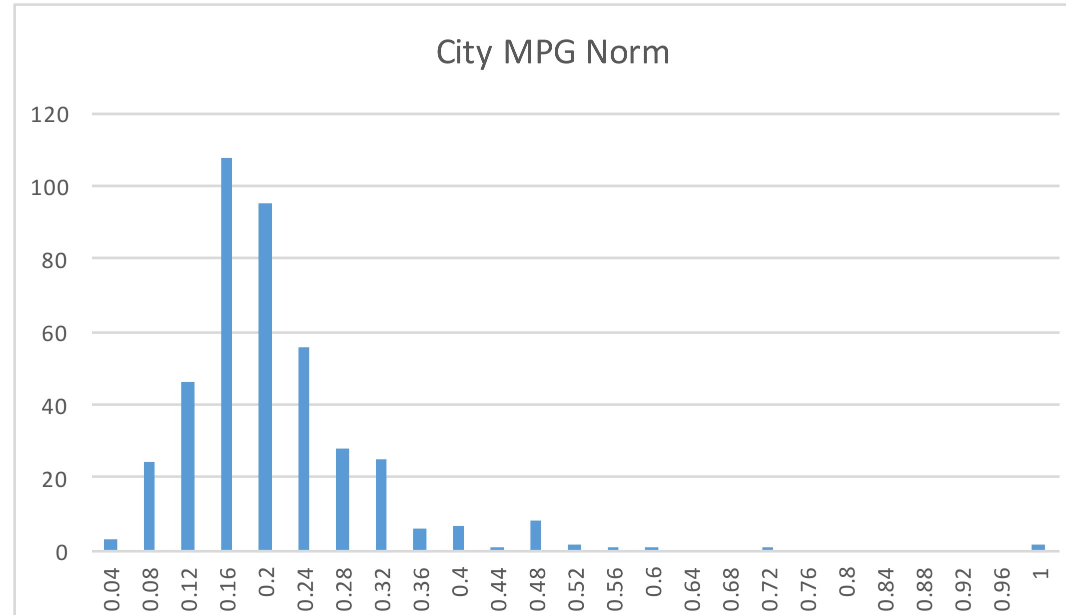

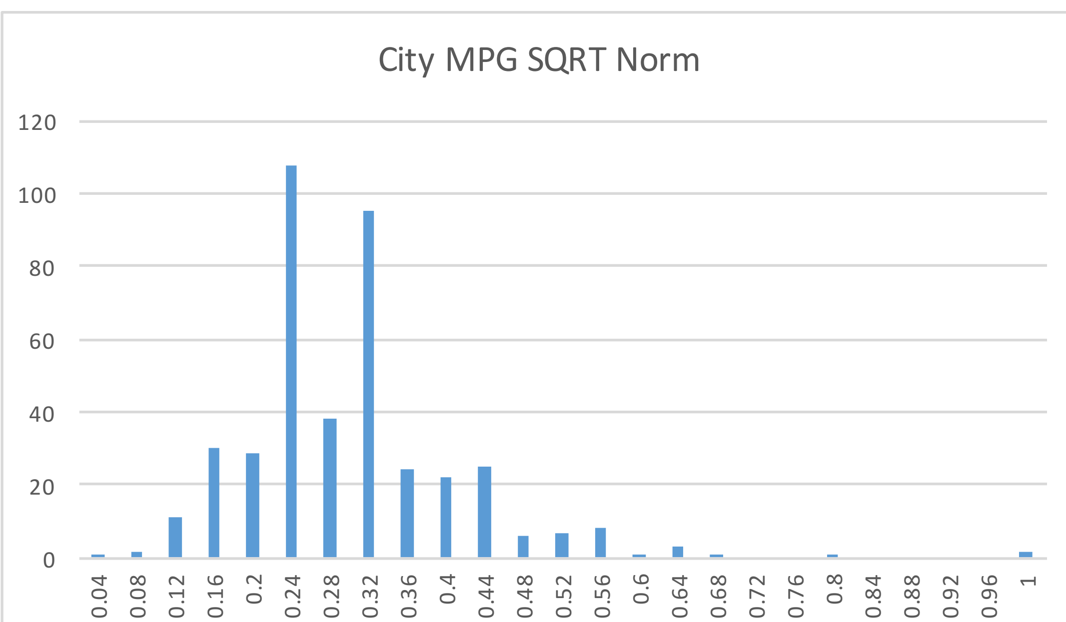

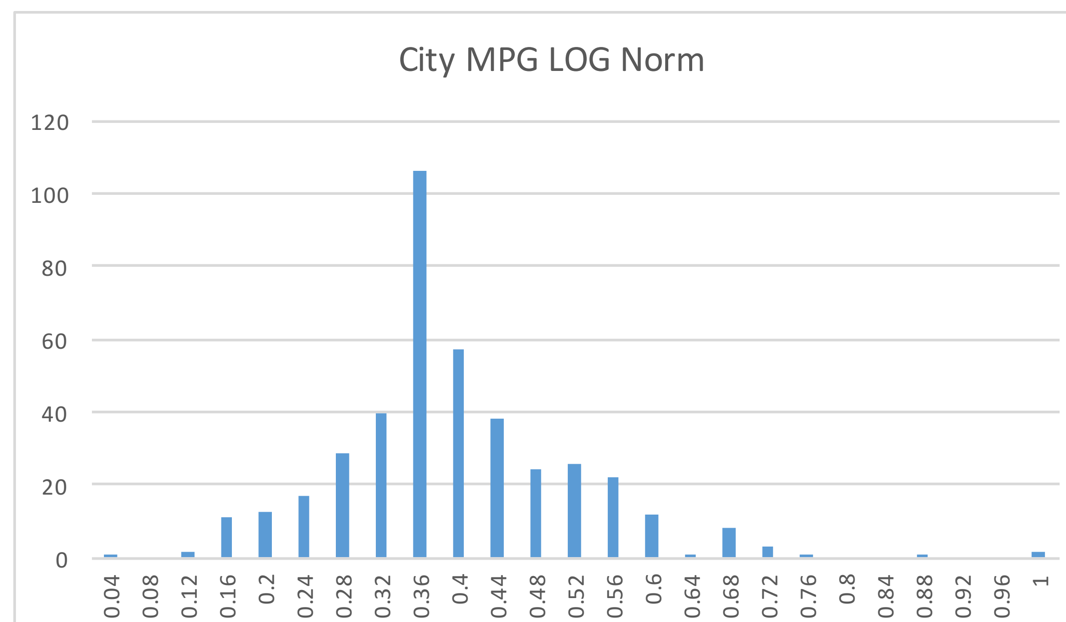

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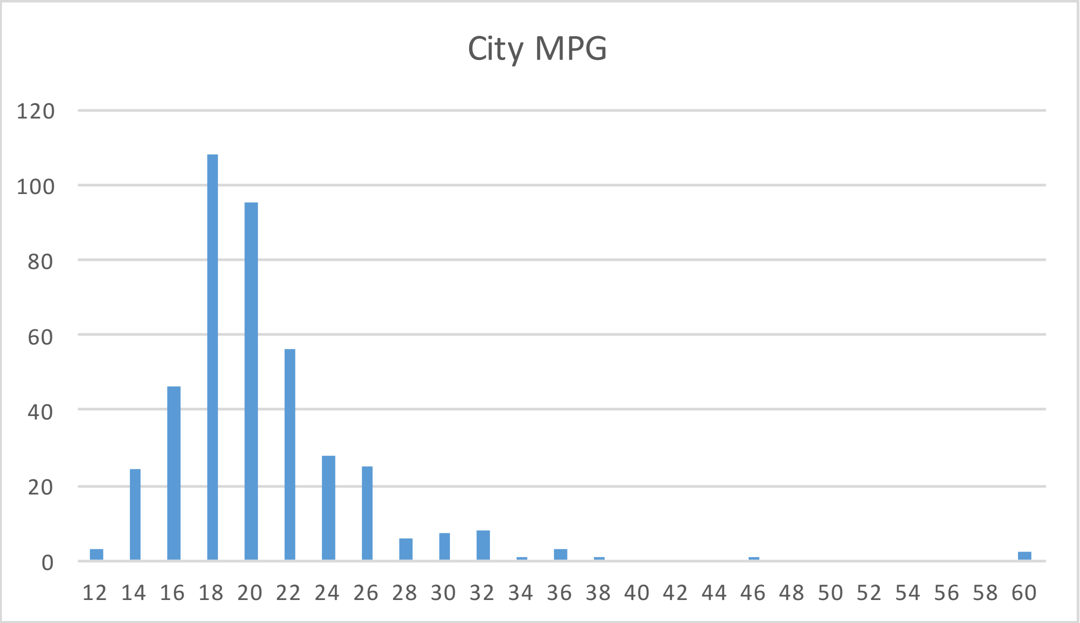
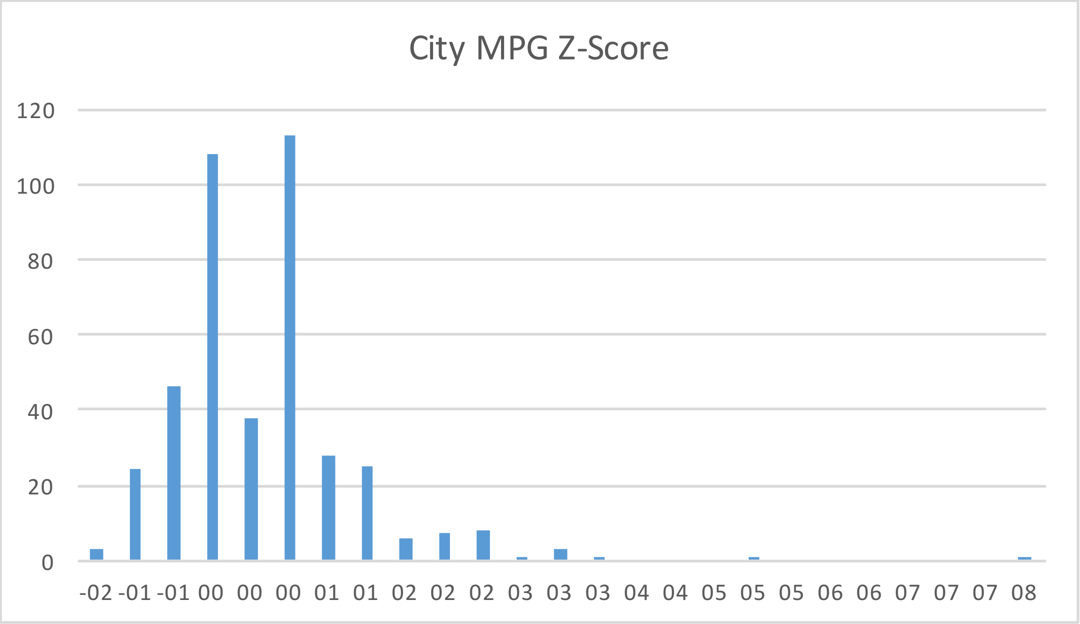
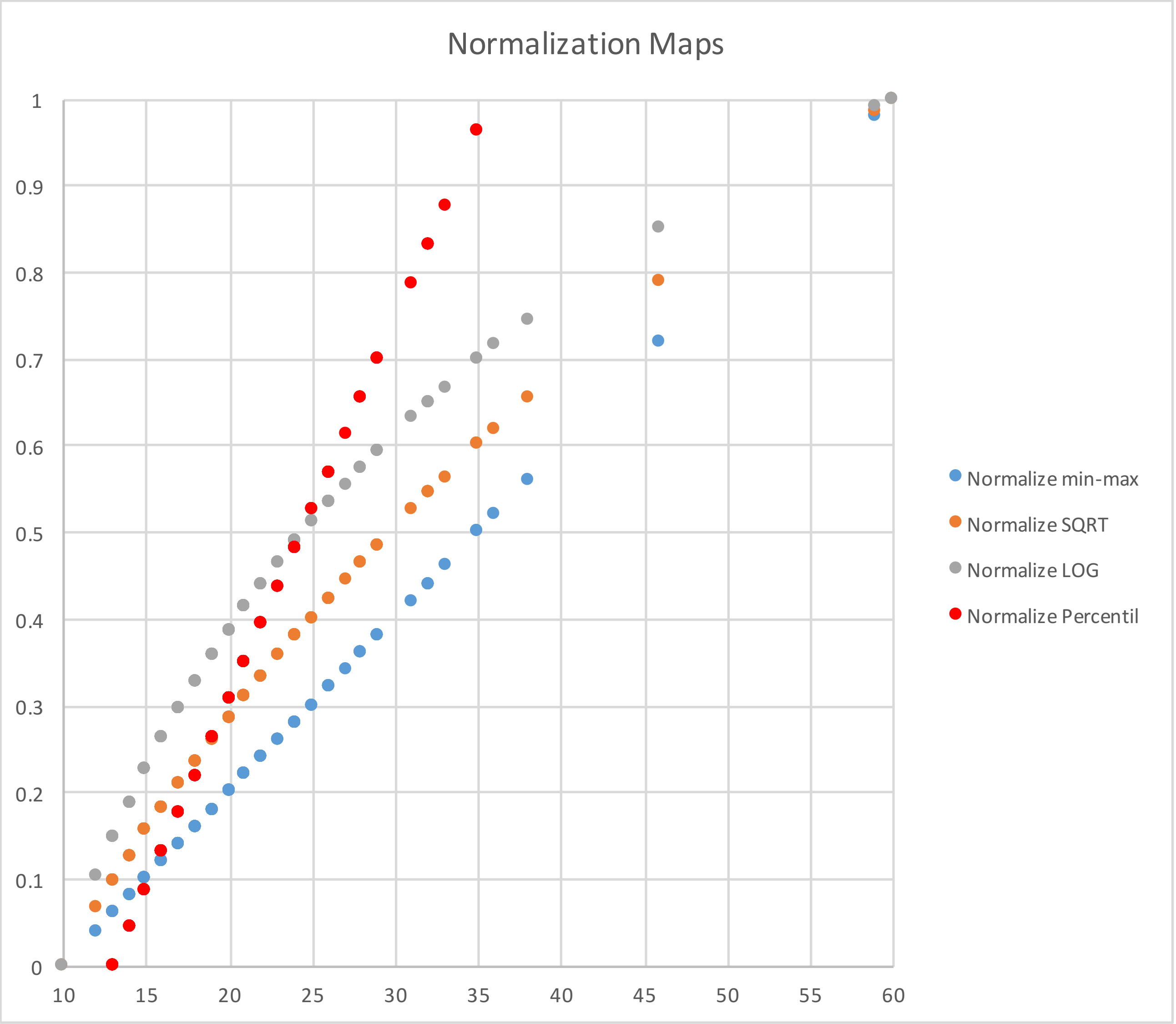


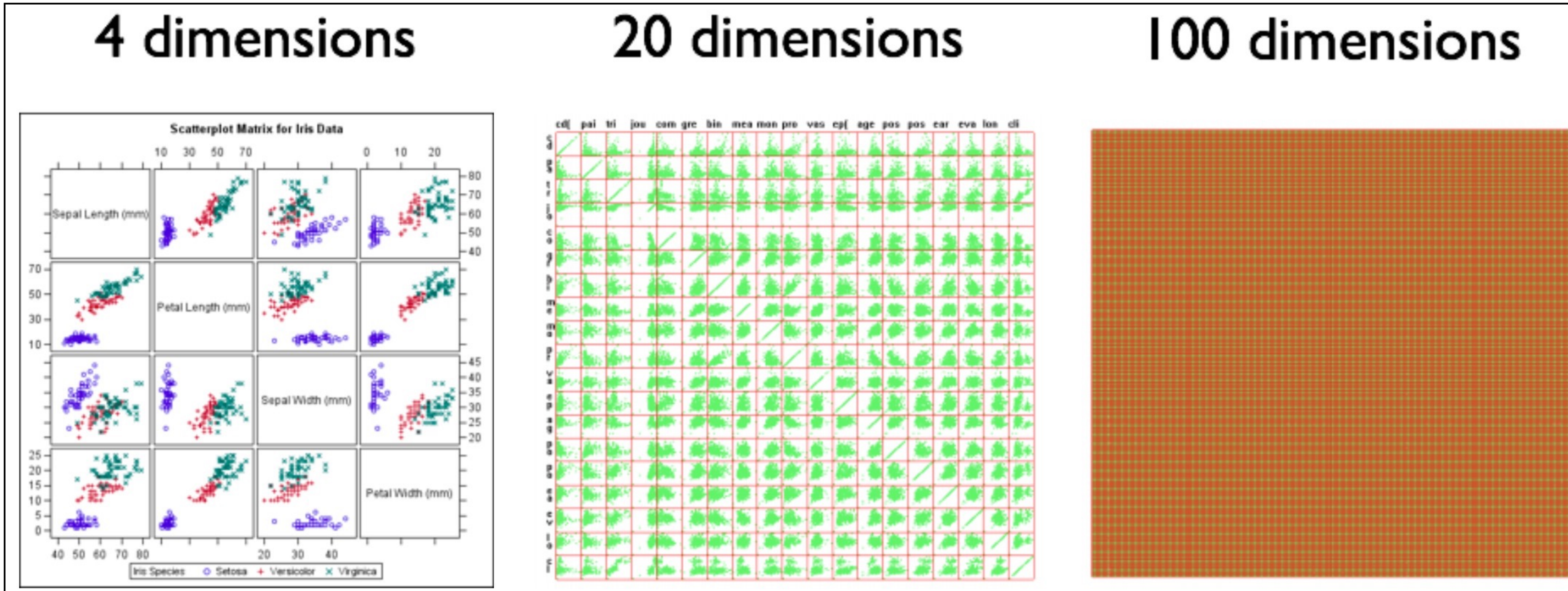




Dimension reduction

- **In situations where the dimensionality of the data exceeds the capabilities of the visualization technique.**

Example of Scatter Plot



* Taken from: Jing Yang's Interactive Hierarchical Dimension Ordering, Spacing and Filtering for Exploration of High Dimensional Datasets.

Bertini DataScience showcase (2014)

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- **Multidimensional Scaling (MDS) -** read more **and** more
- **Non-linear dimension reduction techniques:**
  - **Self-organizing Maps (SOMs) -** read more
  - **Local Linear Embeddings (LLE) -** read more

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Dimension reduction - Principal Component Analysis (PCA)

Iris setosa

Iris versicolor

Iris flower data set

Iris virginica

Dimension reduction - Principal Component Analysis (PCA)

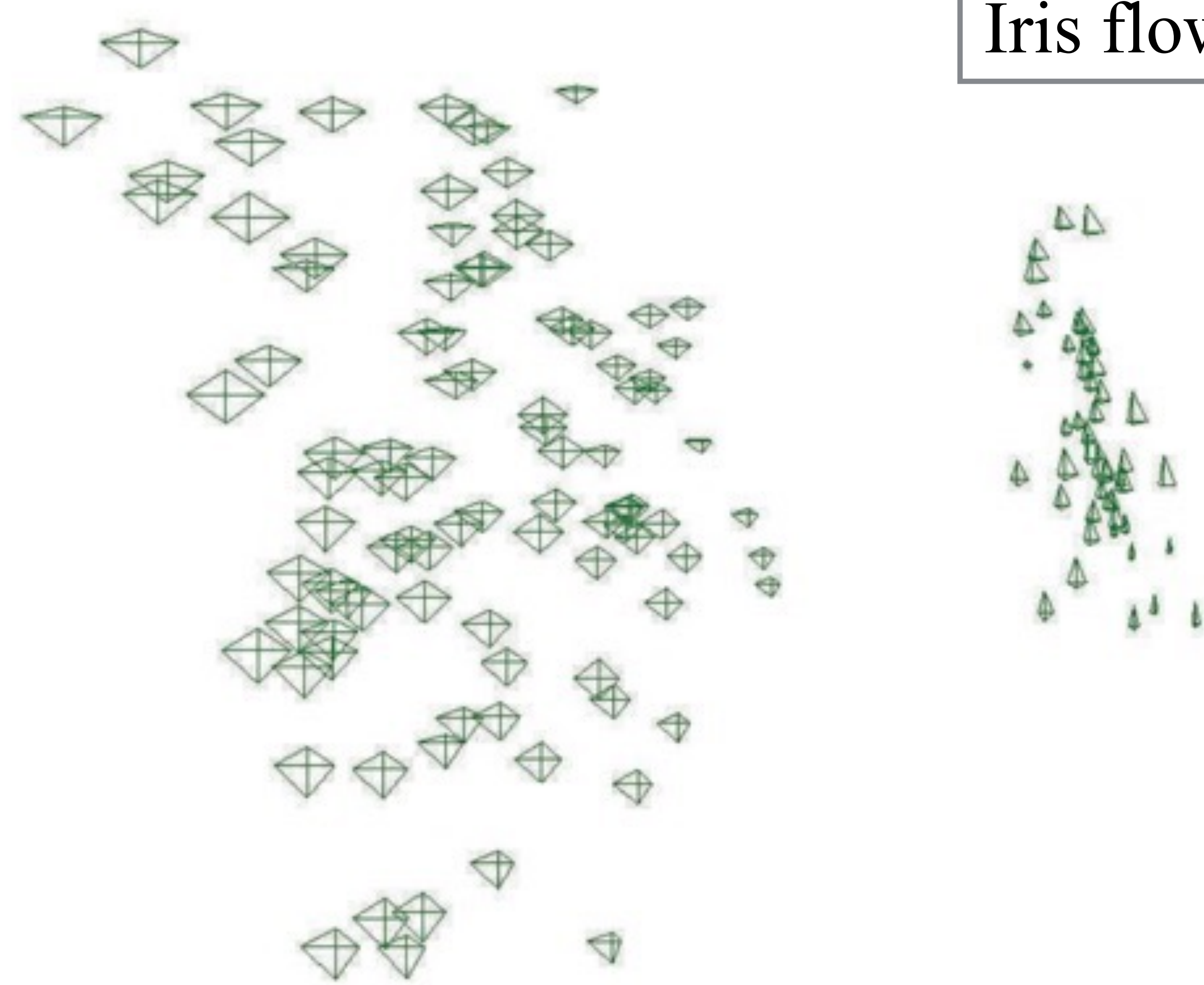
- Figure 2.4 from Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew O. Ward, Georges Grinstein, Daniel Keim, 2010

Iris flower data set

4 Variables

↓

2 Variables



The Iris data set in star glyphs, with the position of each point based on the first two principal components. The star glyph represents four variables as the lengths of the each of the lines emanating from the center of a four-pointed star. Reasonable clustering can be seen.

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    - **Showing random subsets of labels and changing the points with labels being shown on a regular basis, and showing only the labels on objects near the cursor.**

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See more: https://en.wikipedia.org/wiki/Correspondence_analysis

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- **Given all the pairwise similarities, we could use correspondence analysis to map the different nominal values to positions in one dimension. Applying to all nominal dimensions of the data set - multiple correspondence analysis.**

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Other data processing topics

Segmentation

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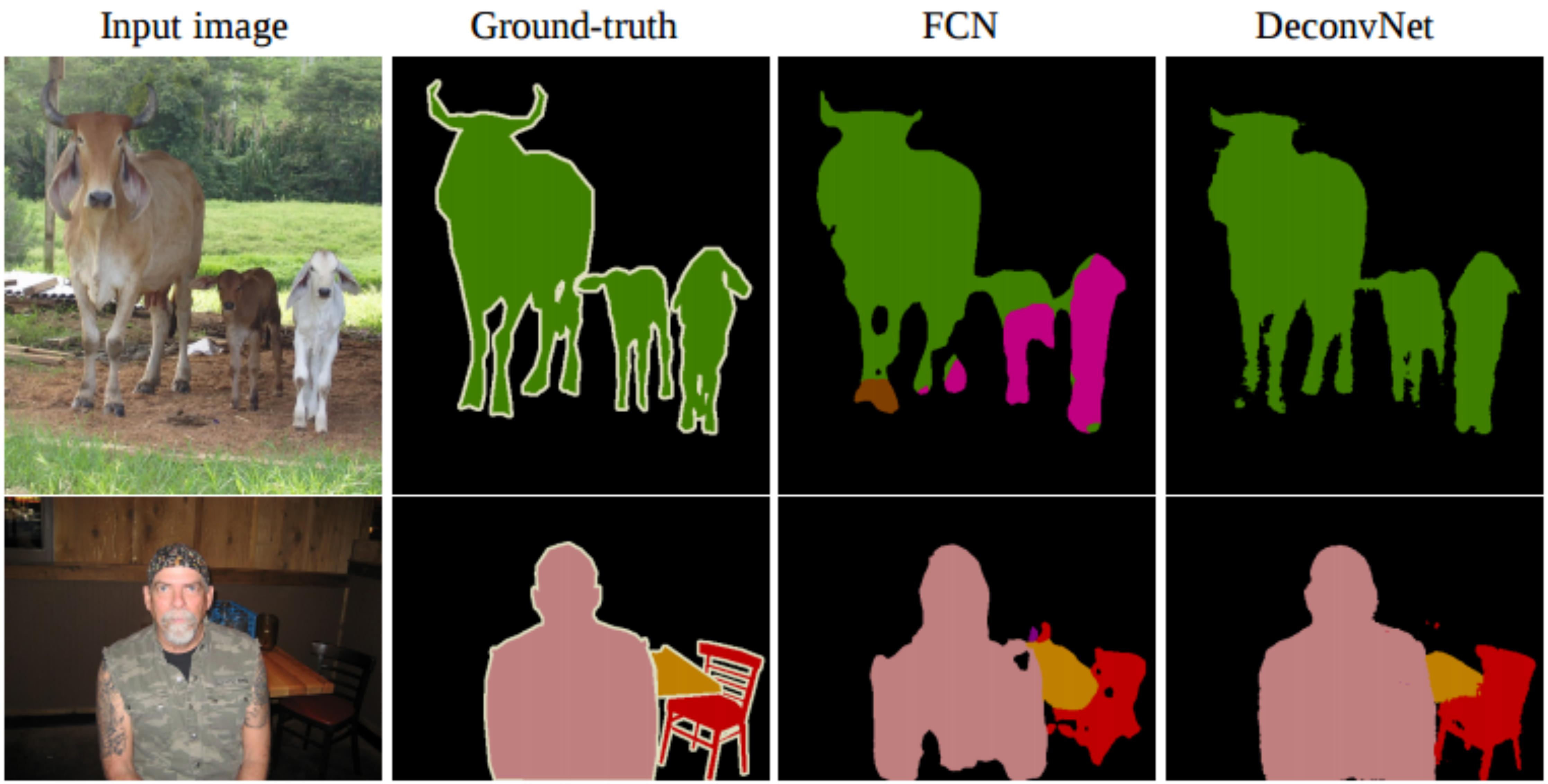
- Common in image data or geo-spatial data (satellite images)

Segmentation



Sampling and subsetting

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- **To transform a data set with one spatial resolution into another data set with a different spatial resolution. For example, we might have an image we would like to shrink or expand, or we might have only a small sampling of data points and wish to fill in values for locations between our samples (assuming that the data is a discrete sampling of a continuous phenomenon).**

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- **The process of interpolation is a commonly used resampling method in many fields, including visualization:**
  - **Linear interpolation**
  - **bi-linear interpolation**
  - **Nonlinear interpolation**

Sampling and subsetting

- **Data subsetting is also a frequently used operation both prior to and during visualization.**
- **This is especially helpful for very large data sets, as the visualization of the entire data set may lead to substantial visual clutter.**
- **Query before visualization versus subsetting during visualization**

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- **Displaying the clusters (or their representation)**
  - **Provide sufficient information for the user to decide whether he or she wishes to perform a drill-down on the data**

Aggregation and Summarization

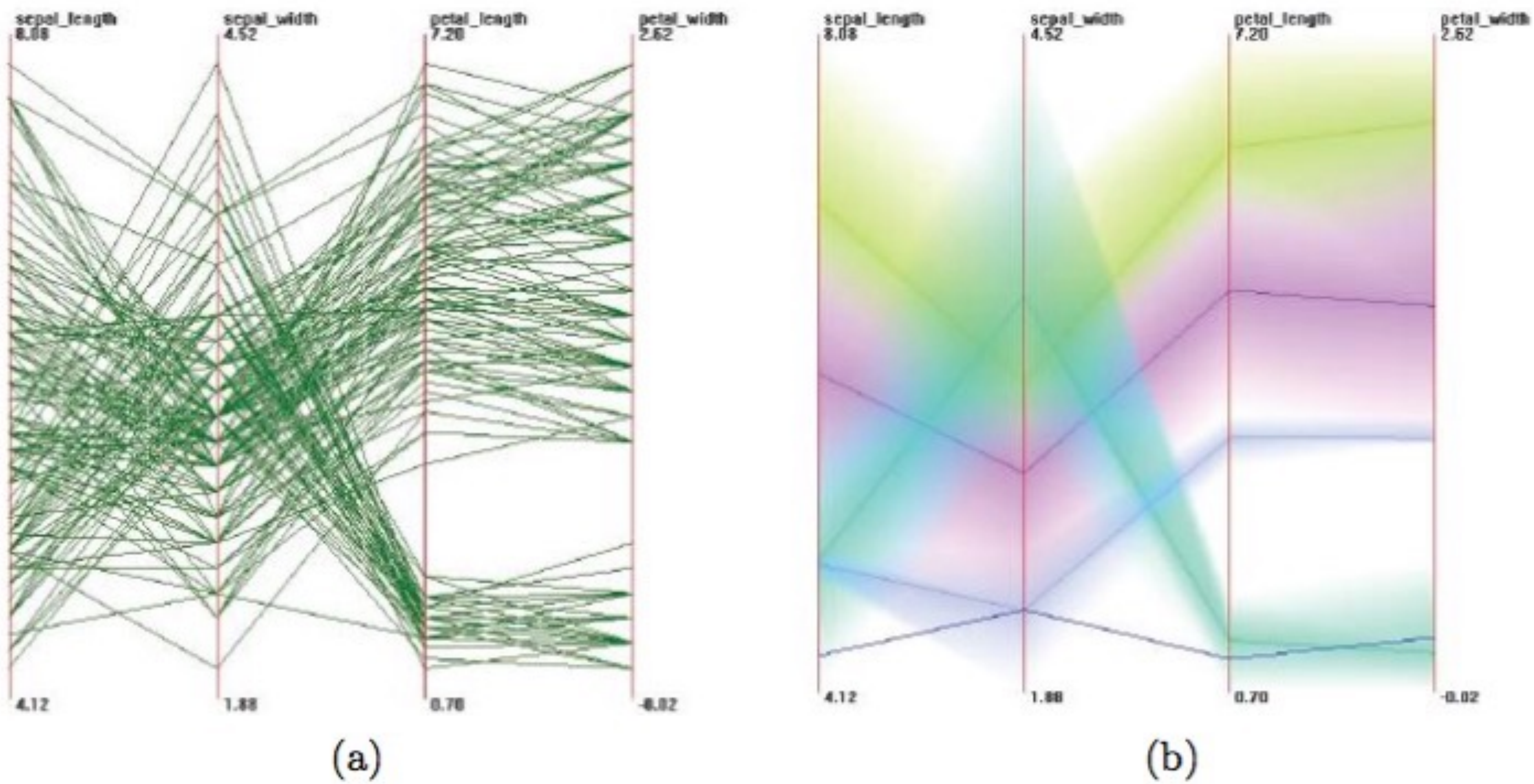

Figure 2.5. The Iris data set in parallel coordinates: (a) the original data; (b) the centers and extents of clusters after aggregation. Each axis in parallel coordinates represents a dimension, with each record being drawn as a polyline through each of the coordinate values on the axes.

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- **See more:**
  - https://en.wikipedia.org/wiki/Smoothing

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- Read more: IDV: Foundations, Techniques, and Applications, Pag 72 - 74

Further Reading and Summary

Further Reading

- **Recommend Readings**
  - Pag 51 - 76 from Interactive Data Visualization: Foundations, Techniques, and Applications
  - Pag 30 - 40 from Visualization Analysis & Design, Tamara Munzner
- **Supplemental readings:**
  - https://en.wikipedia.org/wiki/Outlier
  - https://en.wikipedia.org/wiki/Cluster_analysis
  - https://en.wikipedia.org/wiki/Correspondence_analysis
  - https://en.wikipedia.org/wiki/Cluster_analysis

What you should know

- **The concept of variable or dimension and the diference between independent and dependent variables.**
  - grocking the data => take decisions
- **The various data types taxonomies and the impact of a data type in visualization.**
  - numeric vs non numeric; oder vs non-order; Types of scale;
- **The structural aspects of a data set.**
  - Tables, links, position, grid, etc.
- **Data pre-processing techniques: the goal of each one and the most important ones**
  - Outlier detection and process; normalization; dimensionality reduction, Sampling and subsetting; Aggregation and Summarization

Recommended Actions

- **Install Tableau software (desktop version). Activate with a students license.**
  - http://www.tableau.com/academic/students
- **To get an overview of Tableau see the video:**
  - http://www.tableau.com/learn/tutorials/on-demand/getting-started
- **Get familiar with the dataset 2004 Cars and Trucks Data Set**
  - http://www.idvbook.com/teaching-aid/teaching-aid/data-sets/2004-cars-and-trucks-data/