Introduction to Data Mining

Lecture 1

- What is data mining
- Why do we need data mining
- Data mining tasks
- Course requirements

Data and information

- *Data* – recorded facts
- *Information* – set of patterns that underlie the data – data model
- Information is locked up in databases

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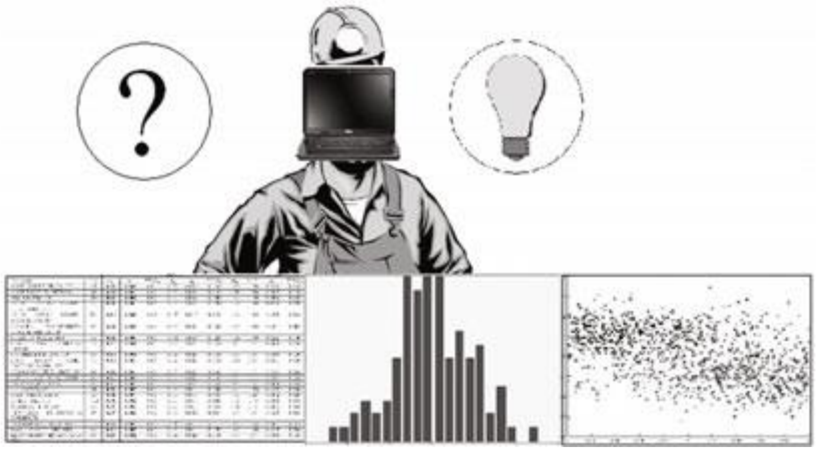
Definition 1



Data mining (Knowledge Discovery in Databases – KDD) – automatic or semi-automatic discovery of *models* and *patterns* from large datasets

- What is data mining
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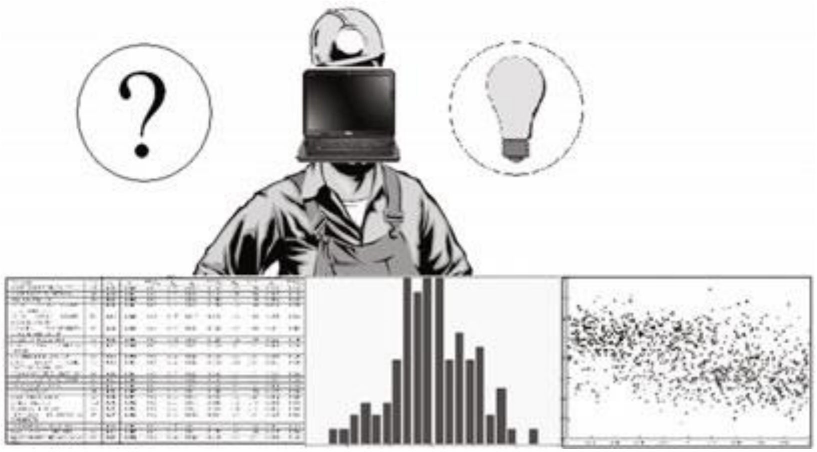
Definition 2



Data mining – extraction of implicit, previously unknown and potentially useful information

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Inferring models from data

- People learn to associate objects with classes
- People categorize things all the time
- People recognize repeating patterns

The difference is:

- The data is digital
- The data is massive
- The inference is automatic (or semi-automatic)

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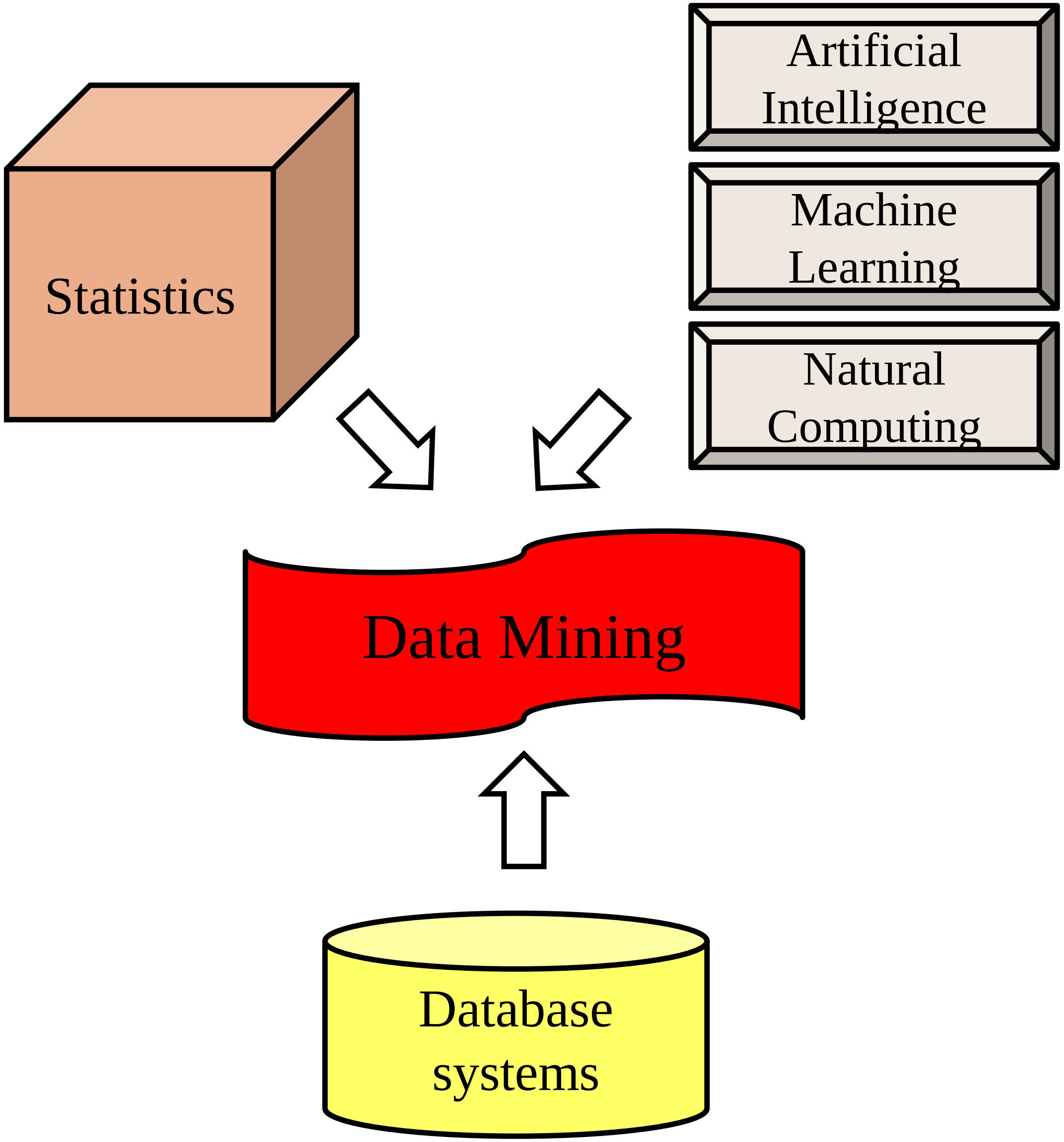
Roots of data mining



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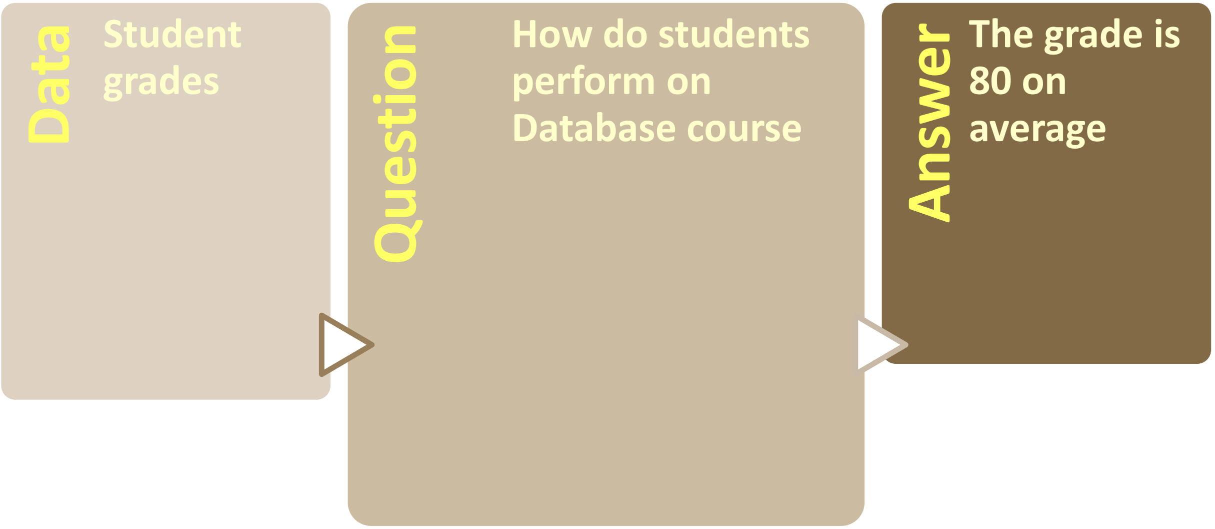
What is (not) data mining



Data

Student grades

Question

How do students perform on Database course

Answer

The grade is 80 on average

Not the data mining

- data manipulation (query)

- **What is data mining**
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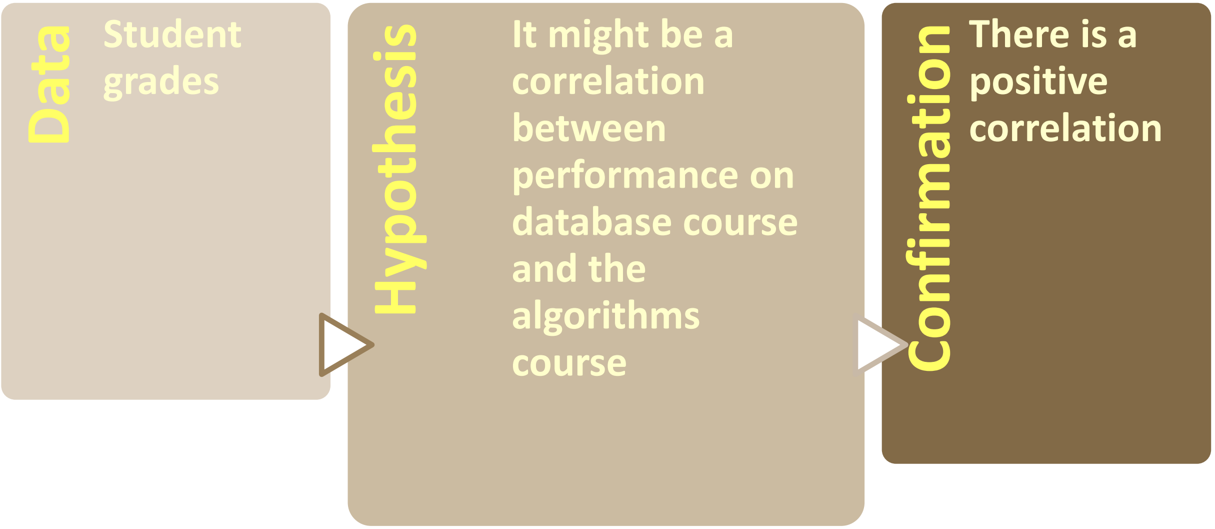
What is (not) data mining



Data

Student grades

Hypothesis

It might be a correlation between performance on database course and the algorithms course

Confirmation

There is a positive correlation

Not the data mining

- statistics (hypothesis testing)

- **What is data mining**
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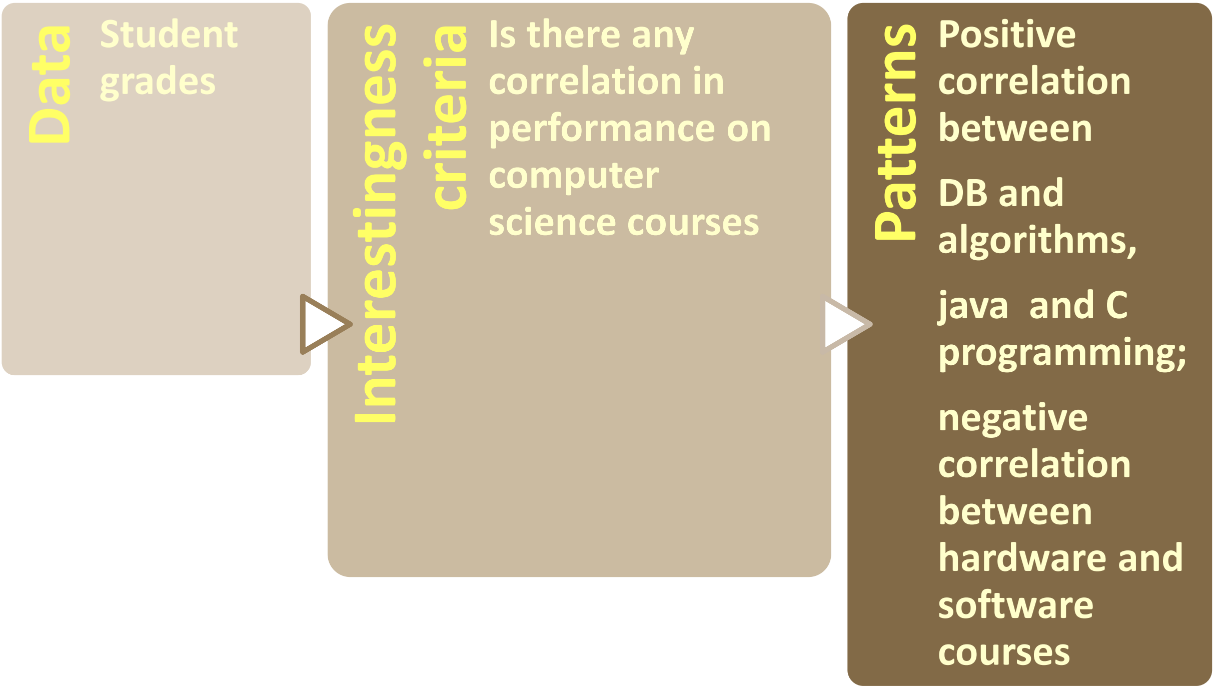
What is (not) data mining



Data

Student grades

Interestingness criteria

Is there any correlation in performance on computer science courses

Patterns

Positive correlation between

DB and algorithms,

java and C programming;

negative correlation between hardware and software courses

Data mining!

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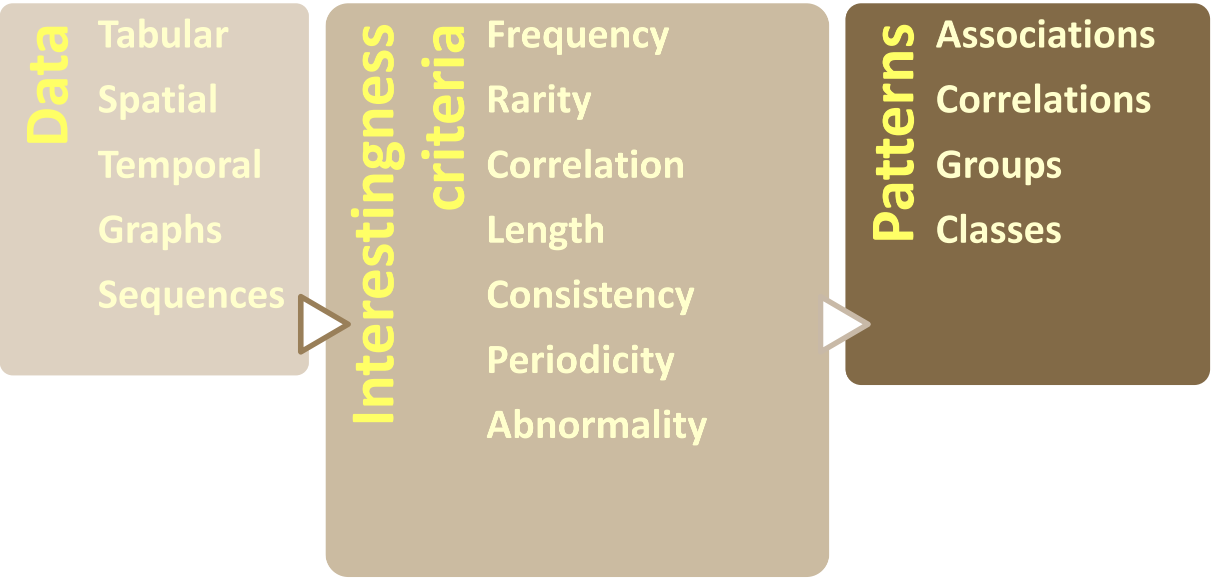
Data mining process



Data
- Tabular
- Spatial
- Temporal
- Graphs
- Sequences

Interestingness criteria
- Frequency
- Rarity
- Correlation
- Length
- Consistency
- Periodicity
- Abnormality

Patterns
- Associations
- Correlations
- Groups
- Classes

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Everything is recorded

- We do not discard data – just buy a new disk
- Ubiquitous electronics record our decisions and choices:
  - What do we buy
  - Our financial habits
  - Our comings and goings
- WWW contains tons of data – every choice we make is recorded

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Data flood

- Largest database in the world: World Data Centre for Climate (WDCC)
  - *220 terabytes of data on climate research and climatic trends,*
  - *110 terabytes worth of climate simulation data.*
  - *6 petabytes worth of additional information stored on tapes.*
- AT&T
  - *323 terabytes of information*
  - *1.9 trillion phone call records*
- Google
  - *91 million searches per day,*
    - *After a year more than 33 trillion database entries.*

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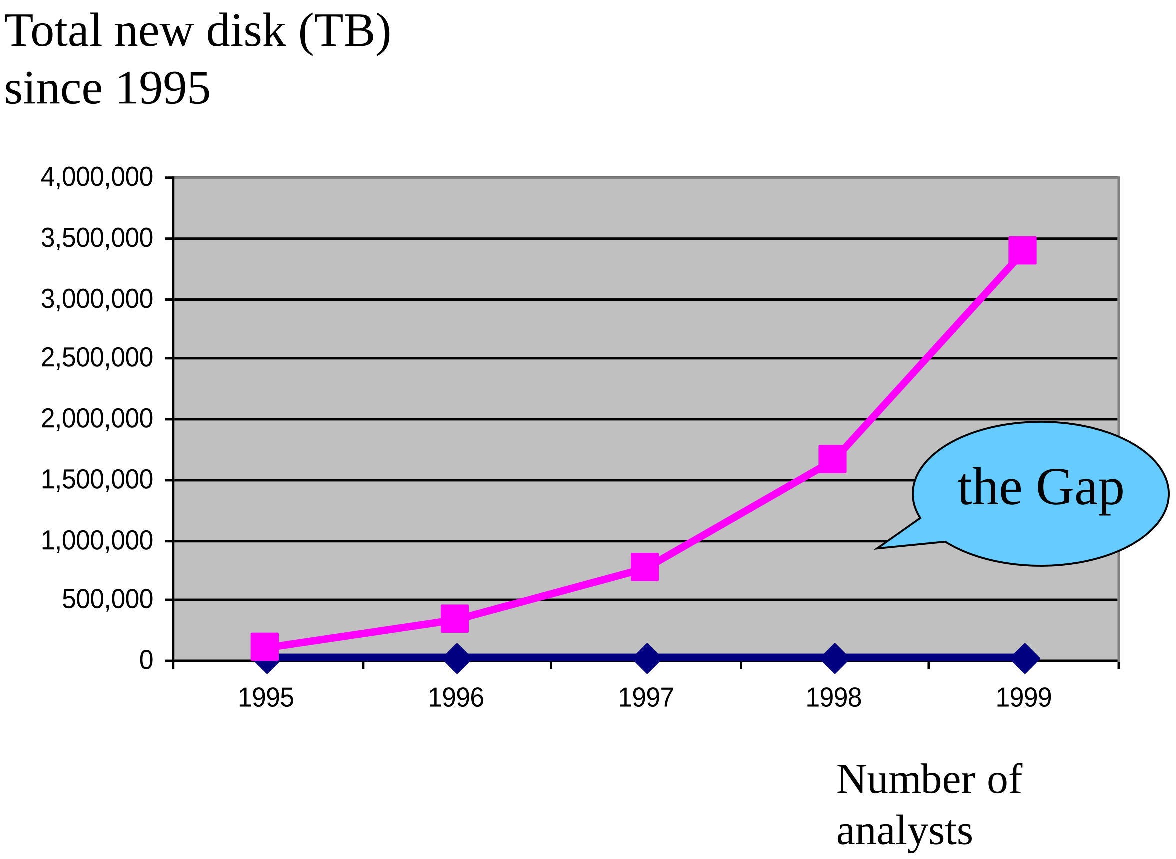
Gap between data and information



From: R. Grossman, C. Kamath, V. Kumar, “Data Mining for Scientific and Engineering Applications”

- What is data mining
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Commercial viewpoint

- Twice as much information was created in 2002 as in 1999 (~30% growth rate)
  - E-commerce
  - Chain transactions
  - Bank transactions
  - Customer profiles

- We can find
  - Purchase patterns
  - Credit Card frauds
  - Border crossing alerts
  - Customer retention

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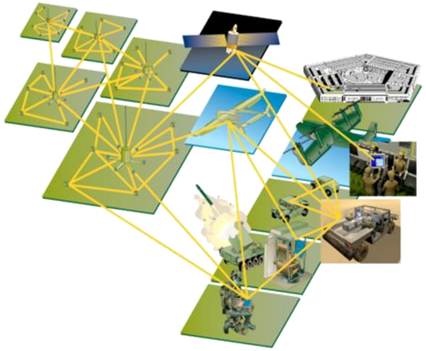
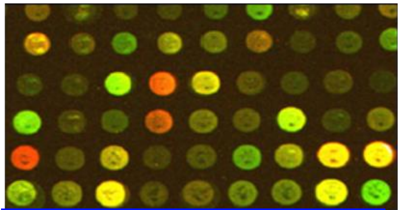
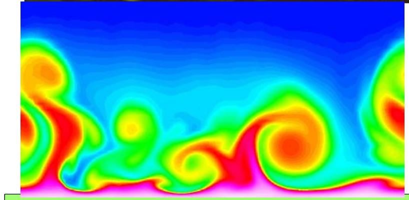
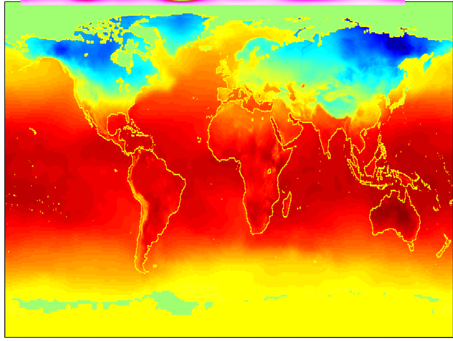


Scientific viewpoint

- Data is collected and stored at enormous speeds (GB/hour).
  - remote sensors on a satellite
  - telescopes scanning the skies
  - scientific simulations generating terabytes of data
  - gene expression profiles
- We can:
  - Classify faint galaxies
  - Find similar gene expressions for different drug treatments
  - Predict structure of a chemical from magnetic resonance data







- What is data mining
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Data mining helps to discover *knowledge*

"*Scientia potentia est*"

("Knowledge is power")

F. Bacon, 1597

Remark:

Like in the original mining, it is possible for data mining to dig the 'mine' of data without eventually discovering the lode containing the "gold nugget" of knowledge.

- What is data mining
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Data mining and privacy

- Can we include sexual and racial attributes?
  - in medicine?
  - in loan application?
- Implicit privacy violations: zip code

- What is data mining
- Why do we need data mining
- **Data mining tasks**
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Interestingness criteria

Interestingness criteria

- Frequency
- Rarity
- Correlation
- Periodicity
- Consistency
- Length

- What is data mining
- Why do we need data mining
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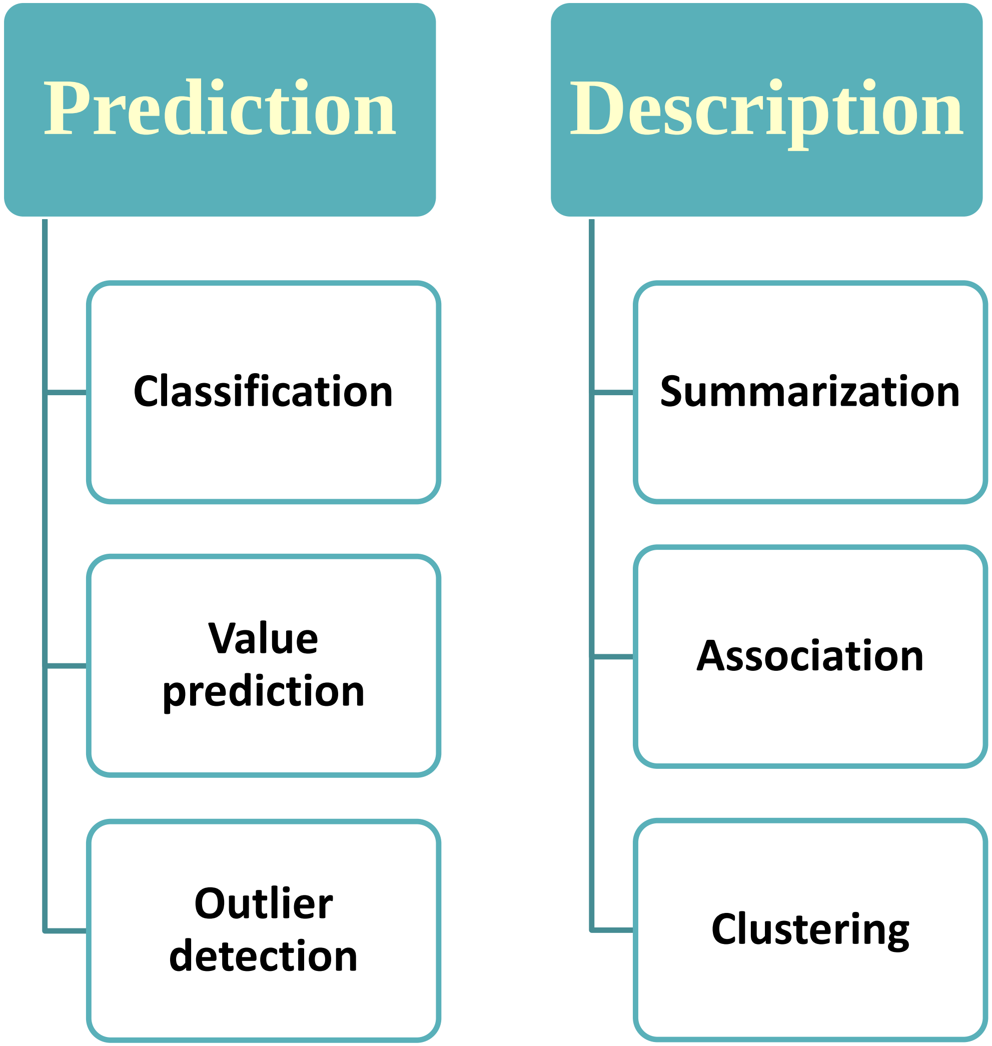
Task types



Prediction

- Classification
- Value prediction
- Outlier detection

Description

- Summarization
- Association
- Clustering

- What is data mining
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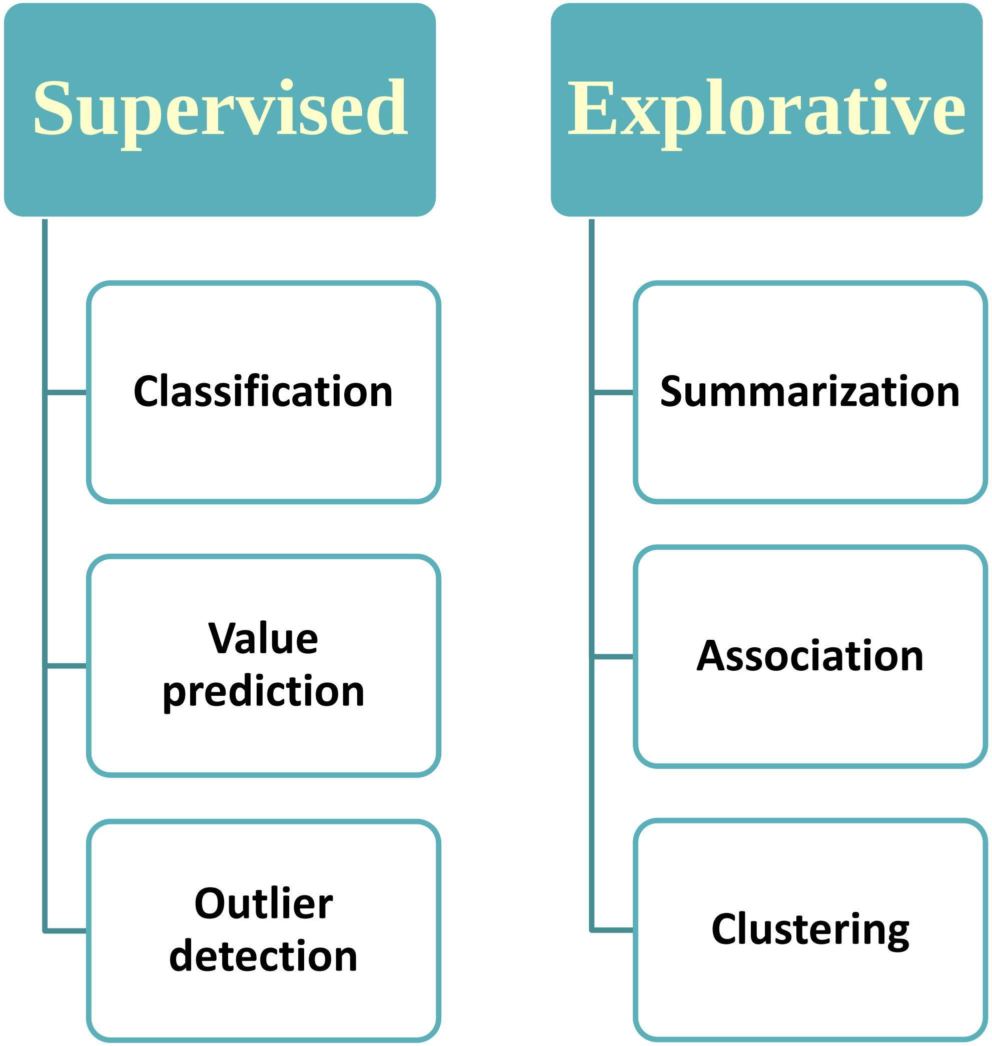
Task types



Supervised

- Classification
- Value prediction
- Outlier detection

Explorative

- Summarization
- Association
- Clustering

- What is data mining
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Tabular input

attributes

class

data record

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	**No**
2	No	Married	100K	**No**
3	No	Single	70K	**No**
4	Yes	Married	120K	**No**
5	No	Divorced	95K	**Yes**
6	No	Married	60K	**No**
7	Yes	Divorced	220K	**No**
8	No	Single	85K	**Yes**
9	No	Married	75K	**No**
10	No	Single	90K	**Yes**

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  - Predictive
  - Descriptive
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Task of type 1: Classification

- Given a collection of records (*training set*)
  - Each record contains a set of *attributes*, one of the attributes is the *class*.

- Find ("learn") a *model* for the class attribute as a function of the values of the other attributes.

- Goal: **previously unseen** records should be assigned a class as accurately as possible.

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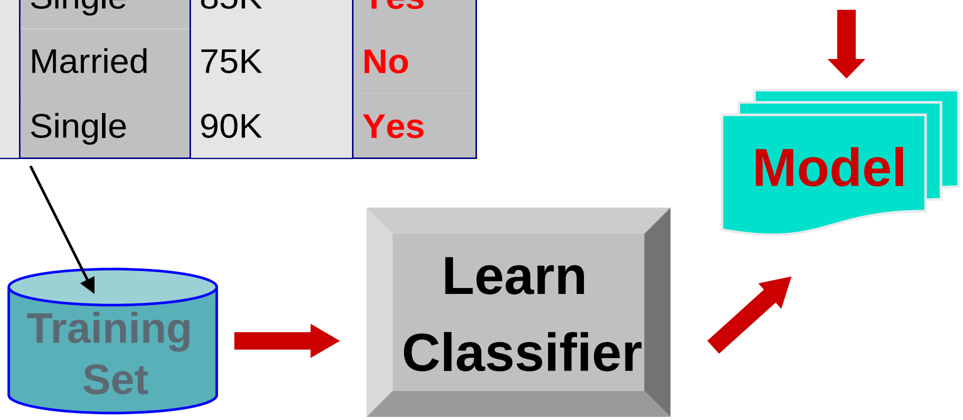
Classification example

Tid	Refund	Marital Status	Taxable Income	Cheat
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

Refund	Marital Status	Taxable Income	Cheat
No	Single	75K	?
Yes	Married	50K	?
No	Married	150K	?
Yes	Divorced	90K	?
No	Single	40K	?
No	Married	80K	?



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Solving classification problem

My neighbour dataset

class label

Temp	Precip	Day	Shop	Clothes	
25	None	Sat	No	Casual	**Walk**
-5	Snow	Mon	Yes	Casual	**Drive**
15	Snow	Mon	Yes	Casual	**Walk**

(Adapted from Leslie Kaelbling's example in the MIT courseware)

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Classification problem

class label

Temp	Precip	Day	Shop	Clothes	
25	None	Sat	No	Casual	**Walk**
-5	Snow	Mon	Yes	Casual	**Drive**
15	Snow	Mon	Yes	Casual	**Walk**
-5	Snow	Mon	Yes	Casual	**?**

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Classification problem: memory

class label

Temp	Precip	Day	Shop	Clothes	
25	None	Sat	No	Casual	**Walk**
-5	Snow	Mon	Yes	Casual	**Drive**
15	Snow	Mon	Yes	Casual	**Walk**
-5	Snow	Mon	Yes	Casual	**Drive**

(Adapted from Leslie Kaelbling's example in the MIT courseware)

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Classification problem: noise

Temp	**Precip**	**Day**	**Clothes**	
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Drive**
25	None	Sat	Casual	**Drive**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**?**

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Classification problem: averaging

Temp	Precip	Day	Clothes	
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Drive**
25	None	Sat	Casual	**Drive**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**
25	None	Sat	Casual	**Walk**

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Classification problem: generalization

Temp	**Precip**	**Day**	**Clothes**	
22	None	Fri	Casual	**Walk**
3	None	Sun	Casual	**Walk**
10	Rain	Wed	Casual	**Walk**
30	None	Mon	Casual	**Drive**
20	None	Sat	Formal	**Drive**
25	None	Sat	Casual	**Drive**
-5	Snow	Mon	Casual	**Drive**
27	None	Tue	Casual	**Drive**
24	Rain	Mon	Casual	**?**

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Learning to predict class label

Three different problems involved in learning:

- memory
- averaging
- generalization.

Type 2. Explorations

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1	Yes	Single	125K
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Discover groups, no class labels

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Task of type 2. Associations

The Market-Basket Model

- A large set of *items*, e.g., things sold in a supermarket.
- A large set of *baskets*, each of which is a small set of the items, e.g., the things one customer buys in one transaction.

Fundamental problem

- What sets of items are often bought together?

Application

- If a large number of baskets contain both hot dogs and mustard, we can use this information. How?

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Solving association problem: market basket

	Itemsets
1	{bread, milk, peanut butter}
2	{bread, milk}
3	{beer, potato chips}
4	{beer, diapers}
5	{beer, milk, diapers}
6	{bread, milk, yogurt}
7	{beer, bread, diapers}
8	{bread, milk, jelly}
9	{beer, cigarettes, diapers}
10	{bread, milk}

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Association problem

	Itemsets
1	{**bread**, **milk**, peanut butter}
2	{**bread**, **milk**}
3	{**beer**, potato chips}
4	{**beer**, **diapers**}
5	{**beer**, **milk**, **diapers**}
6	{**bread**, **milk**, yogurt}
7	{**beer**, **bread**, **diapers**}
8	{**bread**, **milk**, jelly}
9	{**beer**, cigarettes, **diapers**}
10	{**bread**, **milk**}

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Beer and diapers?

	Itemsets
1	{bread, milk, peanut butter}
2	{bread, milk}
3	{**beer**, potato chips}
4	{**beer**, **diapers**}
5	{**beer**, milk, **diapers**}
6	{bread, milk, yogurt}
7	{**beer**, bread, **diapers**}
8	{bread, milk, jelly}
9	{**beer**, cigarettes, **diapers**}
10	{bread, milk}

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On-Line Purchases: potentially useful patterns

Log file

Date	Customer	Product
Dec 20	John	iPod
Dec 23	John	Video camera
Jan 4	Mary	Dumbbells
Jan 4	John	Kindle
Jan 20	Tim	Laptop
Jan 23	Mary	Kindle
Feb 1	Tim	iPod
Feb 3	Tim	Video camera

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On-Line Purchases: group by customer

Transaction: customer, item: product

Date	Customer	Product
Dec 20	John	iPod
Dec 23	John	Video camera
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Jan 4	Mary	Dumbbells
Jan 23	Mary	Kindle
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On-Line Purchases: group by product

Transaction: product, item: customer

Date	Customer	Product
Dec 20	John	iPod
Feb 1	Tim	iPod
Jan 4	Mary	Dumbbells
Dec 23	John	Video camera
Feb 3	Tim	Video camera
Jan 20	Tim	Laptop
Jan 4	John	Kindle
Jan 23	Mary	Kindle

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On-Line Purchases: group by month

Transaction: month, item: product

Date	Customer	Product
Dec 20	John	iPod
Dec 23	John	Video camera
Jan 4	Mary	Dumbbells
Jan 4	John	Kindle
Jan 20	Tim	Laptop
Jan 23	Mary	Kindle
Feb 1	Tim	iPod
Feb 3	Tim	Video camera

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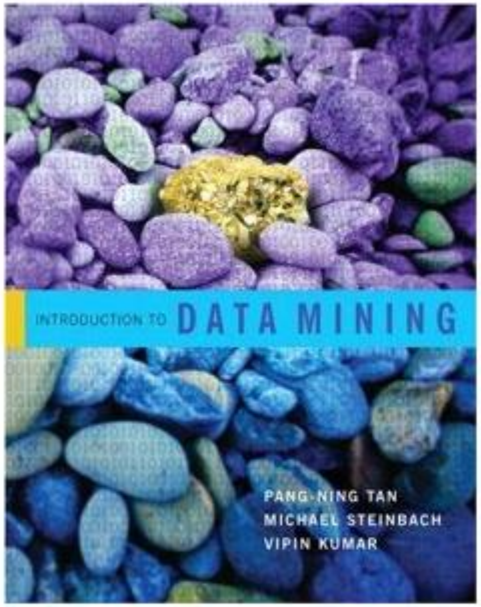
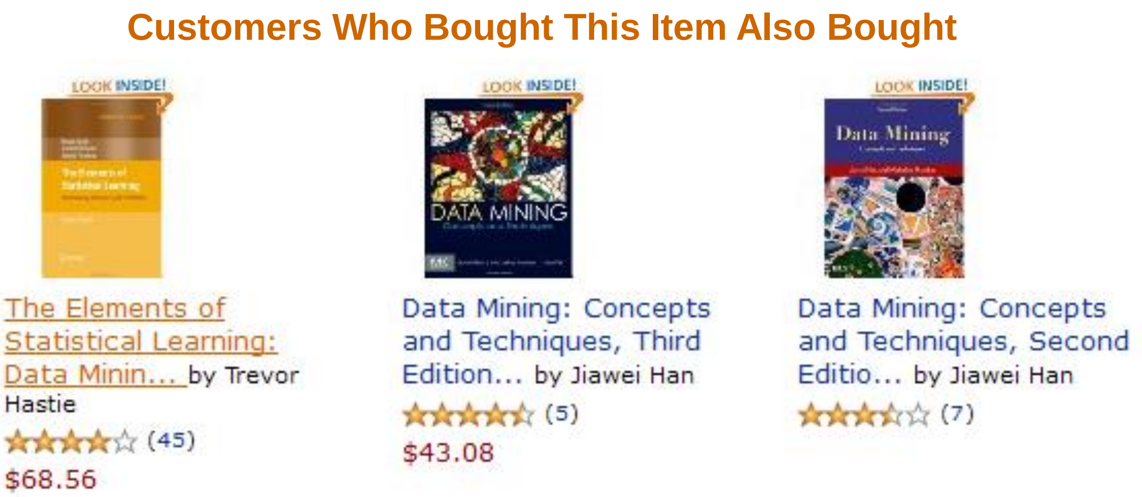
Amazon example





Customers Who Bought This Item Also Bought

The Elements of Statistical Learning: Data Minin... by Trevor Hastie
★★★★☆ (45)
$68.56

Data Mining: Concepts and Techniques, Third Edition... by Jiawei Han
★★★★★ (5)
$43.08

Data Mining: Concepts and Techniques, Second Editio... by Jiawei Han
★★★★☆ (7)

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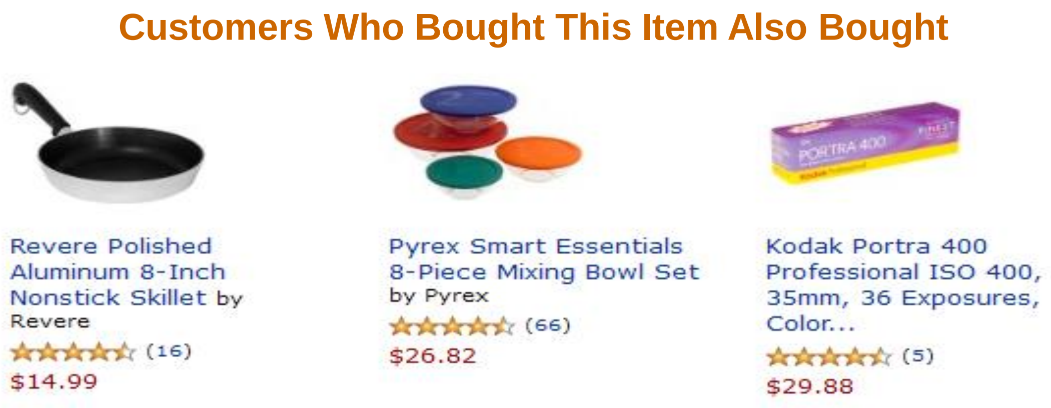
Amazon example ?



Customers Who Bought This Item Also Bought

Revere Polished Aluminum 8-Inch Nonstick Skillet by Revere
★★★★☆ (16)
$14.99

Pyrex Smart Essentials 8-Piece Mixing Bowl Set by Pyrex
★★★★☆ (66)
$26.82

Kodak Portra 400 Professional ISO 400, 35mm, 36 Exposures, Color...
★★★★☆ (5)
$29.88

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Topics: algorithms

- Classification:
  - Decision trees and rule-based classifiers
  - Bayesian inference
  - Support vector machines
  - Natural computing: genetic algorithm and neural networks
- Correlation
  - Frequent itemsets
  - Association rules
  - Frequent sequential and graph patterns
- Clustering
- Feature selection (Principal component analysis)
- Link analysis (PageRank algorithm)

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Labs: learning by doing

- Learning by example: on toy datasets which exhibit features of real-life datasets
- WEKA*) – Waikato Environment for Knowledge Analysis
- JAVA implementations and extensions
- Real-life datasets analysis

*)Weka- unique New Zealand flightless bird with inquisitive nature

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Prerequisites

- Basic knowledge of probabilities
- Linear algebra basics
- Reasoning about the data

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Expected outcomes

- Understanding of basic algorithms
- Ability to select the right algorithm for a problem at hand
- Ability to perform data mining task (coding is optional)
- Validation of results (coding is optional)
- Presentation of results (coding is optional)

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Grading

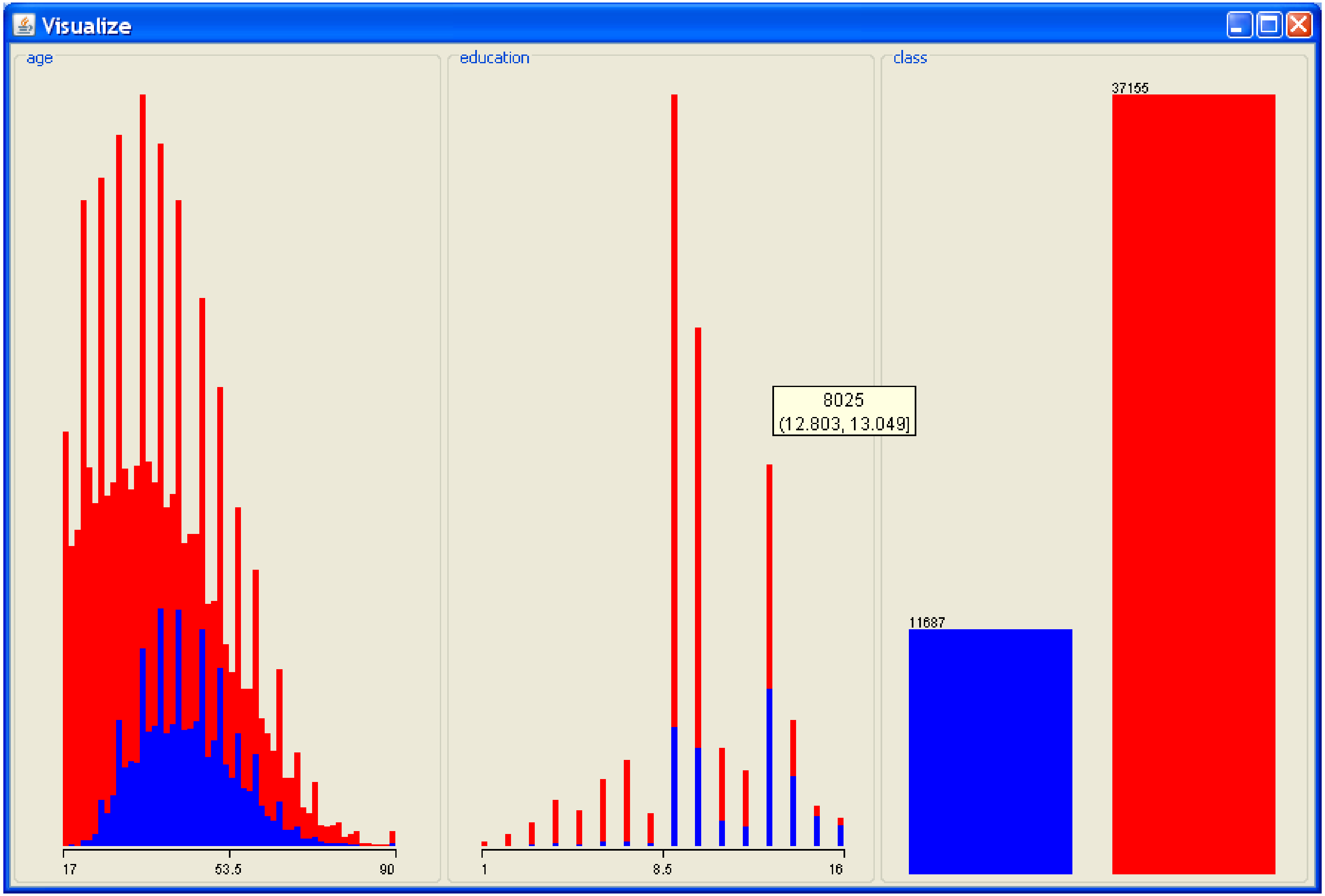
- Quizzes: to monitor understanding. Each correct quiz + 0.5 bonus
- 3 assignments (10% each):
  - Part 1. Solve a toy problem by hand (understanding)
  - Part 2. Perform data mining task on a real dataset (doing)
- Projects (20%) – two types
  - Type 1. Take a real dataset, suggest data mining task, perform task, evaluate and present results
  - Type 2. Introduce a novel data mining approach based on recent publications, show connections to the learned concepts and ability to do independent data mining research
- Exams: (20% and 30%) – test understanding (open book exams)

Lab example: what determines high salary

Adult income dataset (US census 1994)

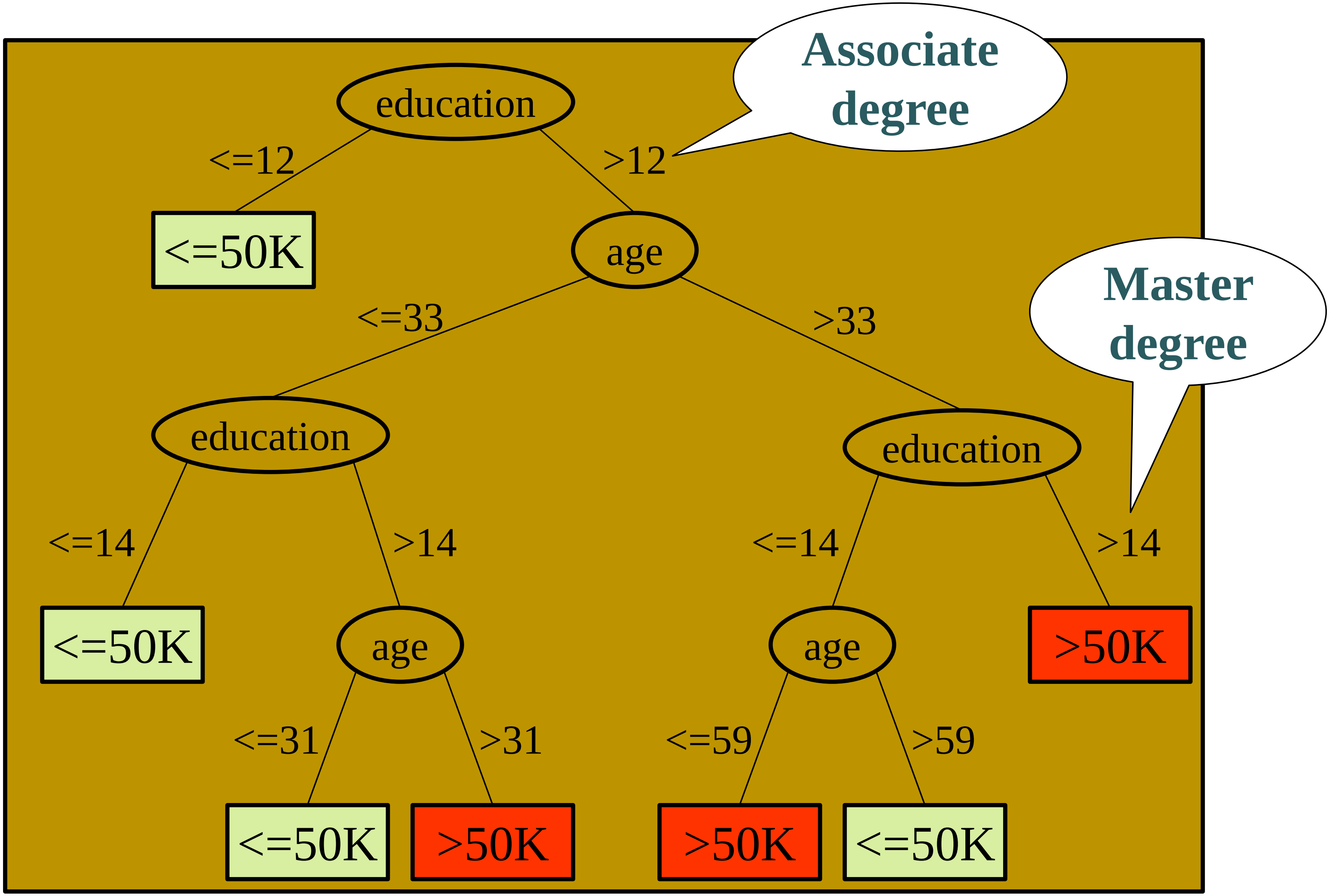
Age	Education	Mar. status	Occupation	Race	Sex	Born in	Yearly income
39	Bachelors	Never-married	Adm-clerical	White	M	US	**<=50 K**
50	Bachelors	Married-civ-spouse	Exec-managerial	White	M	US	**<=50 K**
54	7th-8th	Married-civ-spouse	Machine-op-inspct	White	M	US	**>50K**
37	Bachelors	Never-married	Exec-managerial	Black	M	US	**>50K**
28	Bachelors	Married-civ-spouse	Prof-specialty	Black	F	Cuba	**<=50 K**
37	Masters	Married-civ-spouse	Exec-managerial	White	F	US	**<=50 K**

Visualization of attributes age and education (not data mining)



The results of data mining:

decision tree on age and education attributes


education
<=12
>12
Associate degree
<=50K
age
<=33
>33
Master degree
education
education
<=14
>14
<=14
>14
<=50K
age
age
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