Ricardo Aler Mur

- In this lecture, the Machine Learning subject is introduced by using a classifcation task example, where sky objects have to be classified, that illustrates the main processes that must be followed in other classification tasks. Also, some application examples are used to illustrate the possible domains of application of Machine Learning.

.

- Then, three main concepts are introduced:
  - What can be done (tasks)
  - What kind of models can be learned to solve those tasks
  - Each type of model can be genereted by several different algorithms

- Finally, each kind of task is illustrated by giving an example, showing what the input data looks like and how the obtained models can be interpreted.

PRESENTATION

MACHINE LEARNING I

MASTER IN BIG DATA ANALYTICS

RICARDO ALER MUR (aler@inf.uc3m.es). 2.2B29

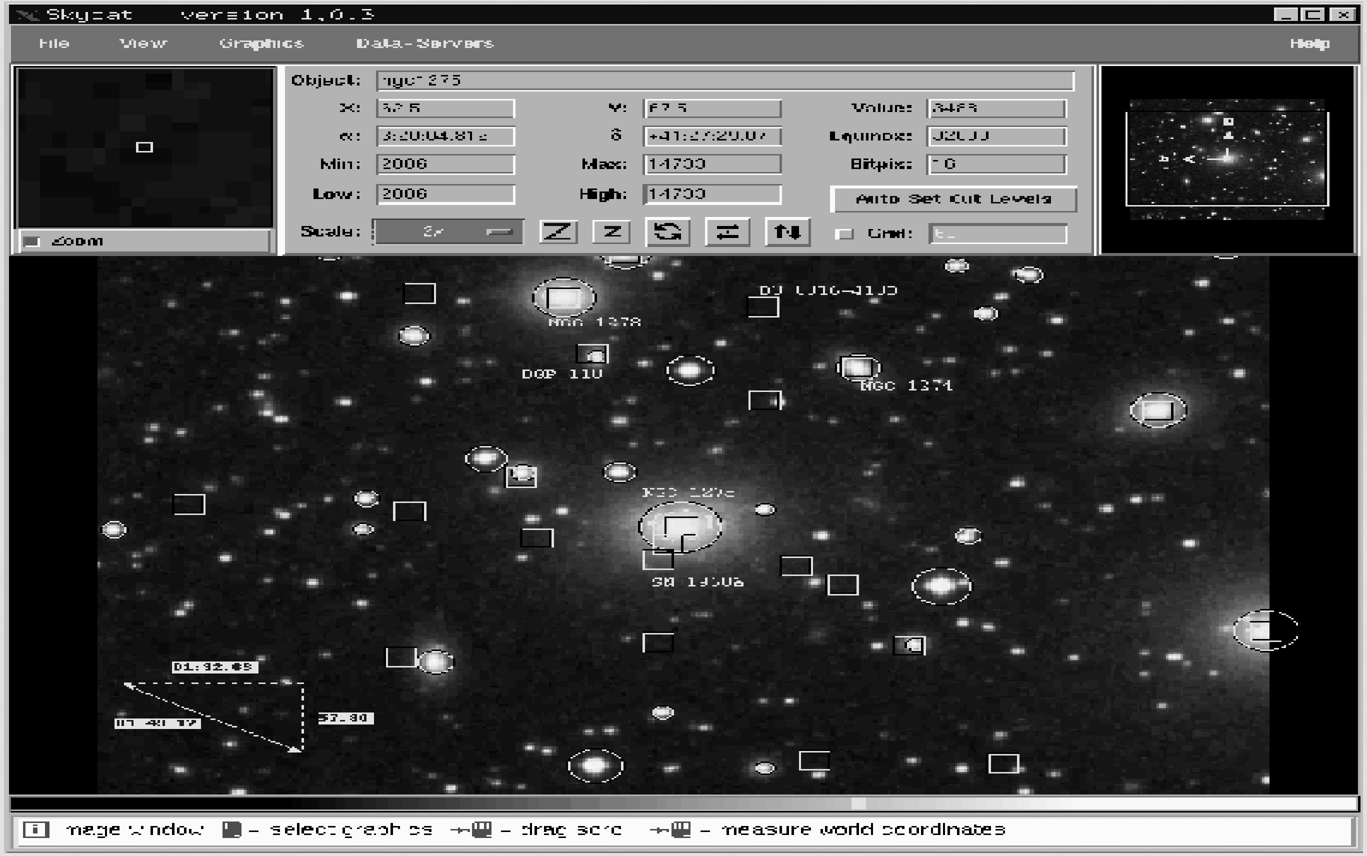
MACHINE LEARNING

- In general, it’s a subfield of **Artificial Intelligence** that tries to make computers and machines learn

- In practice, it tries to create models from data and thus is closely related to statistics. This is the point of view we will follows in this course

WHAT IS MACHINE LEARNING

- Example: Skycat: AUTOMATIC CLASSIFICATION OF OBJECTS IN THE SKY



Object: ngc1275

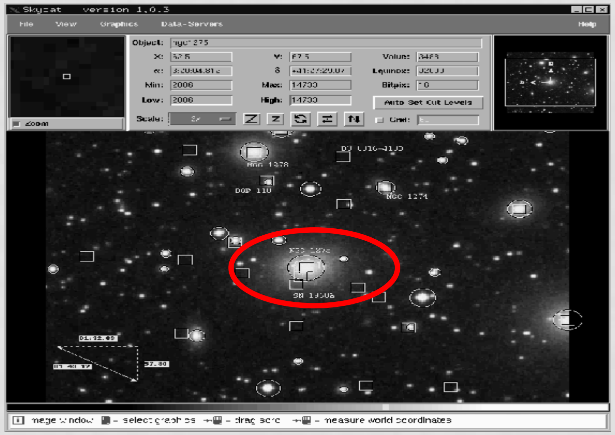
X: 32.5 Y: 67.5 Value: 3483

α: 3:20:04.812 δ: +41:27:29.07 Equinox: J2000

Min: 2006 Max: 14733 Bitpix: 16

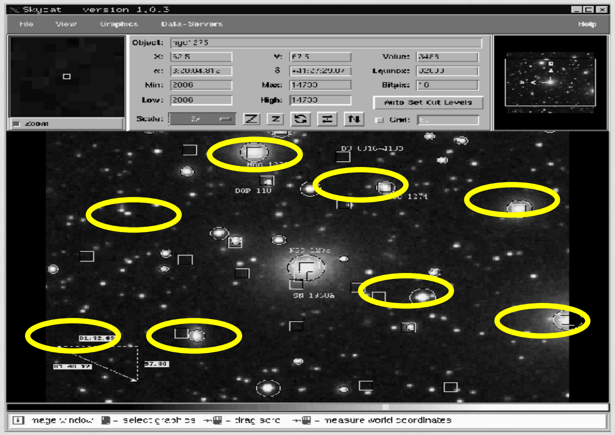
Low: 2006 High: 14733

Scale: 2x

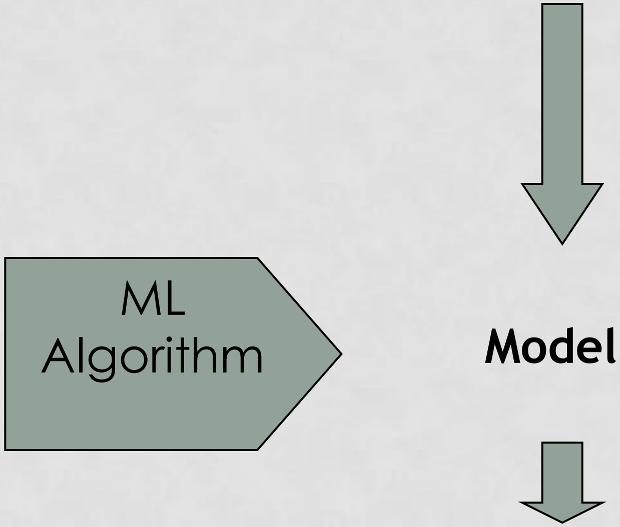


?

Training data (labeled pictures of sky objects: galaxies, stars, nebulae, …)



Pictures in the catalog have been labeled by a human expert (astronomer)



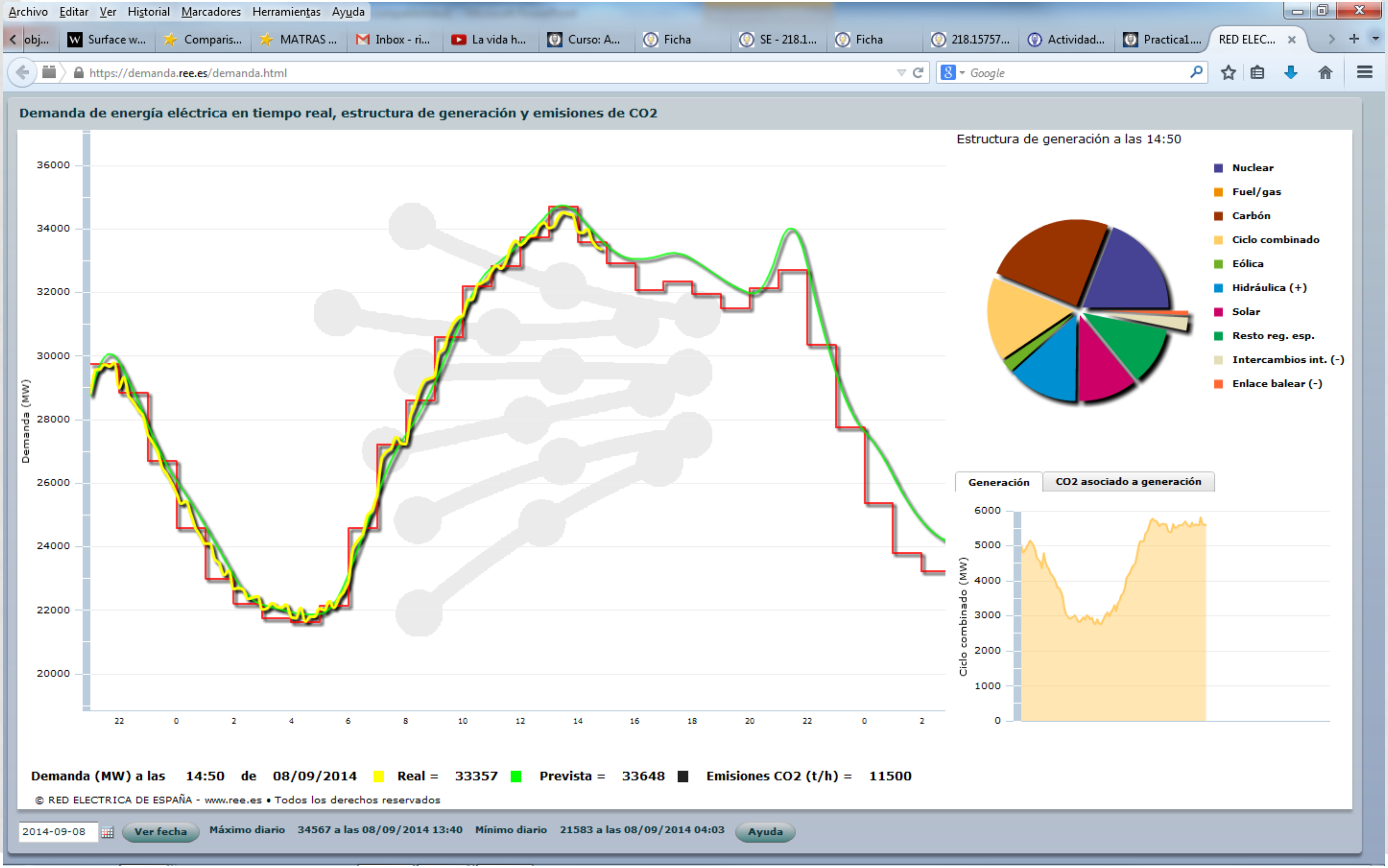
Spiral galaxy

APPLICATIONS

- Finances and banking
  - Credit card fraud detection
  - Credit default prediction
- Market analysis:
  - Market basket analysis
  - Market segmentation
- Insurance:
  - Expensive clients
- Education:
  - Prediction of school dropouts
- Industry:
  - Electric (energy) load forecasting
  - Solar / wind energy forecasting

https://demanda.ree.es/demanda.html

ELECTRIC LOAD FORECASTING



Demanda de energía eléctrica en tiempo real, estructura de generación y emisiones de CO2

Estructura de generación a las 14:50

Demanda (MW) a las 14:50 de 08/09/2014 🟨 Real = 33357 🟩 Prevista = 33648 ■ Emisiones CO2 (t/h) = 11500

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2014-09-08 Ver fecha Máximo diario 34567 a las 08/09/2014 13:40 Mínimo diario 21583 a las 08/09/2014 04:03 Ayuda

Archivo Editar Ver Historial Marcadores Herramientas Ayuda
obj... Surface w... Comparis... MATRAS ... Inbox - ri... La vida h... Curso: A... Ficha SE - 218.1... Ficha 218.15757... Actividad... Practica1.... RED ELEC...
https://demanda.ree.es/demanda.html
Google
36000
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Demanda (MW)
22
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18
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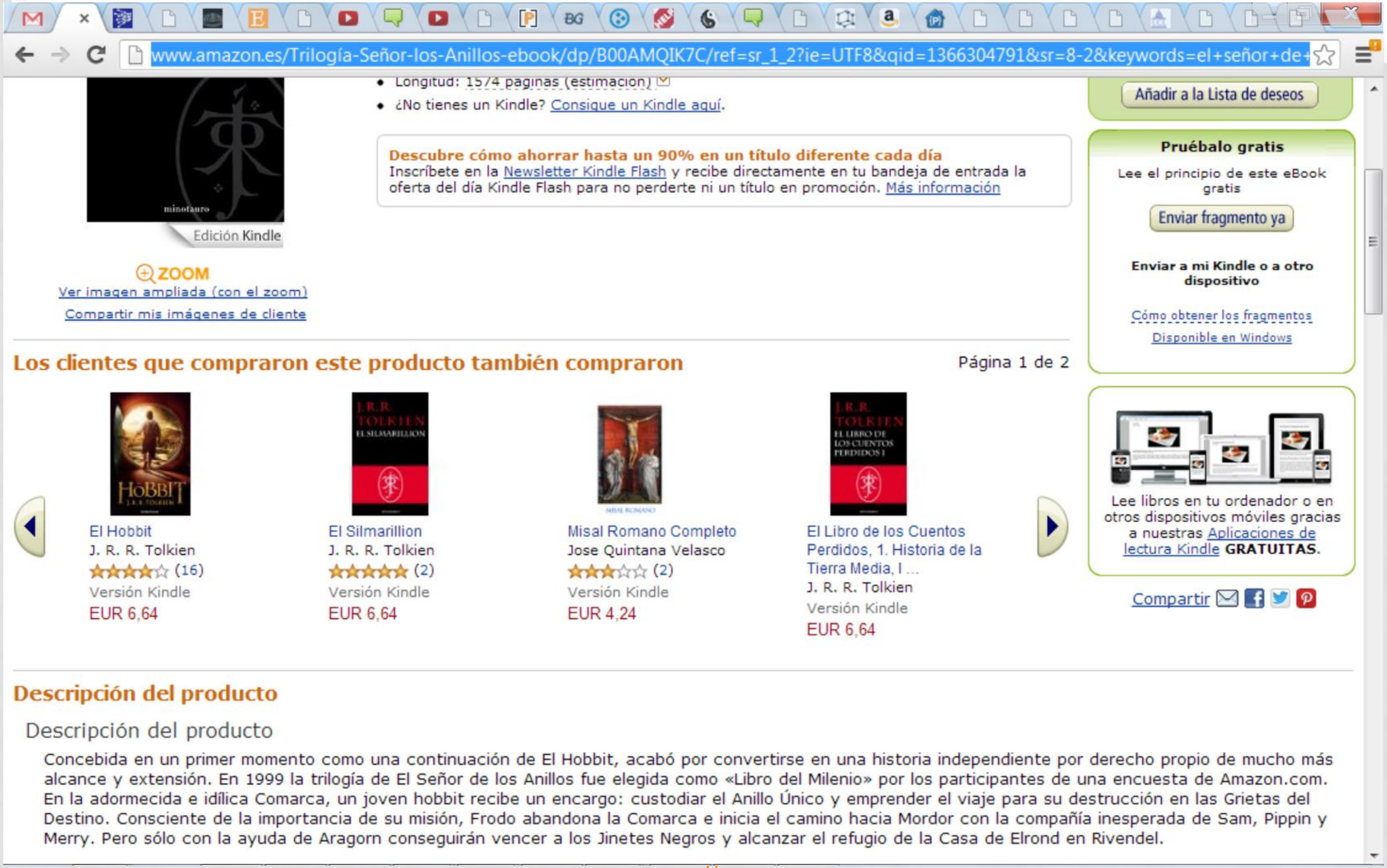
22
0
2
Nuclear
Fuel/gas
Carbón
Ciclo combinado
Eólica
Hidráulica (+)
Solar
Resto reg. esp.
Intercambios int. (-)
Enlace balear (-)
Generación
CO2 asociado a generación
6000
5000
4000
3000
2000
1000
0
Ciclo combinado (MW)

APPLICATIONS II

- Medicine:
  - Illness diagnosis
- Science:
  - Illness prediction from DNA analysis
  - Prediction if a new substance causes cancer
  - SKYCAT
- Internet:
  - Spam detection (SpamAssassin)
  - Web: book recommendation (amazon.com)


www.amazon.es/Trilogía-Señor-los-Anillos-ebook/dp/B00AMQIK7C/ref=sr_1_2?ie=UTF8&qid=1366304791&sr=8-2&keywords=el+señor+de+
minotauro
Edición Kindle
ZOOM
Añadir a la Lista de deseos
Enviar fragmento ya
Compartir

- Longitud: 1574 páginas (estimación)
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Descubre cómo ahorrar hasta un 90% en un título diferente cada día
Inscríbete en la Newsletter Kindle Flash y recibe directamente en tu bandeja de entrada la oferta del día Kindle Flash para no perderte ni un título en promoción. Más información

Ver imagen ampliada (con el zoom)
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Pruébalo gratis
Lee el principio de este eBook gratis

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El Hobbit
J. R. R. Tolkien
★★★★☆ (16)
Versión Kindle
EUR 6,64

El Silmarillion
J. R. R. Tolkien
★★★★★ (2)
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EUR 6,64

Misal Romano Completo
Jose Quintana Velasco
★★★☆☆ (2)
Versión Kindle
EUR 4,24

El Libro de los Cuentos Perdidos, 1. Historia de la Tierra Media, I ...
J. R. R. Tolkien
Versión Kindle
EUR 6,64

Descripción del producto

Descripción del producto

Concebida en un primer momento como una continuación de El Hobbit, acabó por convertirse en una historia independiente por derecho propio de mucho más alcance y extensión. En 1999 la trilogía de El Señor de los Anillos fue elegida como «Libro del Milenio» por los participantes de una encuesta de Amazon.com. En la adormecida e idílica Comarca, un joven hobbit recibe un encargo: custodiar el Anillo Único y emprender el viaje para su destrucción en las Grietas del Destino. Consciente de la importancia de su misión, Frodo abandona la Comarca e inicia el camino hacia Mordor con la compañía inesperada de Sam, Pippin y Merry. Pero sólo con la ayuda de Aragorn conseguirán vencer a los Jinetes Negros y alcanzar el refugio de la Casa de Elrond en Rivendel.

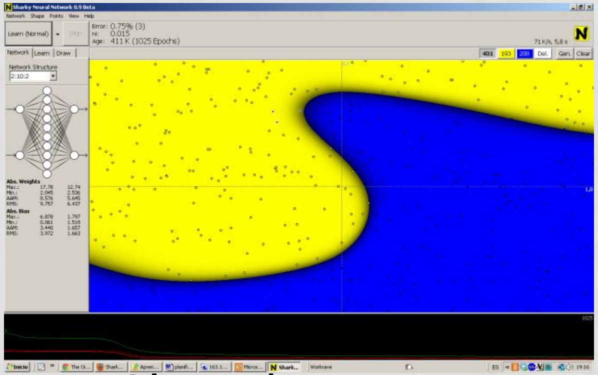
SYLLABUS

1. Overview and introduction to Machine Learning: tasks and models.
2. Predictive models:
   - Decision trees, regression trees
   - K Nearest Neighbour (KNN)
   - Machine Learning pipeline: training, => ML algorithm => model => test / evaluation . Preprocessing, hyperparameter tuning, …
3. Ensemble methods: bagging, boosting, stacking
4. Preprocessing: selection of attributes and methods of dimensionality reduction
5. Machine learning software for Big Data:
   1. Python: scikit-learn, numpy
   2. Mapreduce
   3. Spark: pyspark, MLLIB
6. Other topics:
   1. Online learning
   2. Metaheuristics: genetic algorithms, genetic programming, …

TASKS AND ALGORITHMS

- What can be done?

Classification

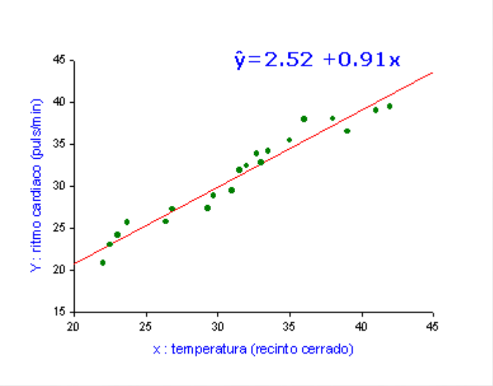


Sharky Neural Network 0.9 Beta

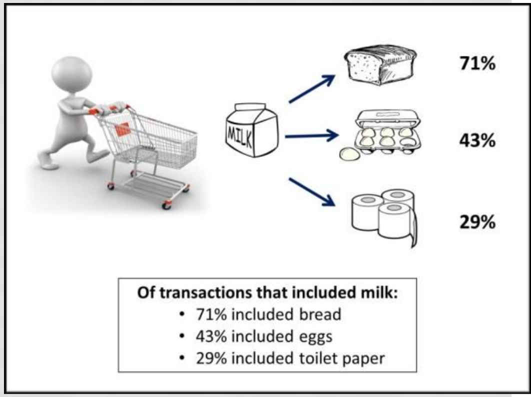
Error: 0.75% (3)
ni: 0.015
Age: 411 K (1025 Epochs)

Network Structure: 2:10:2

Regression



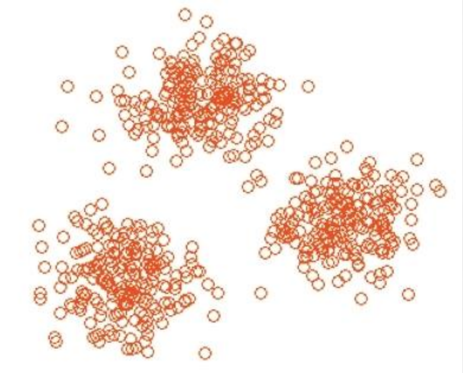
Market basket analysis



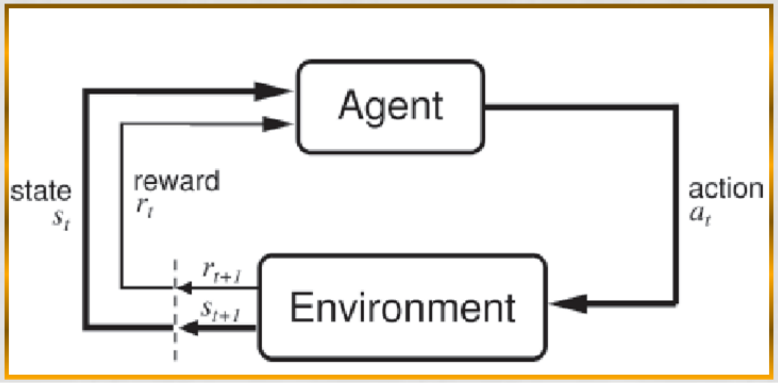
Of transactions that included milk:

- 71% included bread
- 43% included eggs
- 29% included toilet paper

Clustering



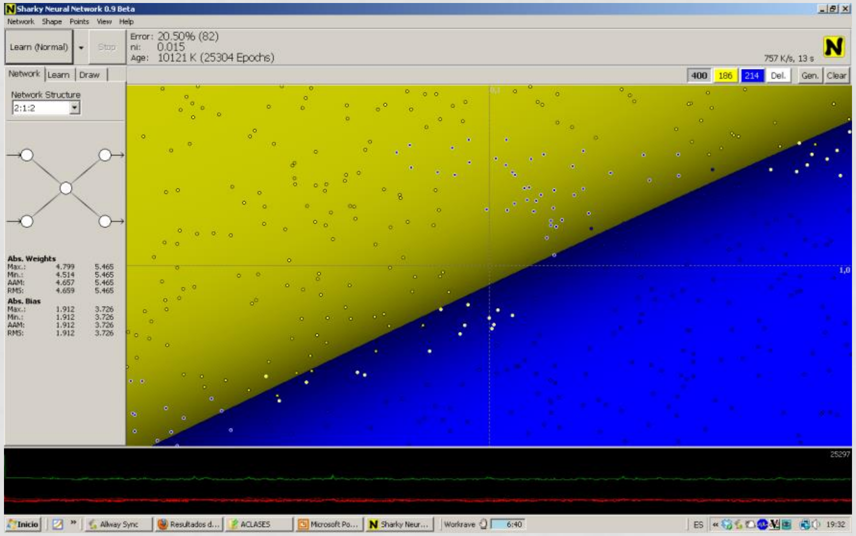
Reinforcement learning



MODELS

- What models can be obtained?

Linear

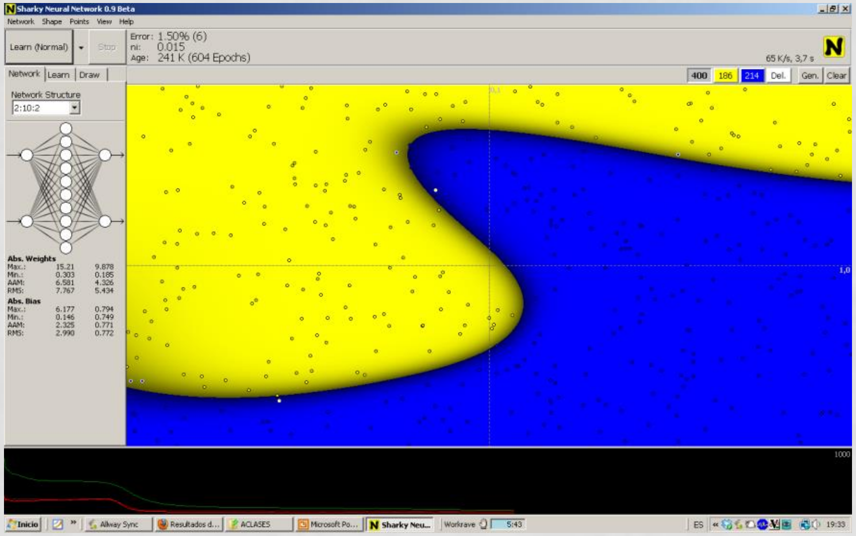


Error: 20.50% (82)
ni: 0.015
Age: 10121 K (25304 Epochs)
757 K/s, 13 s

Network Structure 2:1:2

```
Abs. Weights
Max.:    4.799   5.465
Min.:    4.514   5.465
AAM:     4.657   5.465
RMS:     4.659   5.465
Abs. Bias
Max.:    1.912   3.726
Min.:    1.912   3.726
AAM:     1.912   3.726
RMS:     1.912   3.726
```

Non linear



Error: 1.50% (6)
ni: 0.015
Age: 241 K (604 Epochs)
65 K/s, 3,7 s

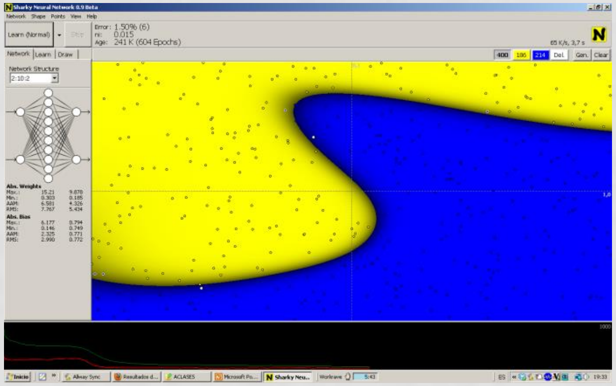
Network Structure 2:10:2

```
Abs. Weights
Max.:    15.21   9.878
Min.:    0.303   0.185
AAM:     6.581   4.326
RMS:     7.767   5.434
Abs. Bias
Max.:    6.177   0.794
Min.:    0.146   0.749
AAM:     2.325   0.771
RMS:     2.990   0.772
```

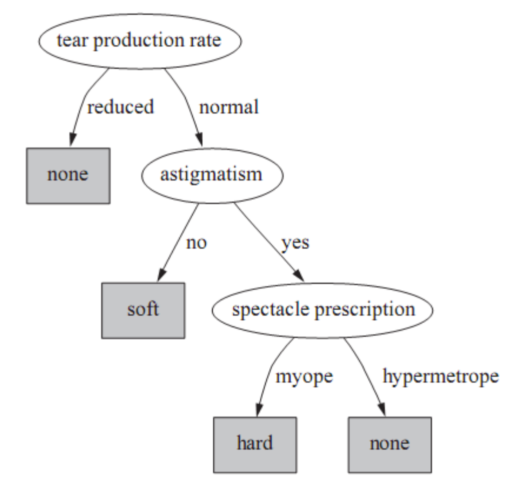
MODELS

- What models can be obtained?

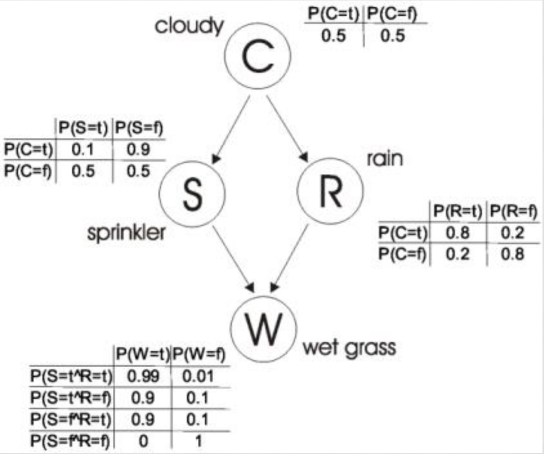
Functions: $y= 3*x^3+2$



Decision trees



Bayesian networks



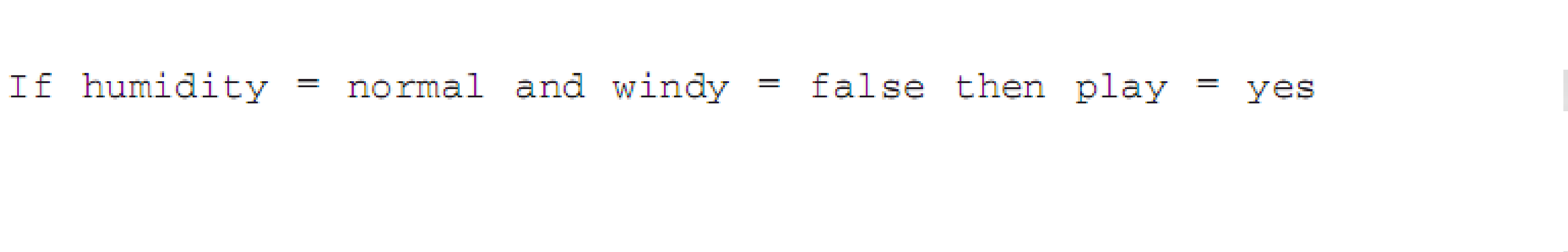
P(C=t)	P(C=f)
0.5	0.5

	P(S=t)	P(S=f)
P(C=t)	0.1	0.9
P(C=f)	0.5	0.5

	P(R=t)	P(R=f)
P(C=t)	0.8	0.2
P(C=f)	0.2	0.8

	P(W=t)	P(W=f)
P(S=t^R=t)	0.99	0.01
P(S=t^R=f)	0.9	0.1
P(S=f^R=t)	0.9	0.1
P(S=f^R=f)	0	1

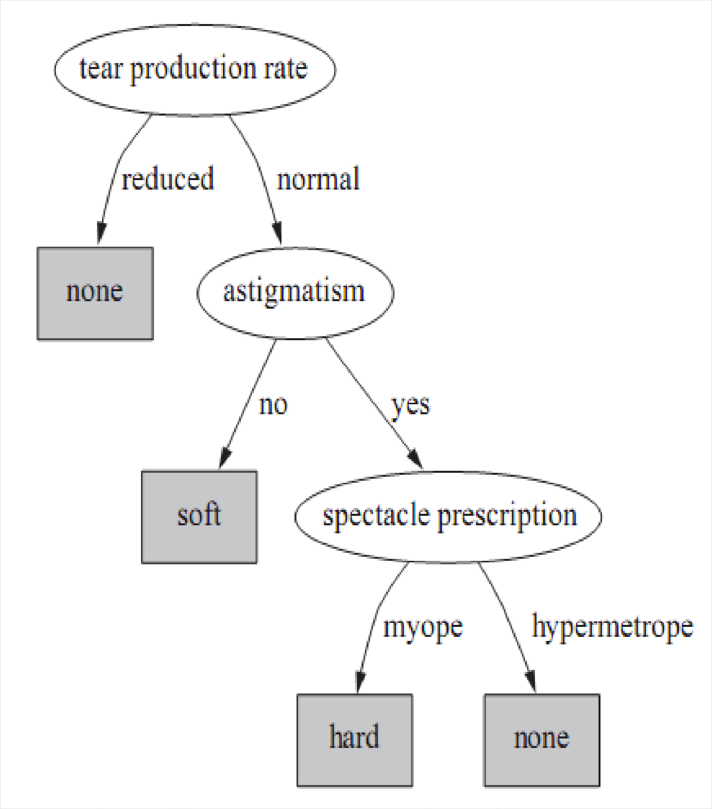
Rules

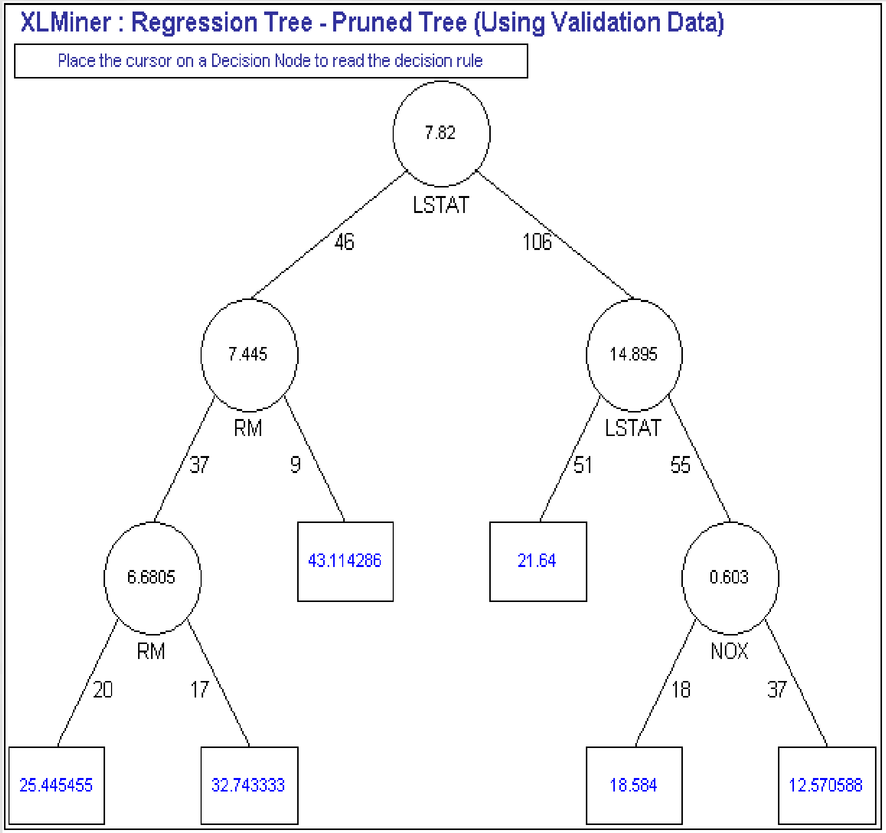


```
If humidity = normal and windy = false then play = yes
```

And many more: neural networks, nearest neighbor, …

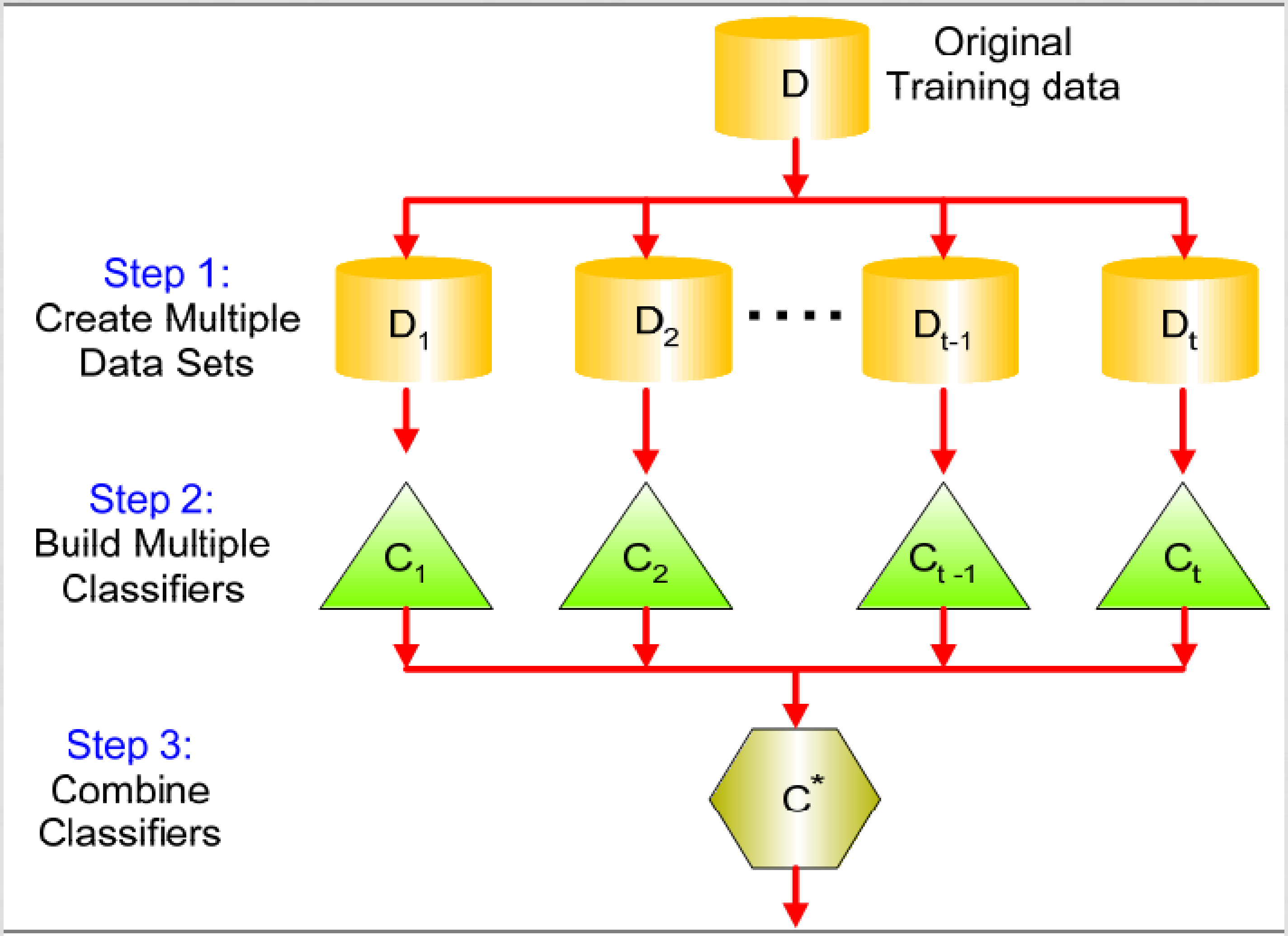
Decision trees and regression trees



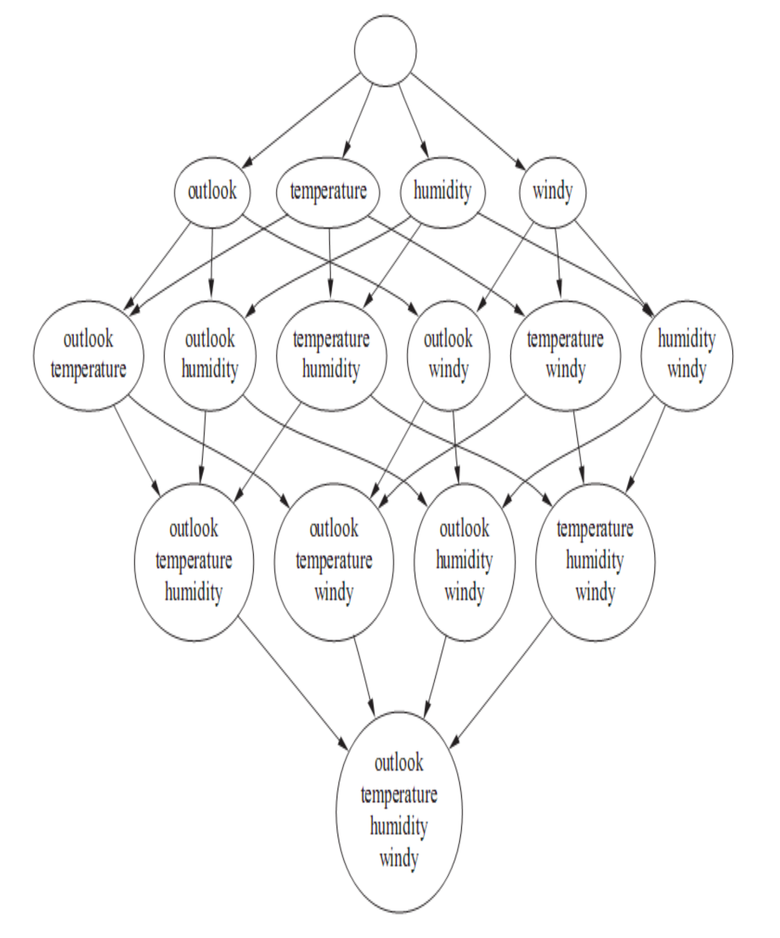

XLMiner : Regression Tree - Pruned Tree (Using Validation Data)

Place the cursor on a Decision Node to read the decision rule

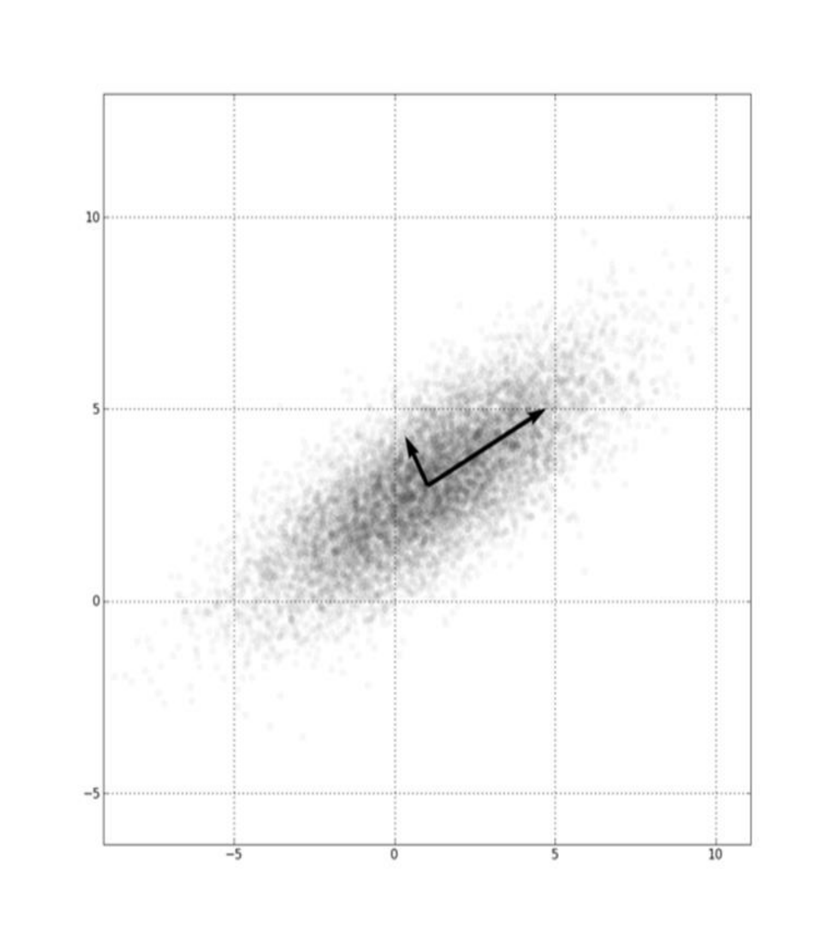
Ensembles of classifiers



ATTRIBUTE SELECTIÓN AND TRANSFORMATION

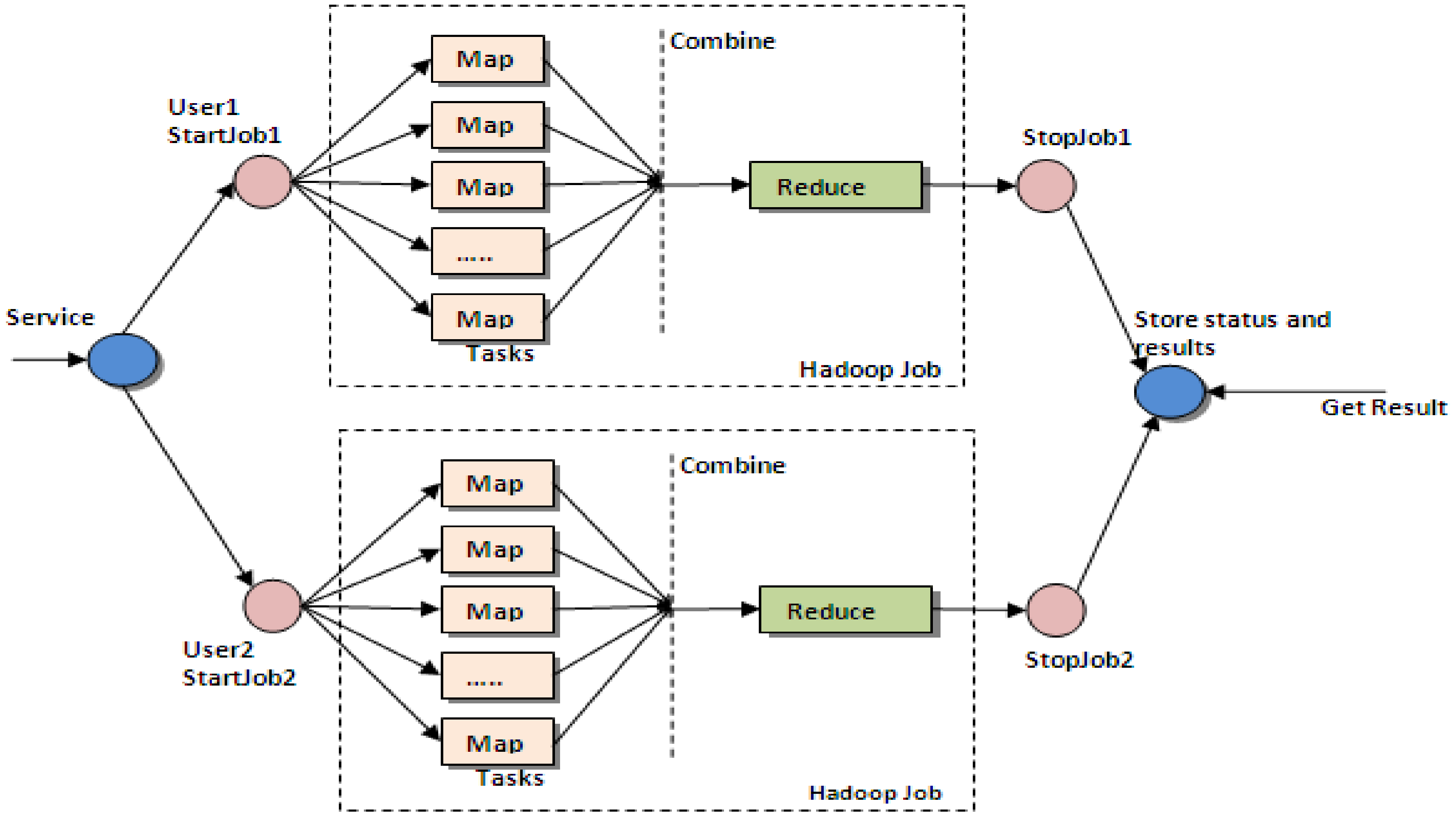


Attribute selection



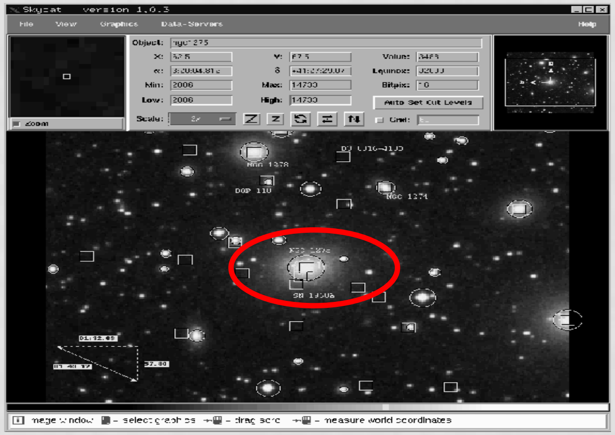
Principal Component Analysis and Random Projections

BIG DATA / MAP-REDUCE, SPARK (MLLIB)



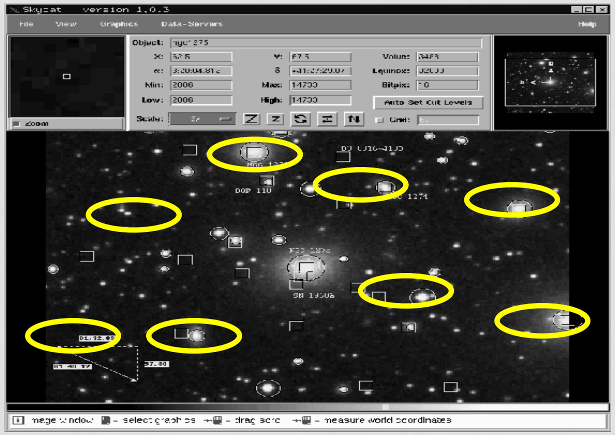
TASKS / MODELS / ALGORITHMS

- What can be done? Tasks:
  - Supervised ML: classification, regression, …
  - Unsupervised ML: clustering, association, …
  - Semi-supervised ML
  - Reinforcement learning
- What kind of models can be learned?
  - Attribute-value:
    - Trees
    - Nearest neighbor
    - Functions: neural networks, support vector machines, …
    - Bayesian networks
    - Ensembles (bagging, boosting, stacking, …)
  - Relational
- How can models be learned? Algorithms:
  - Linear models: linear regression, simple perceptron, naive bayes, SVM with linear kernel, …
  - Neural networks: backpropagation, rprop, …
  - Decision trees: ID3, C4.5, C5.0, …
  - Nearest neighbour: IB1, …

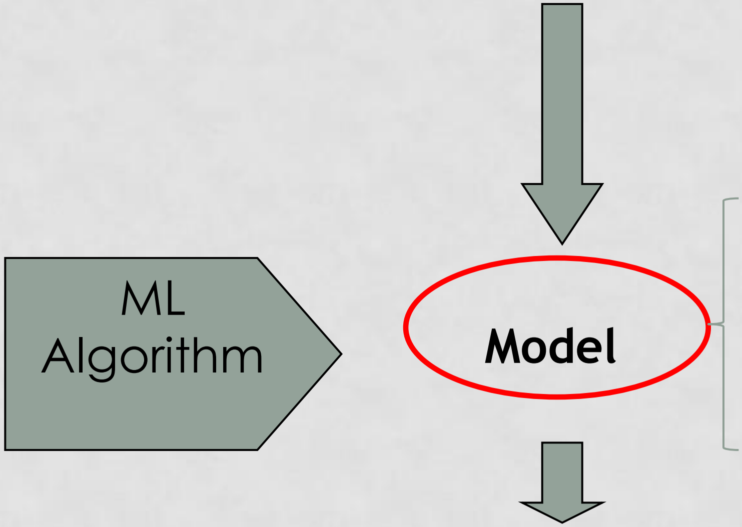


?

Training data (labeled pictures of sky objects: galaxies, stars, nebulae, …)



Pictures in the catalog have been labeled by a human expert (astronomer)



ML Algorithm

Model

- Trees
- Nearest neighbor
- Functions: neural networks, support vector machines, …
- Bayesian networks
- Ensembles (bagging, boosting, stacking, …)

Spiral galaxy

TASKS

- **Inductive learning**(from instances)
  - **Supervised learning:**
    - **Classification:**
    - Regression
  - Semi-supervised learning
  - Unsupervised learning:
    - Clustering
    - Association
  - Reinforcement learning

CLASSIFICATION TASK. AN EXAMPLE:

- Bank credit approval:
  - An Internet bank owns a large data base with information about clients whose credits were approved or rejected
  - The banks requires a model to determine if a new customer will repay the loan or not
  - Instances (client records in the database):
    - Input attributes : credit time-length (years), amount, overdue accounts?, own house?
    - Class: yes/no
  - Rule-based model:
    - **IF** (overdue accounts > 0) **THEN** repay loan = no
    - **IF** (overdue accounts = 0) **AND** ((salary > 2500) **OR** (years > 10)) **THEN** repay loan = yes

CLASSIFICATION TASK. AN EXAMPLE:

test set

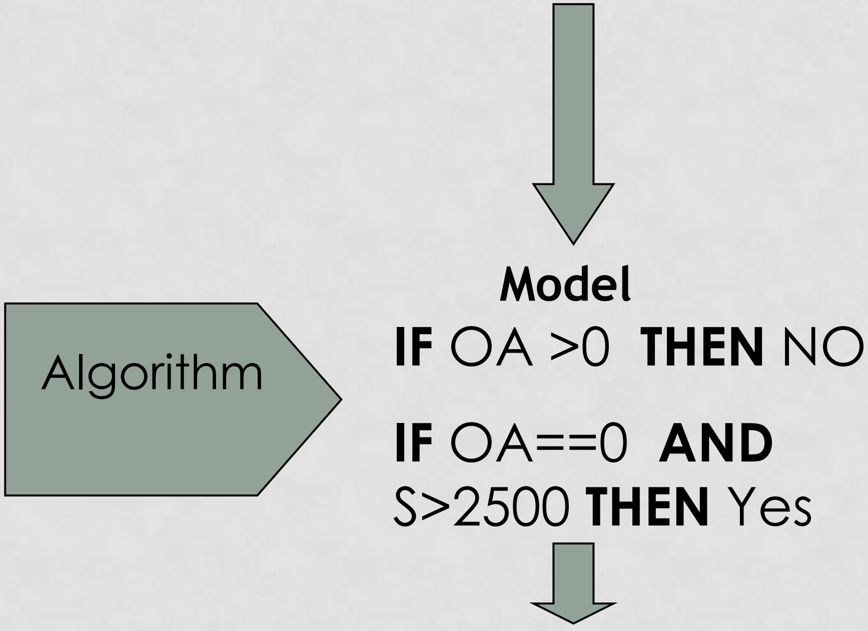
Years	Amount	Salary	Own house?	Overdue accounts?	Repay loan
10	50000	3000	Yes	0	??

T = training set (instances)

Years	Amount	Salary	Own house?	Overdue accounts?	Repay loan
15	60000	1900	Yes	2	No
2	30000	3500	Yes	0	Yes
9	9000	1700	Yes	1	No
15	18000	3000	No	0	Yes
10	24000	2100	No	0	No
	…	…	…	…	…

x (or input attributes)

y (class, or output attribute)



Algorithm

Model

IF OA >0 **THEN** NO

IF OA==0 **AND** S>2500 **THEN** Yes

Repay loan = yes

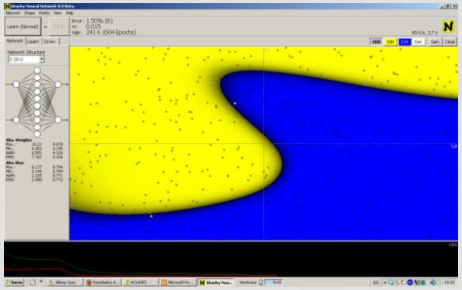
IMPORTANT: MODELS

- In the previous slide, the model built from training data is a set of rules:

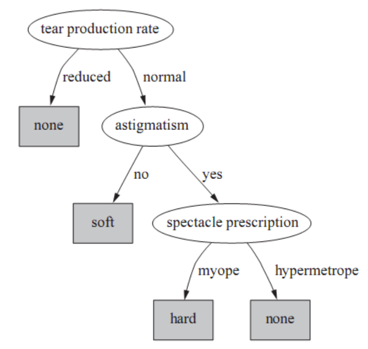
IF OA >0 **THEN** NO **ELSEIF** OA==0 **AND** S>2500 **THEN** Yes

- But there are many more that can be learned:

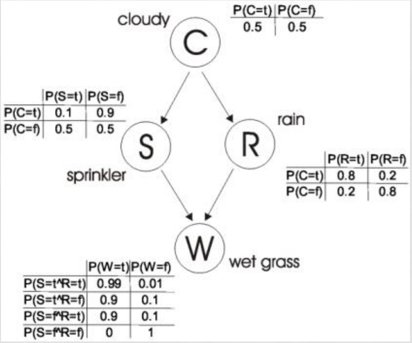
Functions: $y= 3*x^3+2$



Decision trees



Bayesian networks



P(C=t)	P(C=f)
0.5	0.5

	P(S=t)	P(S=f)
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P(C=f)	0.5	0.5

	P(R=t)	P(R=f)
P(C=t)	0.8	0.2
P(C=f)	0.2	0.8

	P(W=t)	P(W=f)
P(S=t^R=t)	0.99	0.01
P(S=t^R=f)	0.9	0.1
P(S=f^R=t)	0.9	0.1
P(S=f^R=f)	0	1

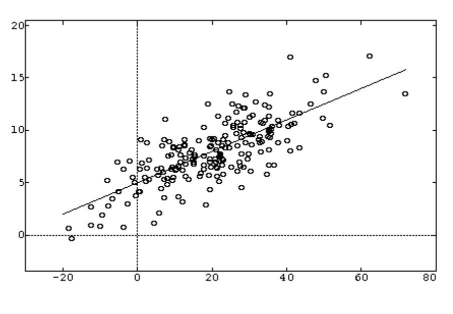
And many more: neural networks, nearest neighbor, support vector machines (SVMs).

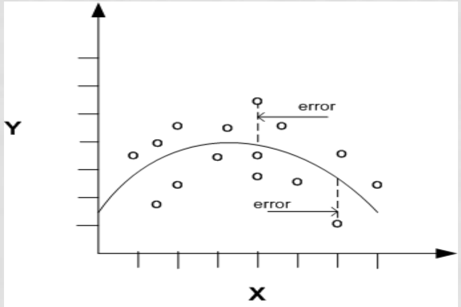
TASKS

- **Inductive learning**(from instances)
  - **Supervised learning:**
    - Classification
    - **Regression**
  - Semi-supervised learning
  - Unsupervised learning:
    - Clustering
    - Association
  - Reinforcement learning

REGRESSION

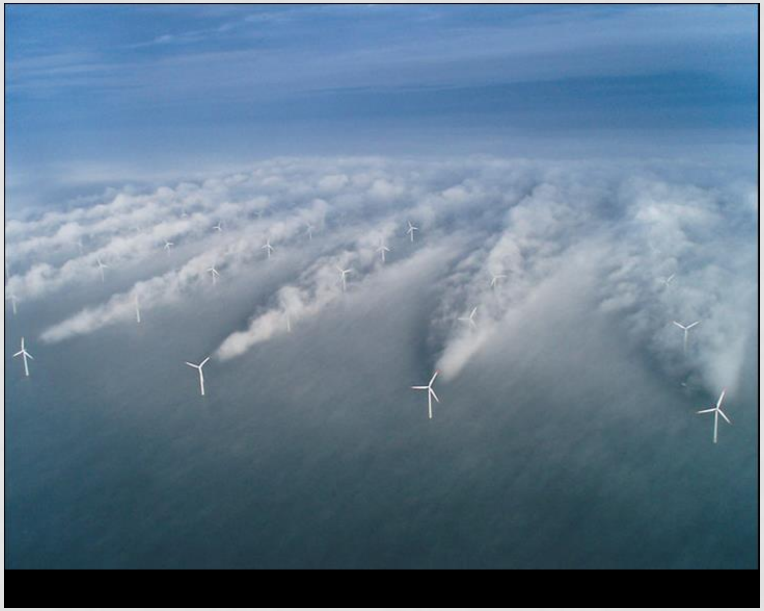
- If the class is continuous, it is a **regression** problem
- Models are typically mathematical functions *y=g(x)*
  - Linear: y = ax+b
  - Non linear: y = a*x^2+bx+c / y = log(sin(x))

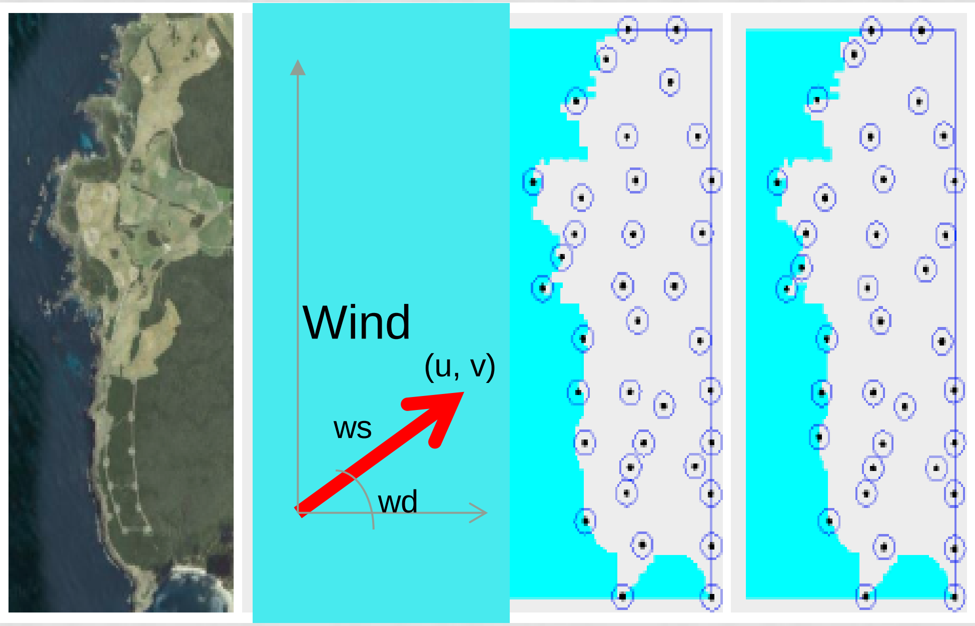




REGRESSION EXAMPLE

- **A wind power forecasting problem: predicting hourly power generation at 7 wind farms**





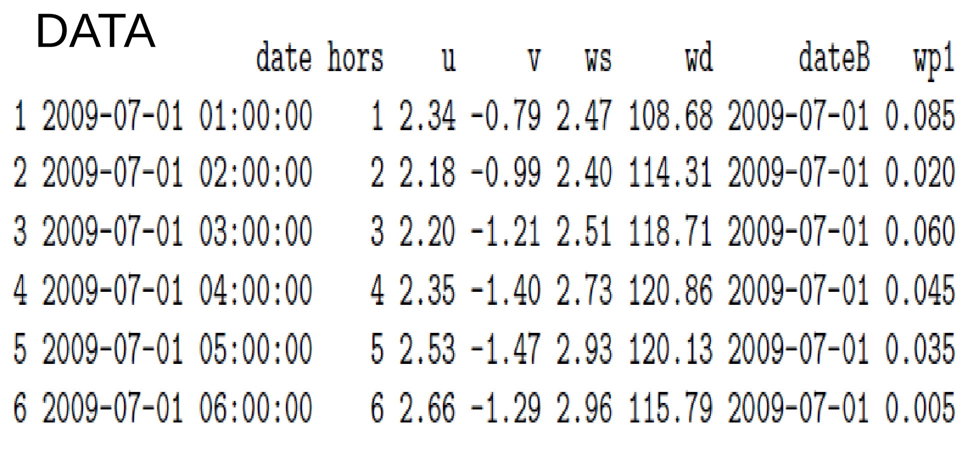
Some input variables:

- ws: wind speed
- wd: wind direction
- (u,v): wind direction vector

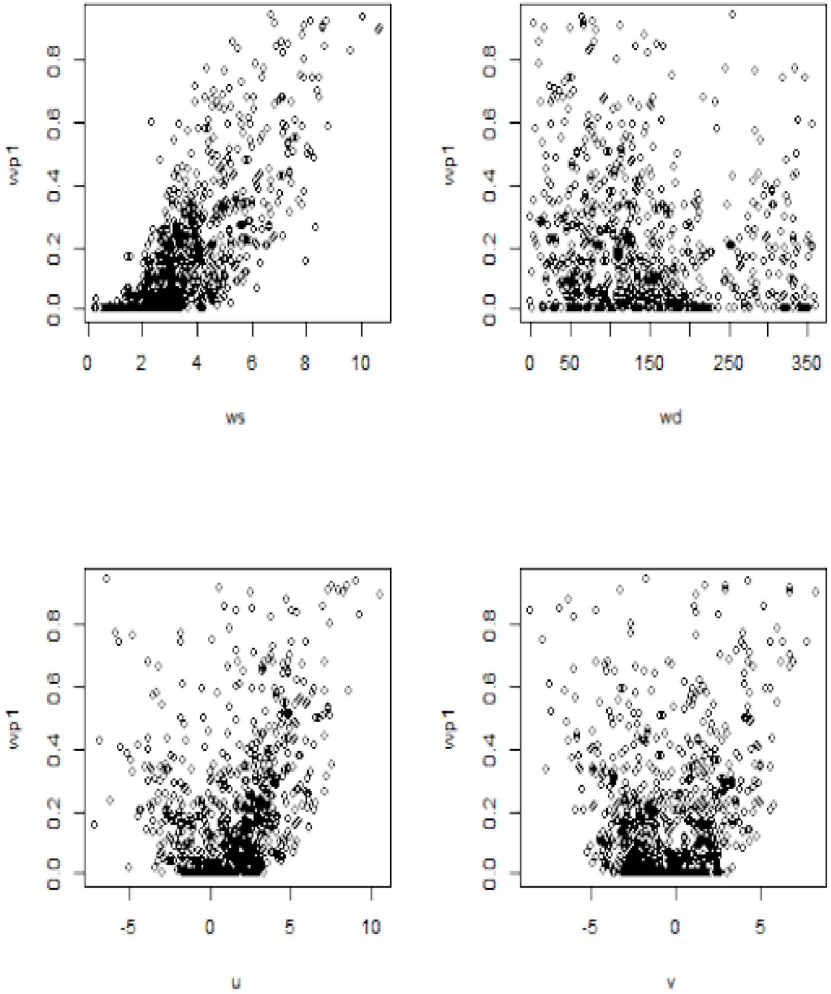
Model to estimate electricity production from ws, wd, u, v?
wp = f(ws, wd, u, v, …)

REGRESSION EXAMPLE

DATA



```
                 date hors    u     v   ws     wd      dateB   wp1
1 2009-07-01 01:00:00    1 2.34 -0.79 2.47 108.68 2009-07-01 0.085
2 2009-07-01 02:00:00    2 2.18 -0.99 2.40 114.31 2009-07-01 0.020
3 2009-07-01 03:00:00    3 2.20 -1.21 2.51 118.71 2009-07-01 0.060
4 2009-07-01 04:00:00    4 2.35 -1.40 2.73 120.86 2009-07-01 0.045
5 2009-07-01 05:00:00    5 2.53 -1.47 2.93 120.13 2009-07-01 0.035
6 2009-07-01 06:00:00    6 2.66 -1.29 2.96 115.79 2009-07-01 0.005
```

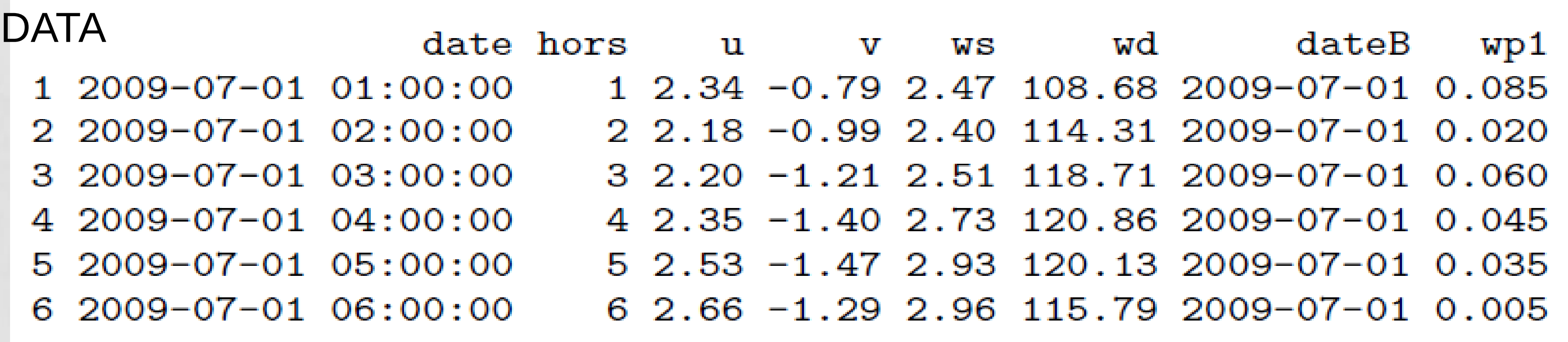


Some input variables:

- ws: wind speed
- wd: wind direction
- (u,v): wind direction vector

REGRESSION EXAMPLE

DATA



```
                 date hors    u     v   ws     wd      dateB   wp1
1 2009-07-01 01:00:00    1 2.34 -0.79 2.47 108.68 2009-07-01 0.085
2 2009-07-01 02:00:00    2 2.18 -0.99 2.40 114.31 2009-07-01 0.020
3 2009-07-01 03:00:00    3 2.20 -1.21 2.51 118.71 2009-07-01 0.060
4 2009-07-01 04:00:00    4 2.35 -1.40 2.73 120.86 2009-07-01 0.045
5 2009-07-01 05:00:00    5 2.53 -1.47 2.93 120.13 2009-07-01 0.035
6 2009-07-01 06:00:00    6 2.66 -1.29 2.96 115.79 2009-07-01 0.005
```

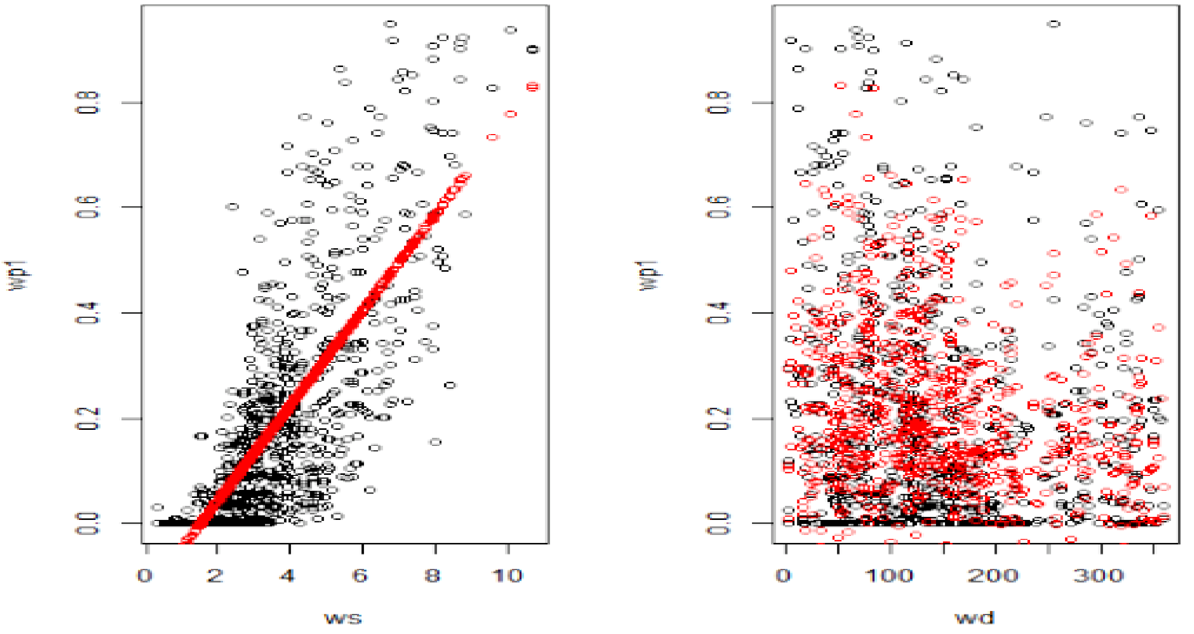
Linear model:

$wp = f(ws, wd, u, v)$

$wp = a_1 * ws + a_2 * wd +$

$+ a_3 * u + a_4 * v + b$

Obviously, a non-linear model could do better

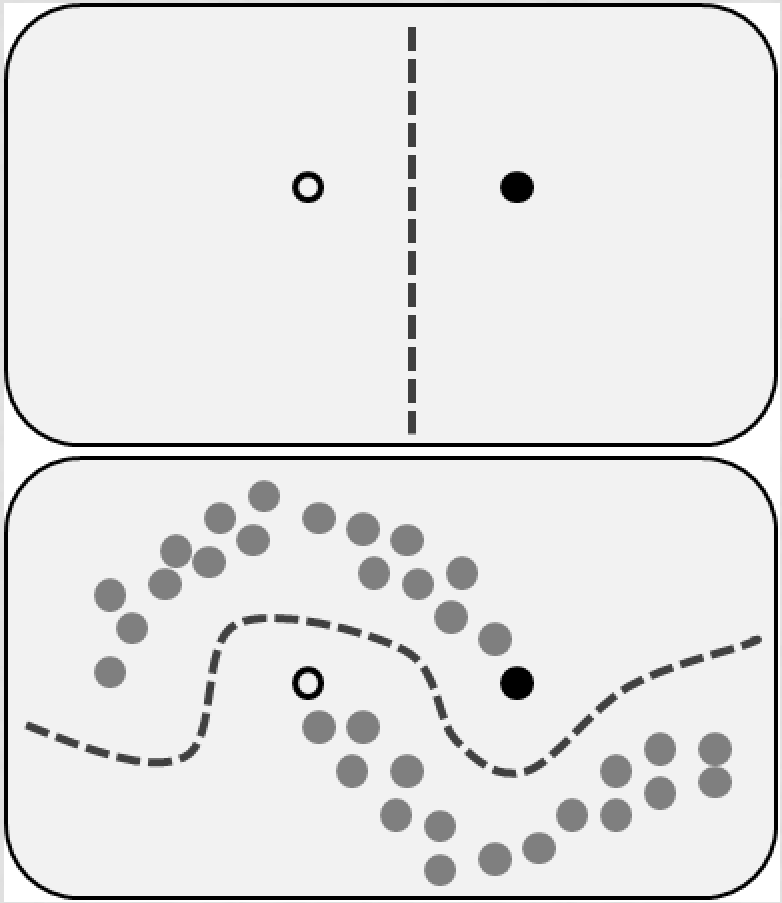


TASKS

- **Inductive learning**(from instances)
  - Supervised learning:
    - Classification
    - Regression
  - **Semi-supervised learning**
  - Unsupervised learning:
    - Clustering
    - Association
  - Reinforcement learning

SEMISUPERVISED LEARNING

- When both labelled and unlabelled instances are available
- Why: labelling instances may be costly (ex: to perform a biopsy to determine if a person has cancer)

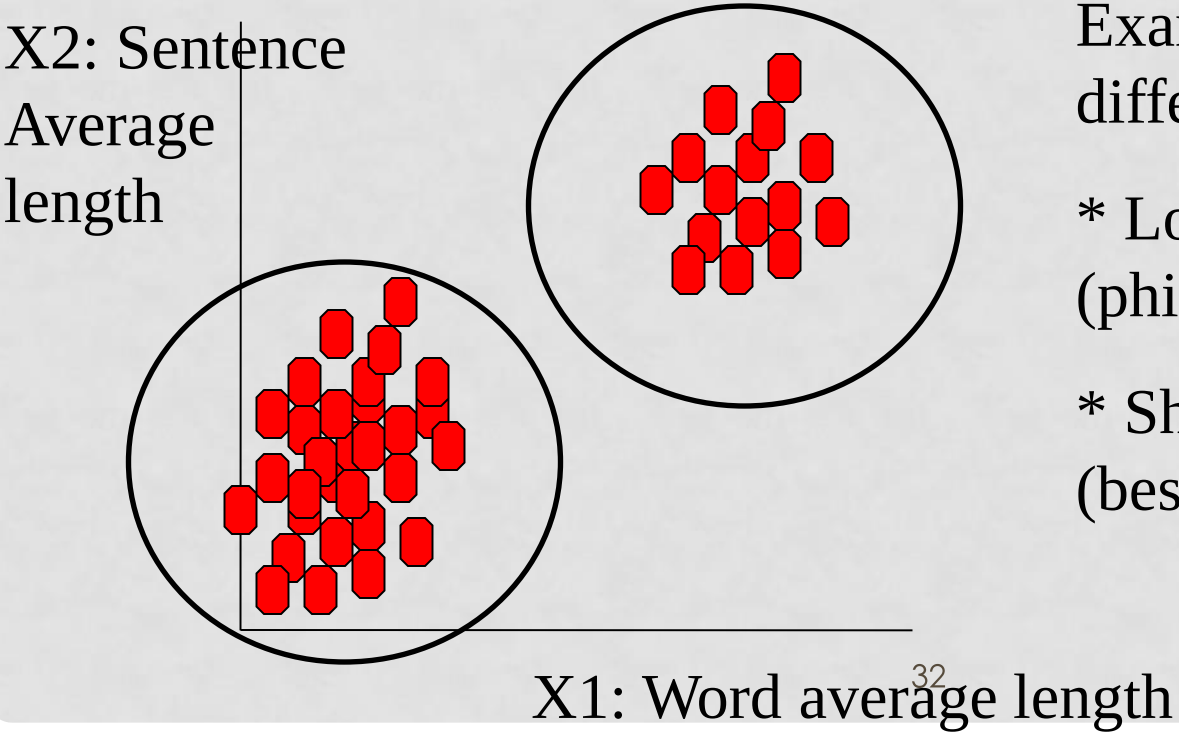


TASKS

- **Inductive learning** (from instances)
  - Supervised learning:
    - Classification
    - Regression
  - Semi-supervised learning
  - **Unsupervised learning:**
    - **Clustering**
    - Association
  - Reinforcement learning

UNSUPERVISED LEARNING (NO LABELS): CLUSTERING

- To determine natural clusterings in instance space, based on the input attributes (no labels)



Example:each point is a different book. 2 groups:

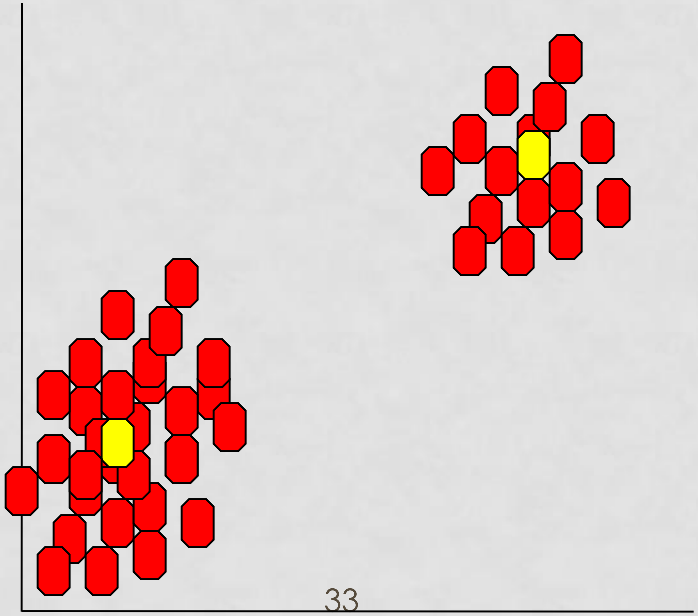
* Long words and sentences (philosophy?)

* Short words and sentences (best-sellers?)

CLUSTER REPRESENTATION

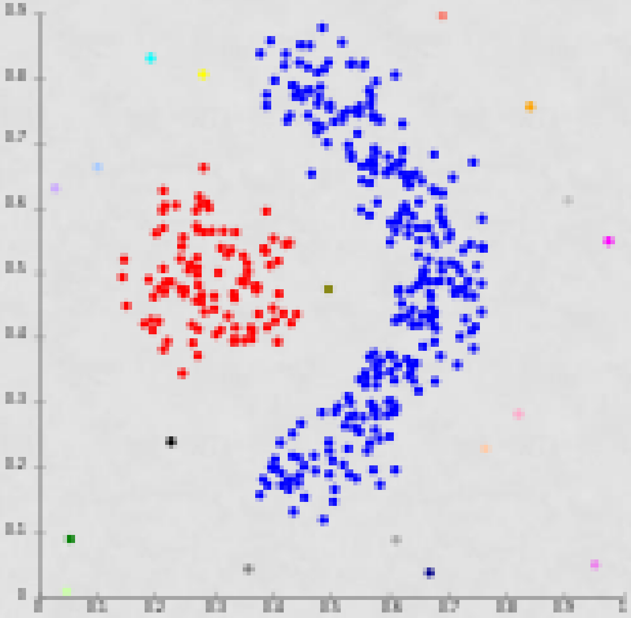
- Most commonly: centroids (ex: k-means algorithm)

K-MEANS: http://www.youtube.com/watch?v=74rv4snLl70



CLUSTERING

- Clustering is not so well defined as classification: clustering based on neighbourhood or connectivity?



CLUSTERING EXAMPLE

- Human resources department would like to cluster employees in order to understand the different types of employee and treat them accordingly (fire problematic workers? ☺).

CLUSTERING EXAMPLE. TRAINING DATA

Id	Salary	Married	Car	Offspring	Own-house	Syndicate	Sick leave	Years working	Sex
1	1000	Yes	No	0	No	No	7	15	M
2	2000	No	Yes	1	No	Yes	3	3	F
3	1500	Yes	Yes	2	Yes	Yes	5	10	M
4	3000	Yes	Yes	1	No	No	15	7	F
5	1000	Yes	Yes	0	Yes	Yes	1	6	F
…	…	…	…	…		…	…	…	…

MODEL (CLUSTERS)

	GROUP 1	GROUP 2	GROUP 3
Salary	1535	1428	1233
Married (No/Yes)	77%/22%	98%/2%	0%/100%
Car	82%/18%	1%/99%	5%/95%
Offspring	0.05	0.3	2.3
Own-house	99%/1%	75%/25%	17%/83%
Syndicated	80%/20%	0%/100%	67%/33%
Sick leave	8.3	2.3	5.1
Years working	8.7	8	8.1
Sex (M/W)	61%/39%	25%/75%	83%/17%

MODEL (CLUSTERS)

- Cluster 1: No offspring and rented house. Low level of syndication. Lots of sick leaves
- Cluster 2: No offspring and own-car. High syndication level. Few sick leaves. Tipically women living in rented houses
- Cluster 3: Married men with children and own-car and own-houses. Low syndication level

TASKS

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MARKET BASKET ANALYSIS (**ASSOCIATION**)

- A supermarket needs to know customer behavior.
  - Ex: if customer buys X then s/he also buys Y
- Service might be improved (putting together products bought together, etc.)

TRAINING DATA (CUSTOMER BASKETS)

Id	Eggs	Oil	Napies	Wine	Milk	Butter	Salmon	Lettuce	…
1	Yes	No	No	Yes	No	Yes	Yes	Yes	…
2	No	Yes	No	No	Yes	No	No	Yes	…
3	No	No	Yes	No	Yes	No	No	No	…
4	No	Yes	Yes	No	Yes	No	No	No	…
5	Yes	Yes	No	No	No	Yes	No	Yes	…
6	Yes	No	No	Yes	Yes	Yes	Yes	No	…
7	No	No	No	No	No	No	No	No	…
8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	…
…	…	…	…	…	…	…	…	…	…

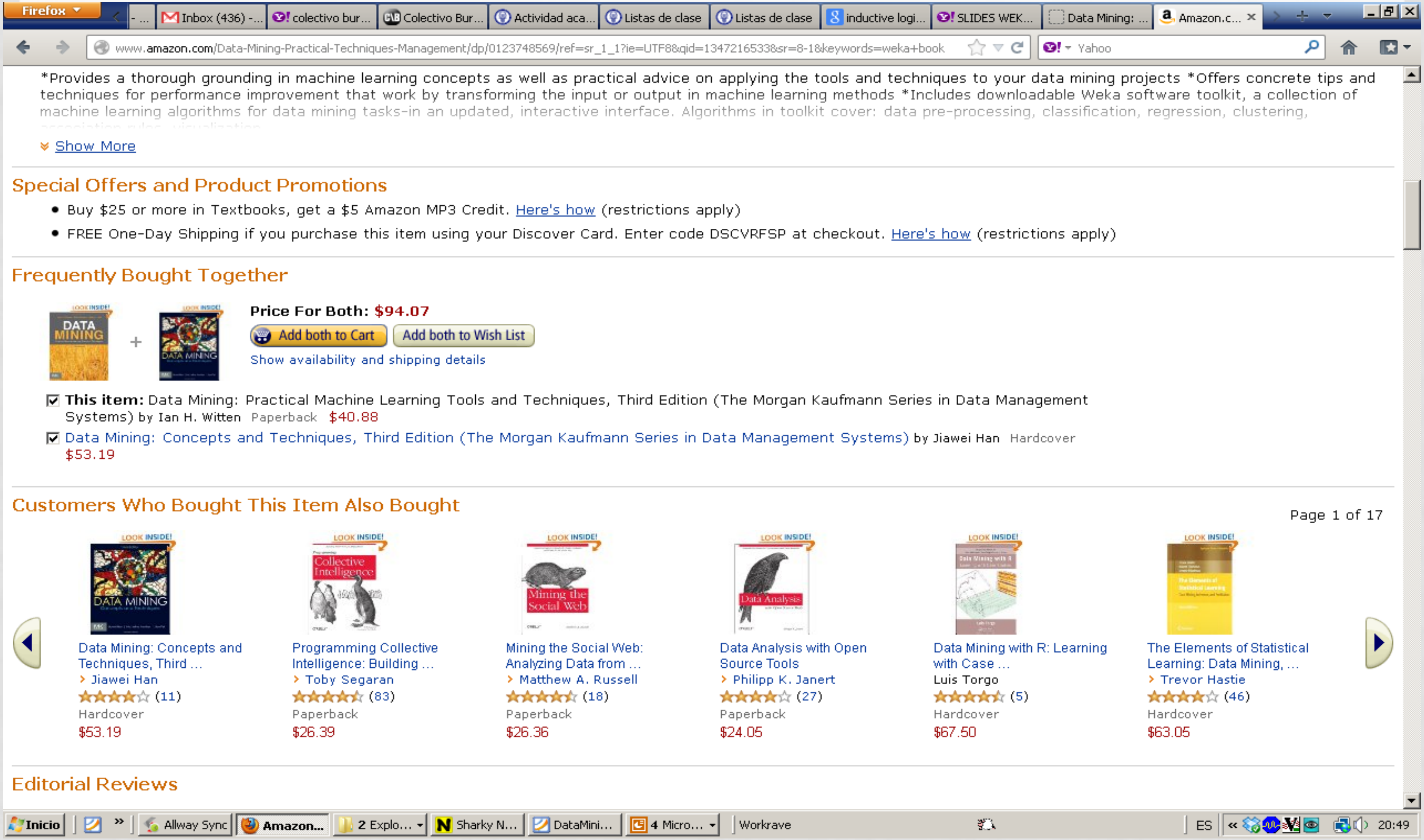
MODEL

- Rules **IF** At_1=a **AND** At_2=b y ... **THEN** At_n=c
  - **IF** nappies=Yes **THEN** milk=Yes
  - **IF** butter = Yes **AND** salmon = Yes **THEN** wine = Yes

- Also: **IF** At_1=a AND At_2=b **THEN** At_n=c, **At_4=D**

Service might be improved (putting together nappies and milk, etc.)

ASSOCIATION



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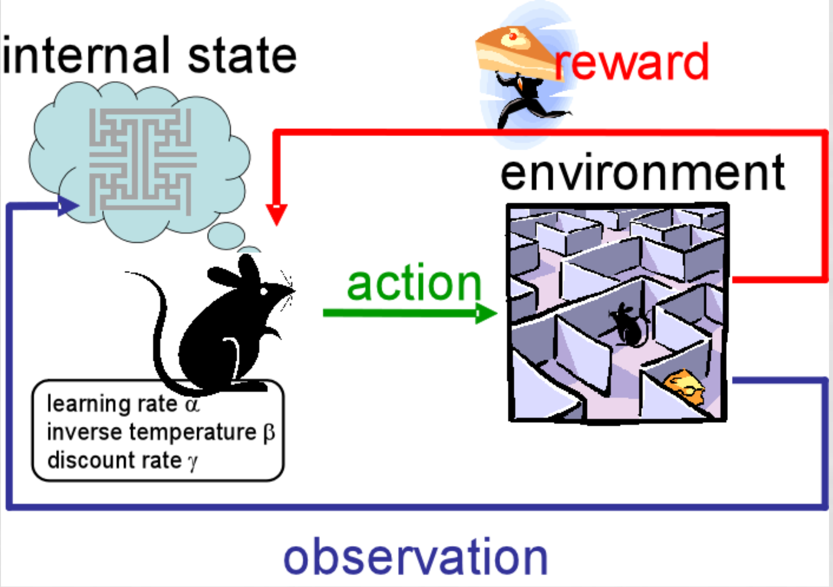
Editorial Reviews

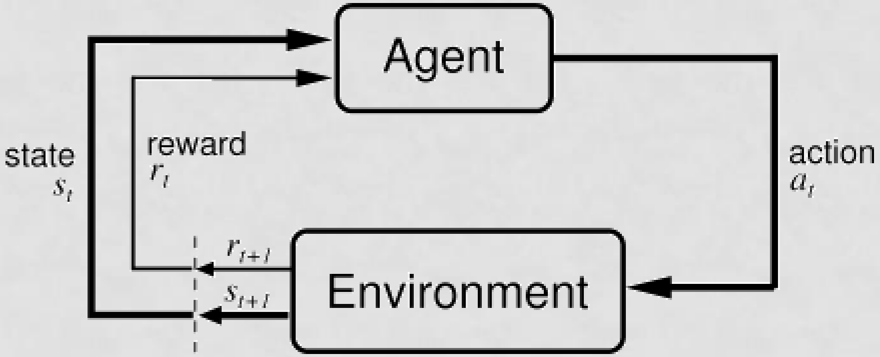
TASKS

- **Inductive learning**(from instances)
  - Supervised learning:
    - Classification
    - Regression
  - Semi-supervised learning
  - Unsupervised learning:
    - Clustering
    - Association
  - **Reinforcement learning**

TASK: REINFORCEMENT LEARNING

- The goal of learning is a “policy” π so that the agent (mouse) knows what to do at each situation (in the case of the mouse, a situation is a particular location within the maze). Robotics.
- Actions:
  - forward
  - turn left
  - turn right





TASKS

- **Inductive learning**(from instances)
  - Attribute-value models
    - Supervised learning:
    - Semi-supervised learning
    - Unsupervised learning:
    - Reinforcement learning
  - **Relational learning**

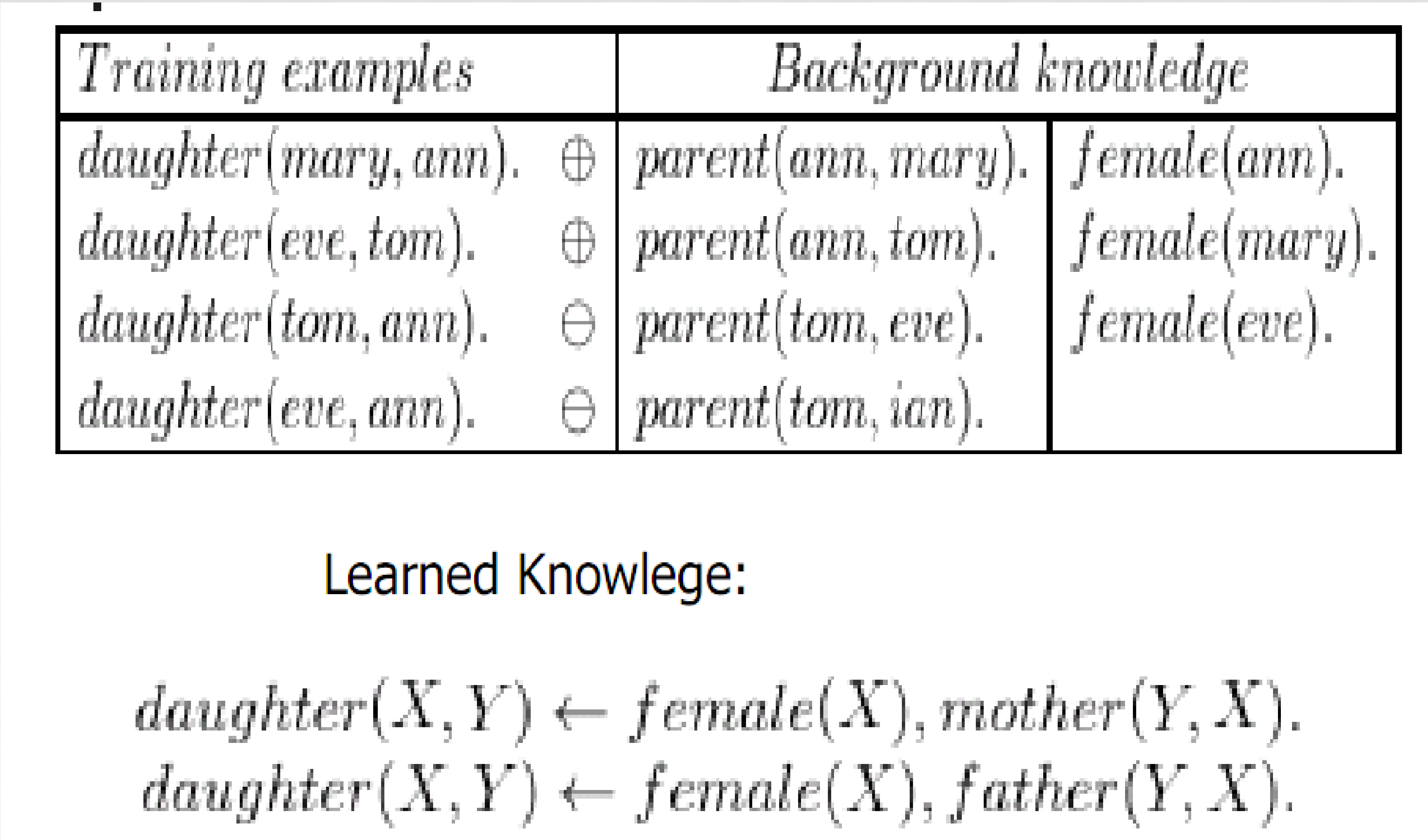
Relational Learning

- For instance, learn the concept of “being a daughter”
- **IF** X is female **AND** Y is the mother of Y **THEN** X is a daugther of Y
- Compare this rule with:

IF Overdue Accounts ==0 **AND** Salary >2500 **THEN** Repay loan = Yes

- Relational rules use variables (X, Y) and relations

Relational Learning: ILP (inductive logic programming



Training examples		*Background knowledge*	
daughter(mary, ann).	⊕	*parent(ann, mary).*	*female(ann).*
daughter(eve, tom).	⊕	*parent(ann, tom).*	*female(mary).*
daughter(tom, ann).	⊖	*parent(tom, eve).*	*female(eve).*
daughter(eve, ann).	⊖	*parent(tom, ian).*	

Learned Knowlege:

$$daughter(X, Y) \leftarrow female(X), mother(Y, X).$$
$$daughter(X, Y) \leftarrow female(X), father(Y, X).$$

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