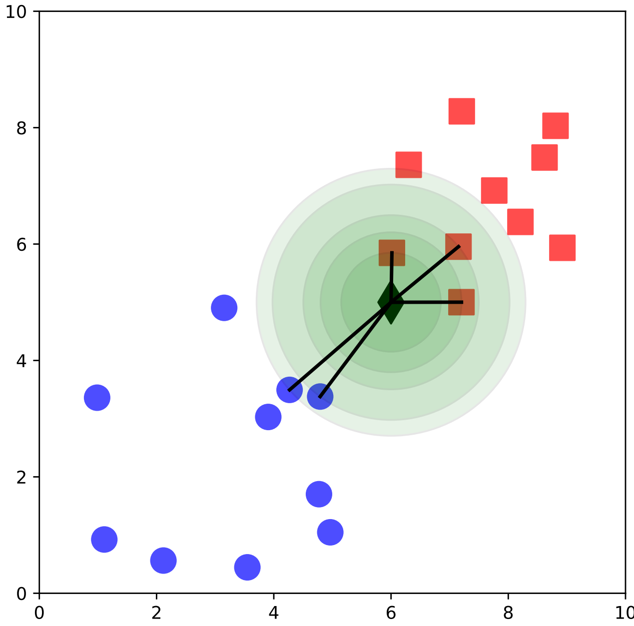
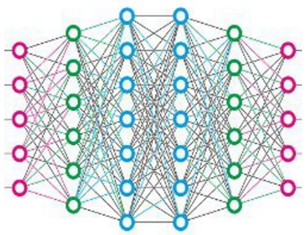
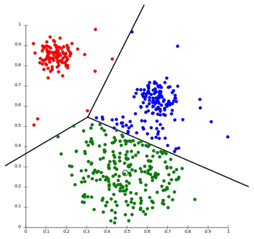
CS 445
Introduction to Machine Learning

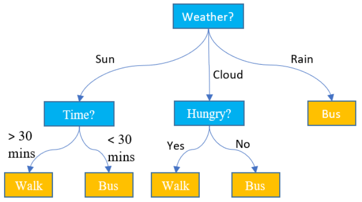
Features and the KNN Classifier

Instructor: Dr. Kevin Molloy



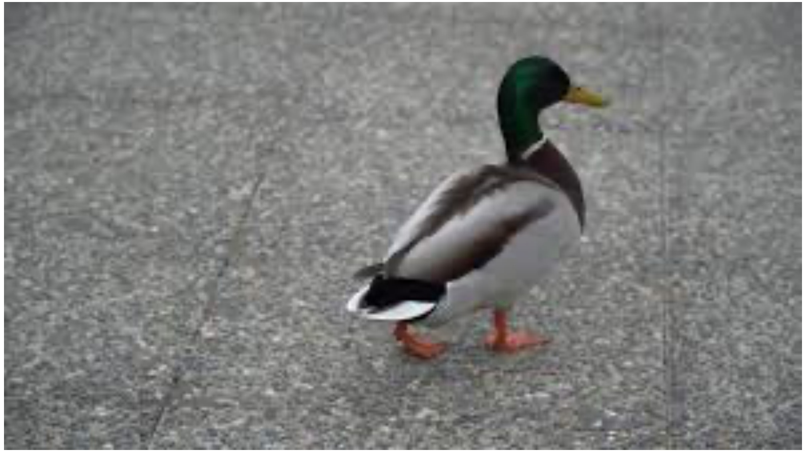






Features

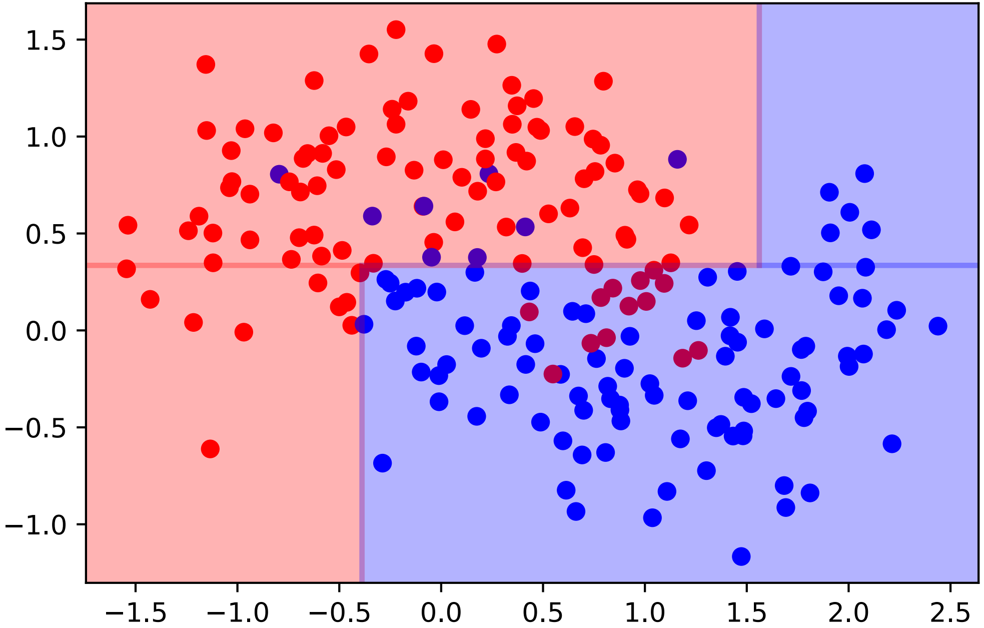
If it walks like a duck, and quacks like a duck, it probably is a duck.



Features describe the observation:

Decision Tree Architecture

Idea: Identify the feature and the value of the feature (split point) that divides the data into 2 groups that minimizes the weighted "impurity" of each group. Repeat this process on each leaf until happy.



Observation: The model splits the data one feature at a time.

Distance (dissimilarity) between observations

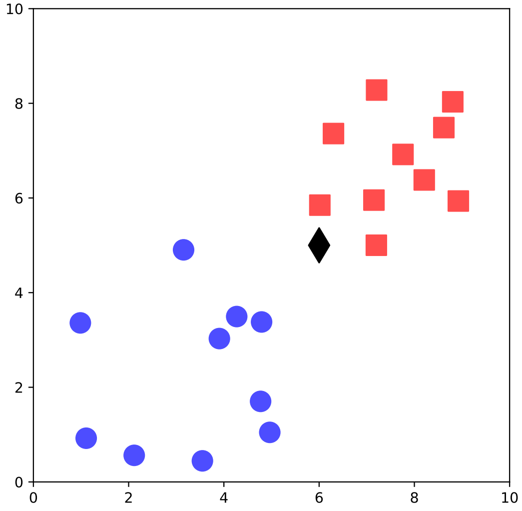
Define a method to measure the distance between two observations. This distance incorporates **a set of** the features into a single number (scalar).

Idea: Small distances between observations imply similar class labels.

Euclidean Distance and Nearest Point Classifier

1. Compute distance from new point *p* (the black diamond) and the training set.

point	Dist to p
1	2.45
2	1.30
3	0.99
…	…
n	8.23



Distance (dissimilarity) between observations

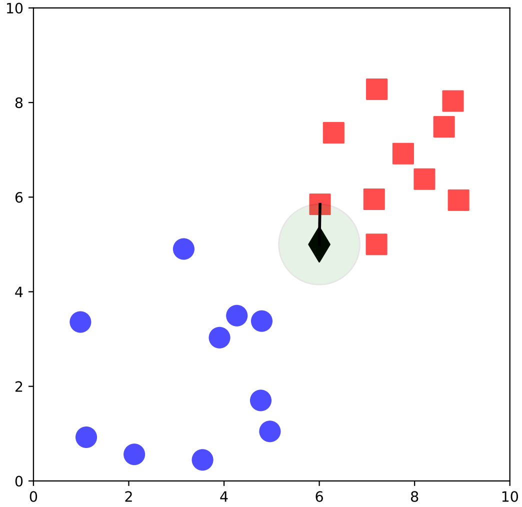
Define a method to measure the distance between two observations. This distance incorporates **all** the features at once.

Idea: Small distances between observations imply similar class labels.

<u>Euclidean Distance and Nearest Point Classifier</u>

1. Compute distance from new point *p* (the black diamond) and the training set.
2. Identify the nearest point and assign its label to point *p*

point	Dist to p
1	2.45
2	1.30
3	0.99
…	…
n	8.23

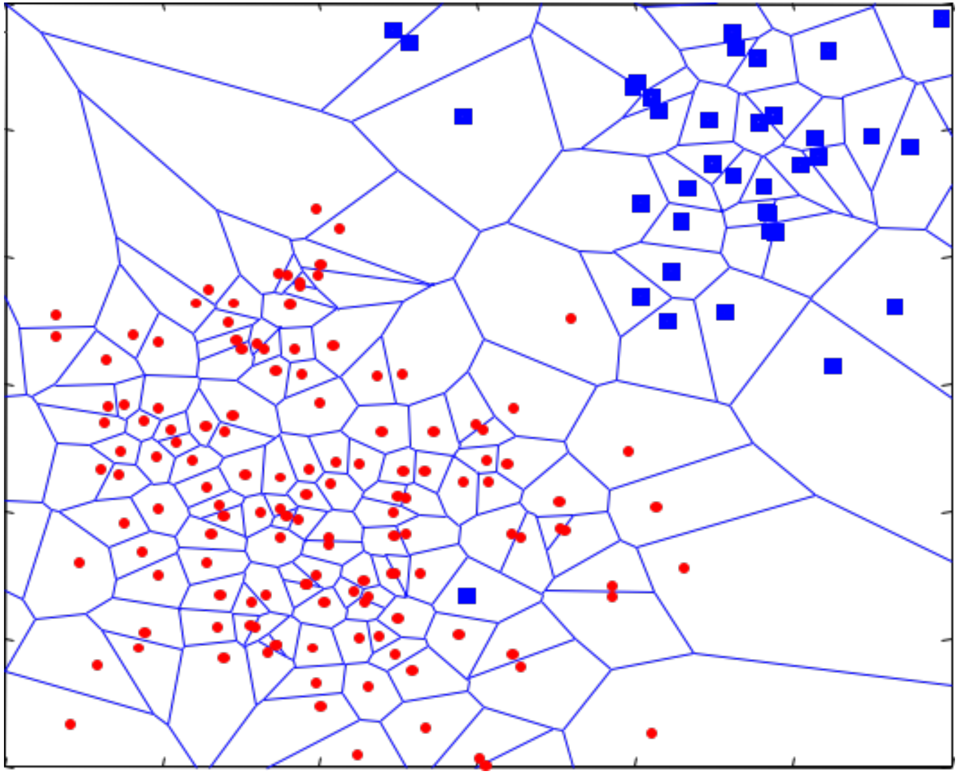


Euclidean Distance and Nearest Point Classifier

Voronoi Diagram

(https://en.wikipedia.org/wiki/Voronoi_diagram)

Create regions such that for any point *p* in the same region, their closest data point (the dots) are the same.



Euclidean Distance and Nearest Point Classifier

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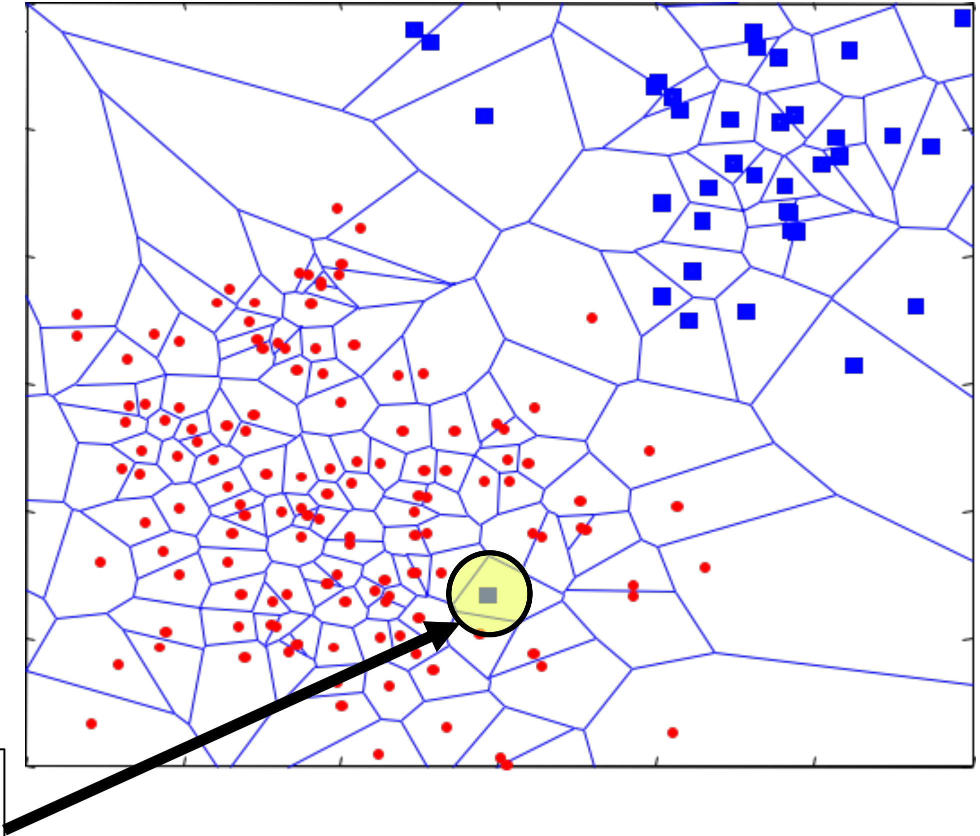
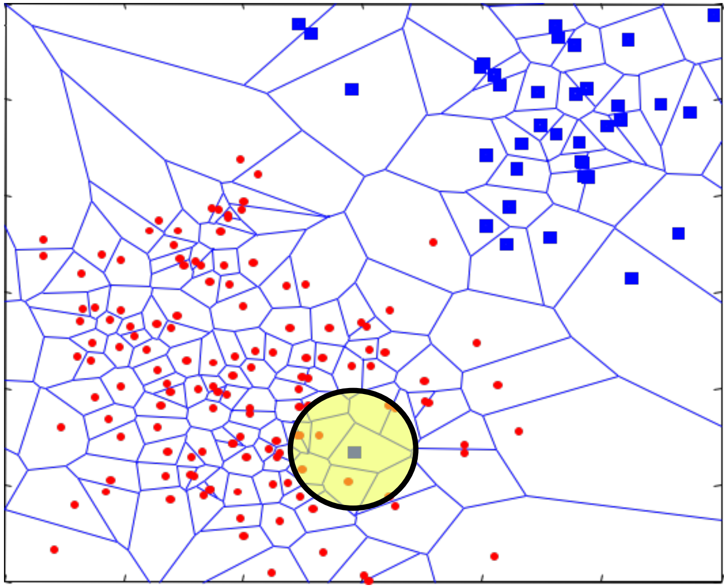


Outlier – an object different than most other objects of the same type

Euclidean Distance and K-Nearest Point Classifier



Idea: Increase the number of neighbors (k) and take a majority vote.

Algorithm

k = number of nearest neighbors

D = training examples and labels (x, y)

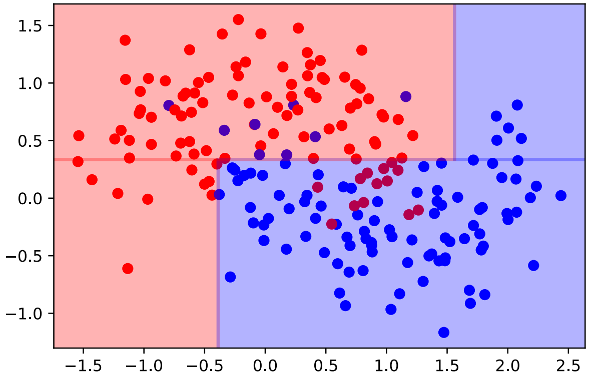
z = point (vector of points) to classify

Compute dist(x_i, z) (distance between z and every training data point x_i)

D_z = set of k closest examples to z ($D_z \subseteq D$)

$z_{predict} = \underset{v}{\operatorname{argmin}} \sum_{(x_i, y_i) \in D_z} I(v == y_i)$

Decision Boundaries:



Boundaries are perpendicular (orthogonal) to the feature being split.

What do the KNN decision boundaries look like?

Will I go Outside to play Today?

Let's try and build a model and predict.

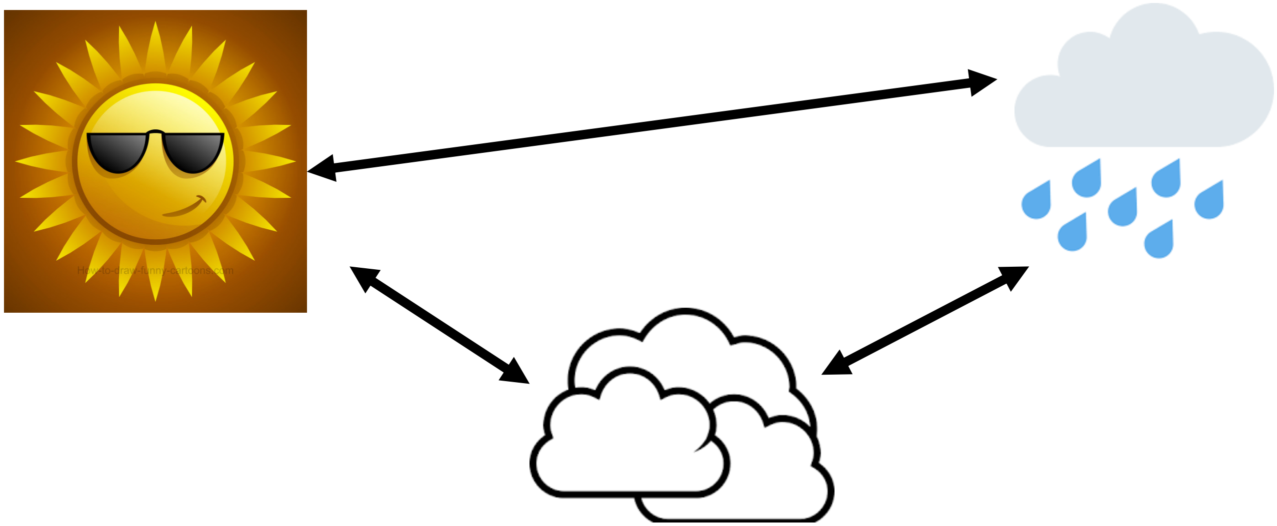
Feature	Values
Weather	Sunny, Rainy, Overcast
Temperature	Hot, Mild, Cold

The label/class will be to predict if the child will play outside (Yes/No).

Issues?

Computing Distances

How to compute a distance between Sunny, Rainy, and Overcast?



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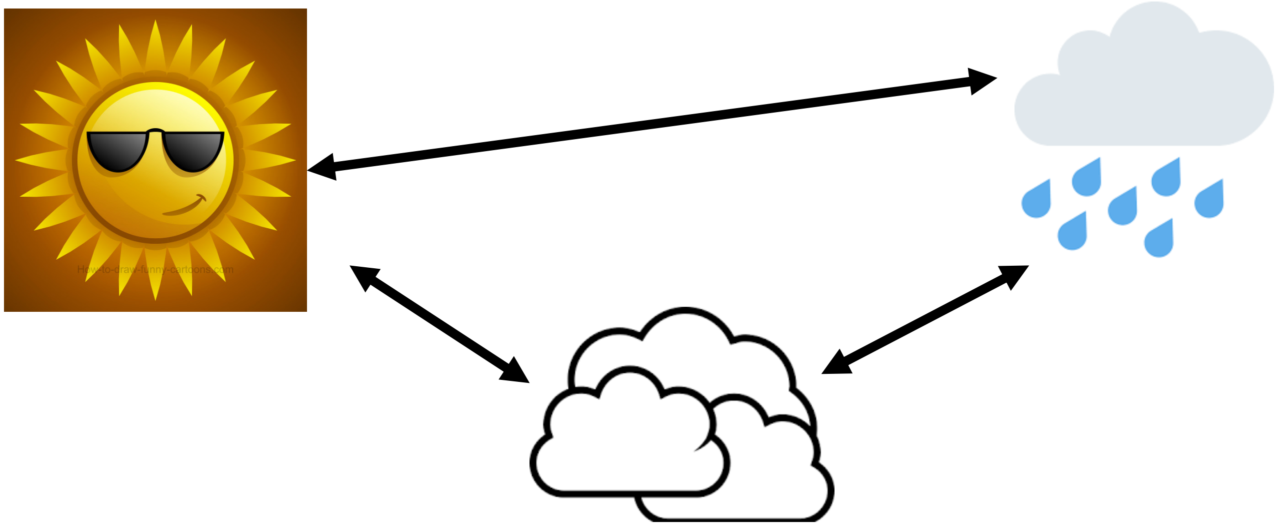

Is Dist(Sunny, Cloudy) == Dist(Sunny, Rainy) ?

Computing Distances

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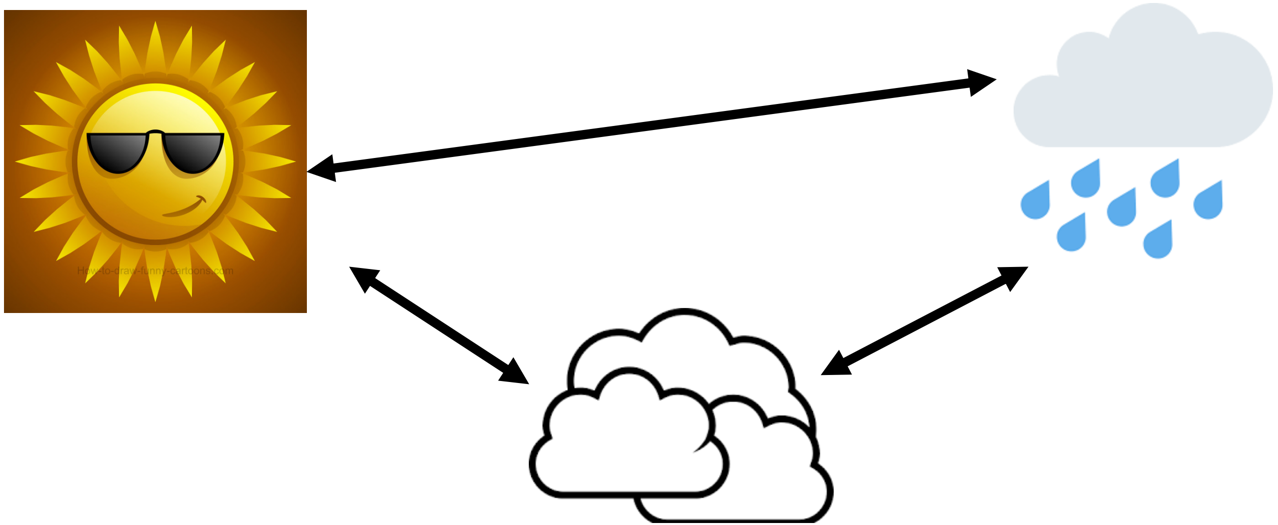
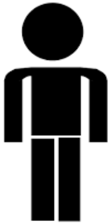


Is Dist(Sunny, Cloudy) == Dist(Sunny, Rainy) ?

Difference between **ordinal** and **nominal** datatypes

(see IDD section 2.1.2)

Smallest Distance means Most Similar?



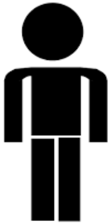
Who is the most similar person to this in the dataset (right)?

Age = 39 Salary = 75,750

Dataset

Age	Salary
23	56K
35	75K
55	76K

Smallest Distance means Most Similar?



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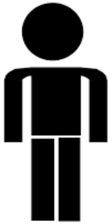

Who is the most similar person to this in the dataset (right)?

p = (Age = 39 , Salary = 75,750)

Dataset

Age	Salary
23	56K
35	75K
55	76K

However, the Euclidian distances say otherwise.

Age	Salary	Distance to point *p*
23	56K	$\sqrt{(39-23)^2+(75750-56000)^2} \approx 19{,}750$
35	75K	$\sqrt{(39-35)^2+(75750-75000)^2} \approx 750$
55	76K	$\sqrt{(39-55)^2+(75750-76000)^2} \approx 251$

Normalization

Idea: Make the range of all features the same.

Start with age. Min value: 23, max value: 55

$$x'_{i,j} = \frac{x_{i,j} - \min(X_i)}{\max(X_i) - \min(X_i)}$$

p = (Age = 39 , Salary = 75,750)

Dataset

Age	Salary
23	56K
35	75K
55	76K

Age	Salary	Dist (orig)	Age normalized	Salary Normalized	Dist (with normalized values)
23	56K	19,750	(23 – 23)/(55-23) = 0	(56k –56k)/(76k – 56k) = 0	
35	75K	750	(35-23)(55-23) = 0.375	(75k – 56k)/(76k-56k) = 0.95	
55	76K	251	(55-23)/(55-23) = 1.0	(76k-56k)/(76k-56k) = 1	

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Idea: Make the range of all features the same.

Start with age. Min value: 23, max value: 55

$$x'_{i,j} = \frac{x_{i,j} - \min(X_i)}{\max(X_i) - \min(X_i)}$$

p = (Age = 39 , Salary = 75,750)

Dataset

Age	Salary
23	56K
35	75K
55	76K

Age	Salary	Dist (orig)	Age normalized	Salary Normalized	Dist (with normalized values)
23	56K	19,750	(23 – 23)/(55-23) = 0	(56k –56k)/(76k – 56k) = 0	1.1
35	75K	750	(35-23)(55-23) = 0.375	(75k – 56k)/(76k-56k) = 0.95	0.13
55	76K	251	(55-23)/(55-23) = 1.0	(76k-56k)/(76k-56k) = 1	0.50