Machine Learning - Regression

CS102
Spring 2018
Big Data Tools and Techniques

- Basic Data Manipulation and Analysis
  Performing well-defined computations or asking well-defined questions ("queries")

- Data Mining
  Looking for patterns in data

- Machine Learning
  Using data to build models and make predictions

- Data Visualization
  Graphical depiction of data

- Data Collection and Preparation
Machine Learning

Using data to build models and make predictions

**Supervised** machine learning
- Set of labeled examples to learn from: training data
- Develop model from training data
- Use model to make predictions about new data

**Unsupervised** machine learning
- Unlabeled data, look for patterns or structure (similar to data mining)
Machine Learning

Using data to build models and make predictions

**Supervised** machine learning
- Set of labeled examples to learn from: training data
- Develop **model** from training data
- Use model to make predictions about new data

**Unsupervised** machine learning
- Unlabeled data; look for patterns or structure (similar to data mining)

Also...
- **Reinforcement learning**
  Improve model as new data arrives
- **Semi-supervised learning**
  Labeled + unlabeled
- **Active learning**
  Semi-supervised, ask user for labels
Regression

Using data to build models and make predictions

- **Supervised**

- **Training data, each example:**
  - Set of predictor values - “independent variables”
  - Numeric output value - “dependent variable”

- **Model is function from predictors to output**
  - Use model to predict output value for new predictor values

- **Example**
  - **Predictors:** mother height, father height, current age
  - **Output:** height
Other Types of Machine Learning

Using data to build models and make predictions

- **Classification**
  - Like regression except output values are labels or categories
  - Example
    - **Predictor values:** age, gender, income, profession
    - **Output value:** buyer, non-buyer

- **Clustering**
  - Unsupervised
  - Group data into sets of items similar to each other
  - Example - group customers based on spending patterns
Back to Regression

- **Set of predictor values** - “independent variables”
- **Numeric output value** - “dependent variable”
- **Model is function from predictors to output**

Training data

\[ w_1, x_1, y_1, z_1 \rightarrow o_1 \]
\[ w_2, x_2, y_2, z_2 \rightarrow o_2 \]
\[ w_3, x_3, y_3, z_3 \rightarrow o_3 \]

......

Model

\[ f(w, x, y, z) = o \]
Goal: Function $f$ applied to training data should produce values as close as possible in aggregate to actual outputs

**Training data**

- $w_1, x_1, y_1, z_1 ightarrow o_1$
- $w_2, x_2, y_2, z_2 ightarrow o_2$
- $w_3, x_3, y_3, z_3 ightarrow o_3$
- ......

**Model**

$f(w, x, y, z) = o$

- $f(w_1, x_1, y_1, z_1) = o_1'$
- $f(w_2, x_2, y_2, z_2) = o_2'$
- $f(w_3, x_3, y_3, z_3) = o_3'$
Simple Linear Regression

We will focus on:

• One numeric predictor value, call it \( x \)
• One numeric output value, call it \( y \)

- Data items are points in two-dimensional space
We will focus on:

- One numeric predictor value, call it $x$
- One numeric output value, call it $y$
- Functions $f(x)=y$ that are lines (for now)
Simple Linear Regression

Functions $f(x)=y$ that are lines: $y = ax + b$

$y = 0.8x + 2.6$
“Real” Examples (from Overview)
Summary So Far

- Given: Set of known (x,y) points
- Find: function $f(x)=ax+b$ that “best fits” the known points, i.e., $f(x)$ is close to $y$
- Use function to predict $y$ values for new $x$’s
  - Also can be used to test correlation
Correlation and Causation (from Overview)

**Correlation** - Values track each other
- Height and Shoe Size
- Grades and SAT Scores

**Causation** - One value directly influences another
- Education Level $\rightarrow$ Starting Salary
- Temperature $\rightarrow$ Cold Drink Sales
Correlation - Values track each other
• Height and Shoe Size
• Grades and SAT Scores

Find: function $f(x) = ax + b$ that “best fits” the known points, i.e., $f(x)$ is close to $y$

The better the function fits the points, the more correlated $x$ and $y$ are
Regression and Correlation

The better the function fits the points, the more correlated $x$ and $y$ are

- **Linear functions only**
- **Correlation** - Values track each other
  - Positively - when one goes up the other goes up
- **Also negative correlation**
  - When one goes up the other goes down
  - Latitude versus temperature
  - Car weight versus gas mileage
  - Class absences versus final grade
- Calculating simple linear regression
- Measuring correlation
- Regression through spreadsheets
- Shortcomings and dangers
- Polynomial regression
Calculating Simple Linear Regression

Method of least squares

- Given a point and a line, the error for the point is its vertical distance $d$ from the line, and the squared error is $d^2$

- Given a set of points and a line, the sum of squared error (SSE) is the sum of the squared errors for all the points

- **Goal:** Given a set of points, find the line that minimizes the SSE
Calculating Simple Linear Regression

**Method of least squares**

\[ SSE = d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2 \]
Calculating Simple Linear Regression

Method of least squares

**Goal:** Find the line that minimizes the SSE

![Graph showing Method of least squares]

**SSE** = \( d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2 \)

**Good News!**
There are many software packages to do it for you
Measuring Correlation

More help from software packages...

Pearson’s Product Moment Correlation (PPMC)

• “Pearson coefficient”, “correlation coefficient”
• Value $r$ between 1 and -1
  1 maximum positive correlation
  0 no correlation
  -1 maximum negative correlation

Coefficient of determination

• $r^2$, $R^2$, “R squared”
• Measures fit of any line/curve to set of points
• Usually between 0 and 1
• For simple linear regression $R^2 = \text{Pearson}^2$
Measuring Correlation

More help from software packages...

Pearson’s Product Moment Correlation (PPMC)

• “Pearson coefficient”, “correlation coefficient”
• Value $r$ between 1 and -1
  
  1 maximum positive correlation
  0 no correlation
  -1 maximum negative correlation

Coefficient of determination

• $r^2$, $R^2$, “R squared”
• Measures fit of any line/curve to set of points
• Usually between 0 and 1
• For simple linear regression $R^2 = \text{Pearson}^2$

Swapping $x$ and $y$ axes yields same values

“The better the function fits the points, the more correlated $x$ and $y$ are”
Correlation Game

http://aionet.eu/corguess (*)

Try to get:
Right answers ≥ 10, Guesses ≤ Right answers × 2

Anti-cheating: Pictures = Right answers + 1

(*) Improved version of “Wilderdom correlation guessing game” thanks to Poland participant Marcin Piotrowski

Other correlation games:
http://guessthecorrelation.com/
http://www.rossmanchance.com/applets/GuessCorrelation.html
http://www.istics.net/Correlations/
Regression Through Spreadsheets

City temperatures (using Cities.csv)

1. temperature (y) versus latitude (x)
2. temperature (y) versus longitude (x)
3. latitude (y) versus longitude (x)
4. longitude (y) versus latitude (x)
Spreadsheet “correl()” function
Shortcomings of Simple Linear Regression

Anscombe’s Quartet (From Overview)

Also identical $R^2$ values!
Goal: Function $f$ applied to training data should produce values as close as possible in aggregate to actual outputs.

Training data:
- $w_1, x_1, y_1, z_1 \rightarrow o_1$
- $w_2, x_2, y_2, z_2 \rightarrow o_2$
- $w_3, x_3, y_3, z_3 \rightarrow o_3$
- $\ldots$

Model:
- $f(w, x, y, z) = o$
- $f(w_1, x_1, y_1, z_1) = o_1'$
- $f(w_2, x_2, y_2, z_2) = o_2'$
- $f(w_3, x_3, y_3, z_3) = o_3'$
Polynomial Regression

Given: Set of known \((x,y)\) points
Find: function \(f\) that “best fits” the known points, i.e., \(f(x)\) is close to \(y\)

\[
f(x) = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n
\]

- “Best fit” is still method of least squares
- Still have coefficient of determination \(R^2\) (no \(r\))
- Pick smallest degree \(n\) that fits the points reasonably well

Also exponential regression: \(f(x) = a b^x\)
Dangers of (Polynomial) Regression

Overfitting and Underfitting (From Overview)
Anscombe’s Quartet in Action
Regression Summary

- Supervised machine learning
- Training data:
  Set of input values with numeric output value
- Model is function from inputs to output
  Use function to predict output value for inputs
- Balance complexity of function against “best fit”
- Also useful for quantifying correlation
  For linear functions, the closer the function fits the points, the more correlated the measures are