# Primer on Machine Learning

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# Contents

# Machine Learning is Everywhere

- pattern detection and recognition (iphone touch ID, face ID, word autocomplete, speech to text)
- history based recommendation (youtube, facebook, google search, amazon,...)
  - products for customers
  - customers for providers
- email filtering and classification (gmail)

# Machine Learning and Artificial Intelligence

1950s *[getting] machines to exhibit behavior, which if done by humans, would be assumed to involve the use of intelligence*[1]

now *computational methods to automatically learn and to improve with experience*[2]

ML[3] statistical ("statistical learning")

AI analytical (knowledge, logic)

[1] Arthur Samuel, 1983

[2] http://www.mlplatform.nl/what-is-machine-learning/

[3] may mean Maximum Likelihood: abbrev. not widely used

# Machine Learning Now

- big data
  - data science, data mining, ...
  - myth: machine learning needs big data[4]
- fast computers
- emerging new methods
  - deep learning, reinfocement learning, ...

[4] see NY/SF homes toy data

# General Outline

1. formulate task (EN, ST)
2. collect data (EN, ST)
3. "engineer" data (EN, PR, DSS, HPC)
4. modeling (ST, EN)
5. fit/learn/train model(s) on data (LIB, PR, HPC)
6. validate, select (LIB, ST, PR, HPC)
7. apply model to test data (LIB)
8. interpret results (EN, ST)
9. report (DOC)

| skill set | |
|---|---|
| EN | expert knowledge |
| ST | statistics |
| PR | programming |
| DSS | domain spec. software |
| HPC | high performance computing |
| LIB | ML libraries[a] |
| DOC | LaTeX, Web |

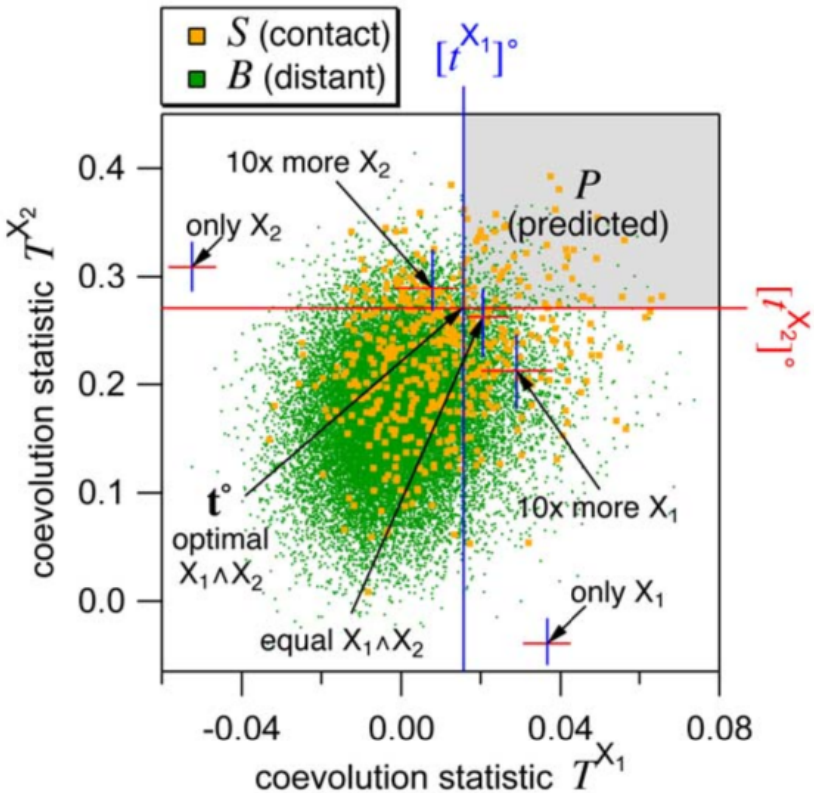
[a] Python, R, Java, Julia, Scala, Matlab

# My Story with Machine Learning

## Myth: it's like cooking

| skill | 2006 | 2017 |
|---|---|---|
| expert knowledge | ? | ? |
| statistics | - | + |
| programming | - | + |
| domain spec. softw. | - | + |
| high perform. comp. | - | ? |
| ML libraries | - | ? |
| LaTeX, Web. | - | + |

PLoS One. 2012;7(5):e36546.



# Contents

# Tasks

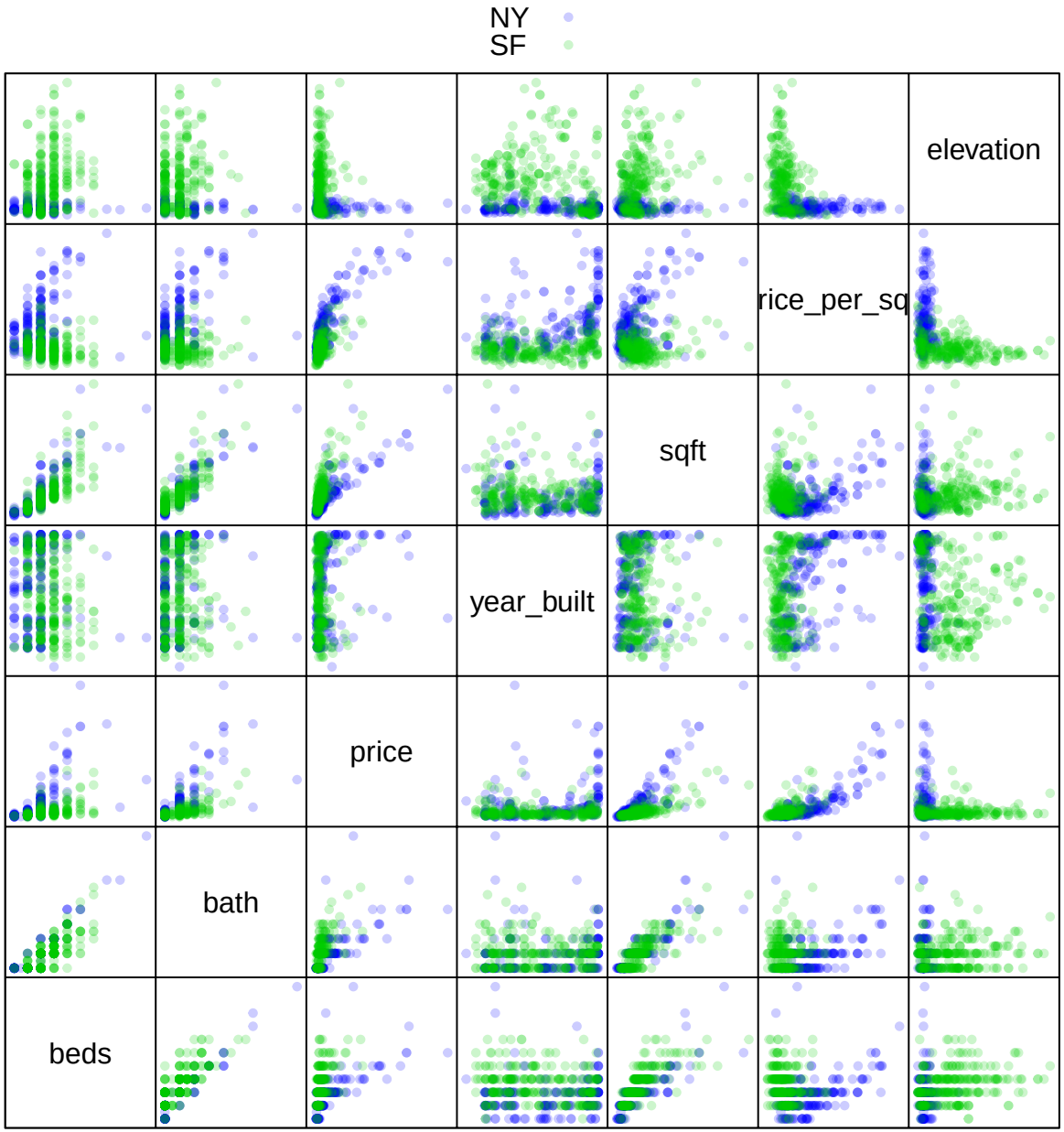
1. supervised learning: training *and* test data
   - prediction, classification
     - pattern recognition
     - business, medical, ... predictions & decisions
2. unsupervised learning: *only* training data
   - structure discovery
     - social, biol., tech. networks, associations,...
     - probabilistic expert systems
   - hypothesis testing, feature subset selection
     - research, marketing
   - matrix completion (imputation)
     - recommendation systems

# The "Home" Data for Classification

## Useless except for demonstration

| observation | input features / variables | | | | output |
|---|---|---|---|---|---|
| $i$ | $x_{i1}$ | $x_{i2}$ | ... | $x_{ip}$ | $y_i$ |
| home | price/sqft | elevation | ... | beds | city |
| training data | | | | | |
| 1 | 999 | 10 | ... | 2 | NY |
| 2 | 1939 | 0 | ... | 2 | NY |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| 491 | 764 | 163 | ... | 1 | SF |
| 492 | 762 | 216 | ... | 3 | SF |
| test data | | | | | |
| 493 | 1196 | 40 | ... | 2 | ? |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

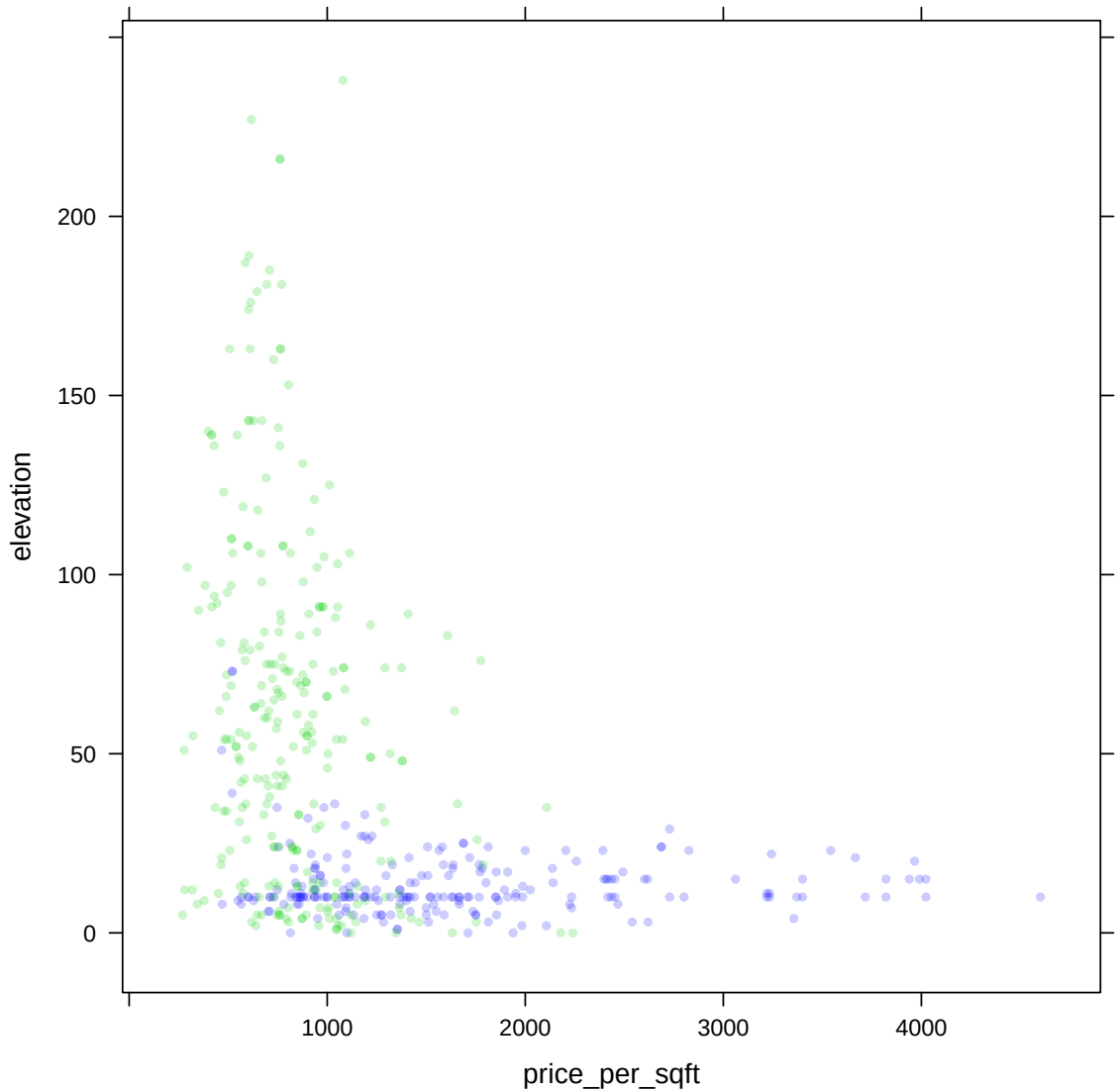
# Home Data Overview




Scatter Plot Matrix

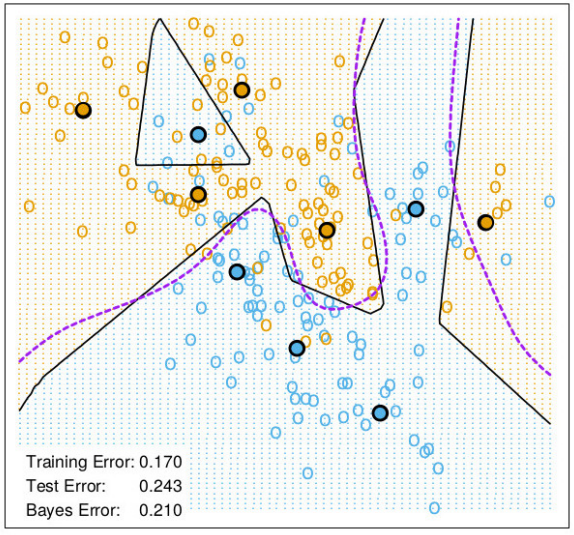
# Informative Features

## 2 input features: 2D plots

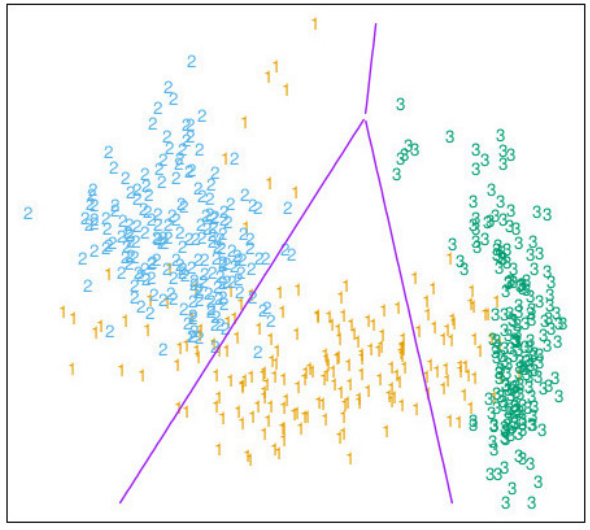


# Models for Classification

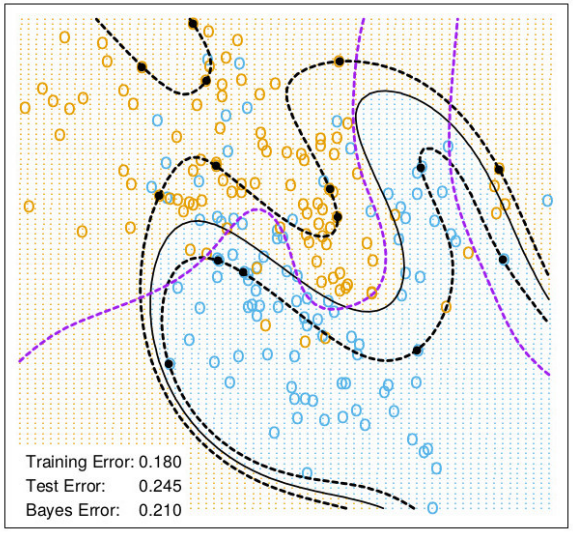
K-means classifier



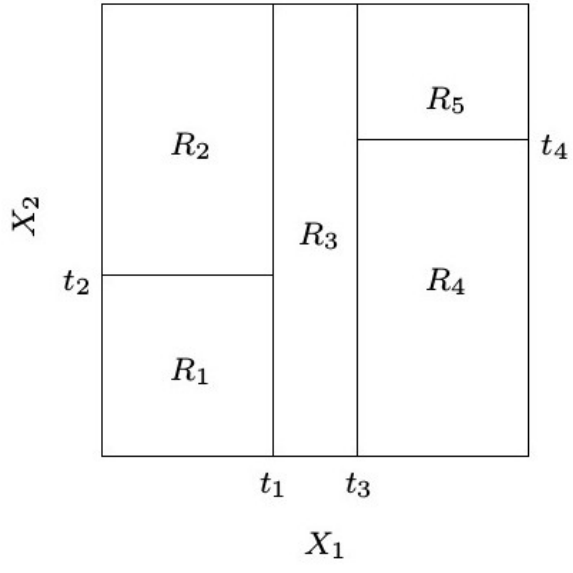

generalized linear regression



support vector machine



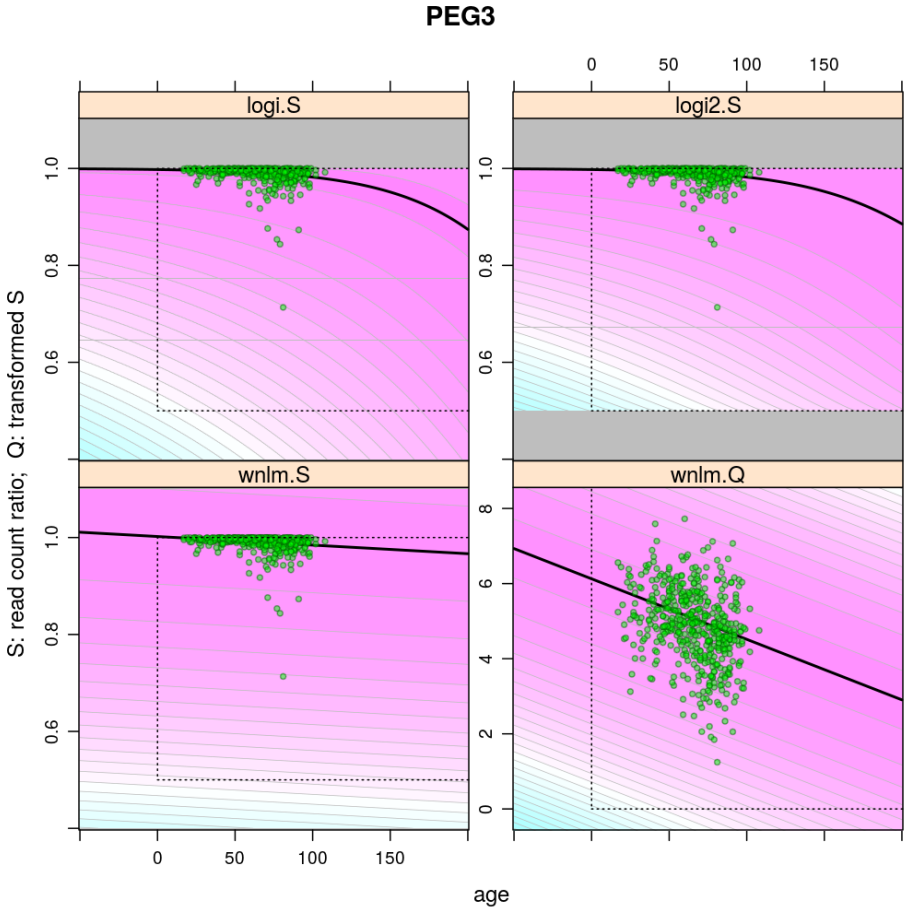

decision tree (poor perform.)



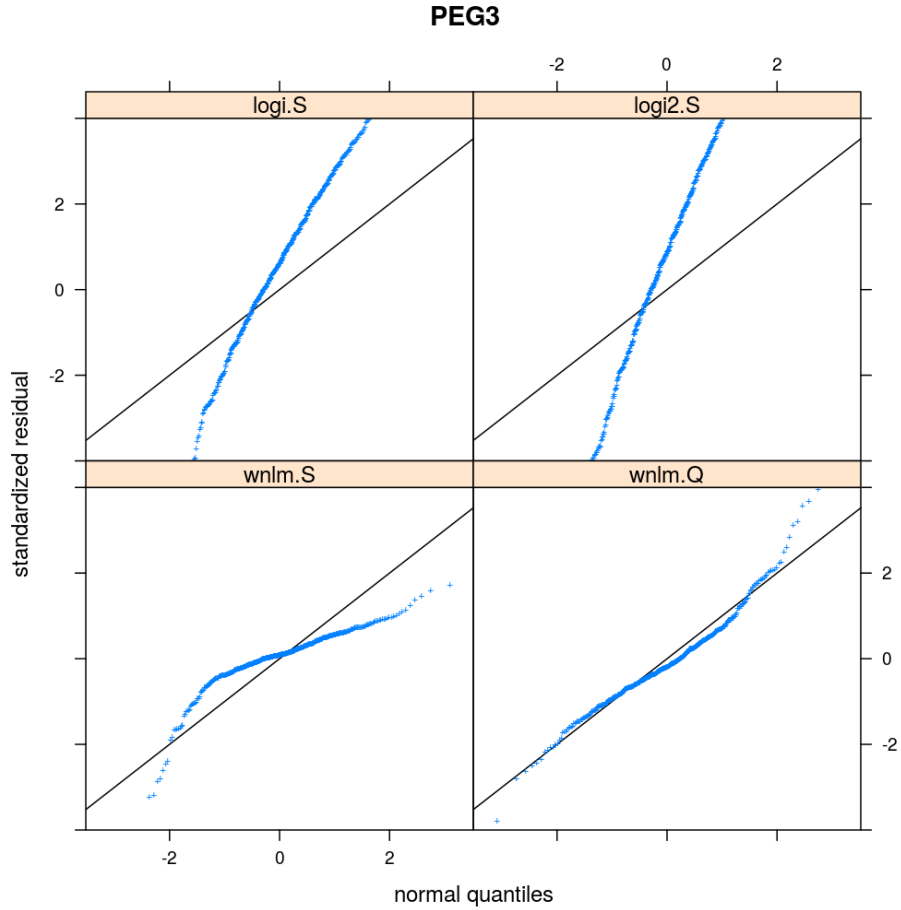
# Which Model to Select? The One That Fits the Best![5]

## Information theory, optimality, model ensemble

subjective evaluation




diagnostics




[5] should also be: simple, interpretable, fast to fit,...

# Contents

# Building on "Visual Intro..."[6]

what we will address in addition to "Visual Intro..."

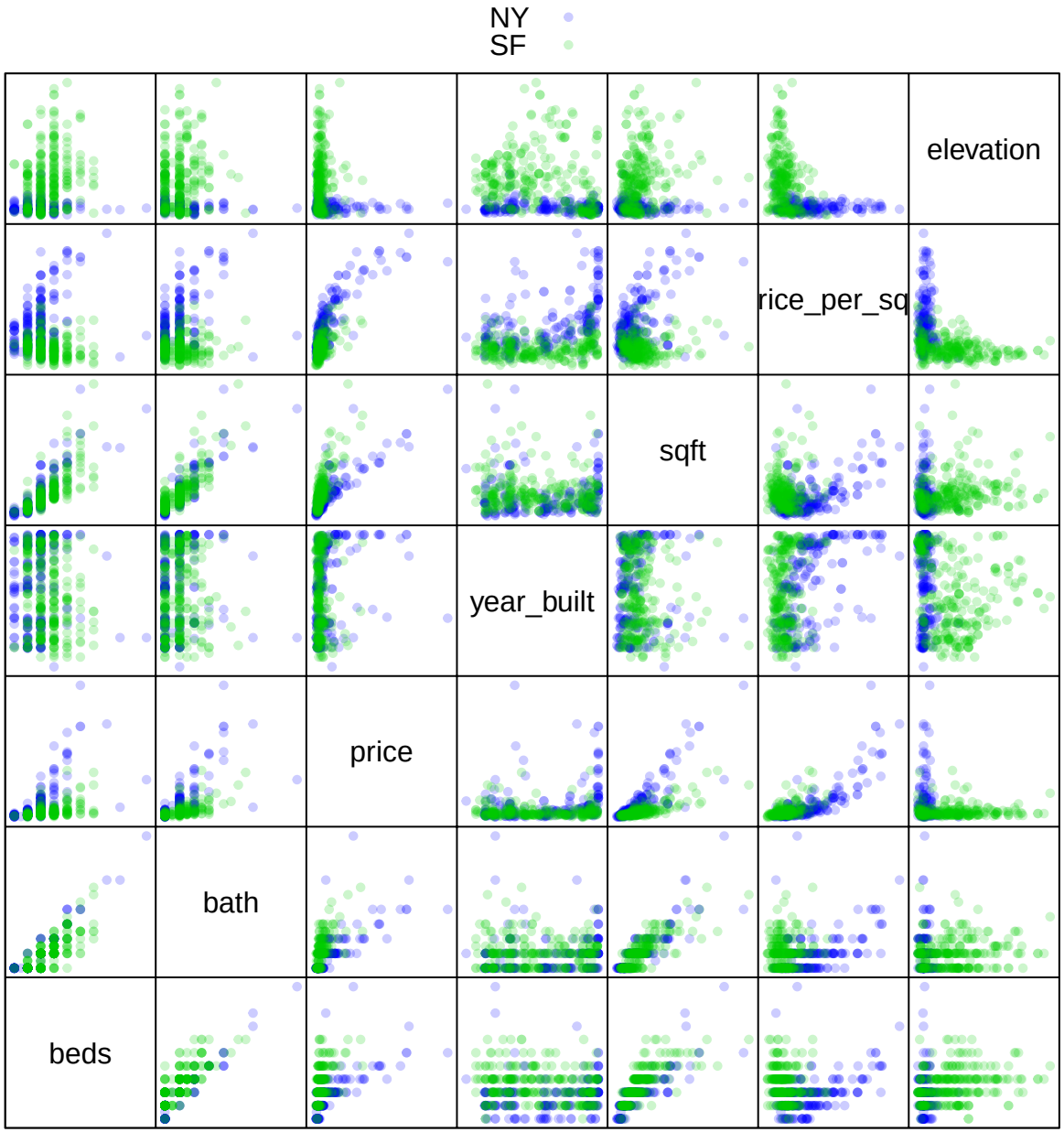
- model validation/selection
- prediction

what we won't

- real World task
- data collection/engineering
- model selection
- validation, performance

[6] http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

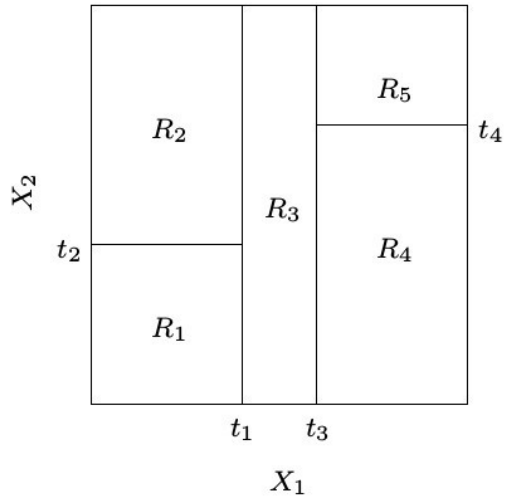
# Home Data Overview

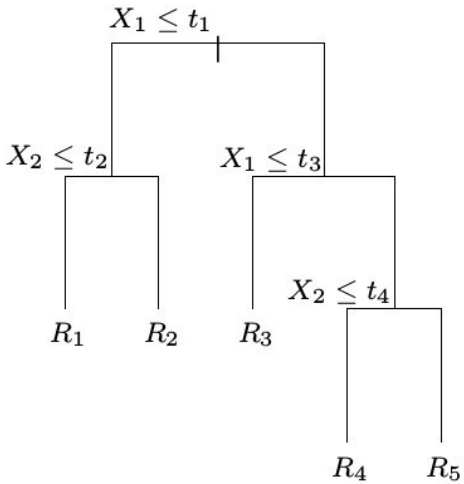


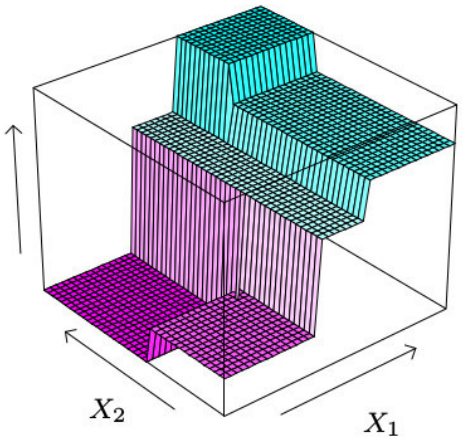

Scatter Plot Matrix

# Decision Tree is Ideal for Demo

## Tree Grows as We Partition Recursively



# Demo with "Visual Intro"[7]

Observe progressive growth of tree!

[7] http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

# Our Analysis; Why R?

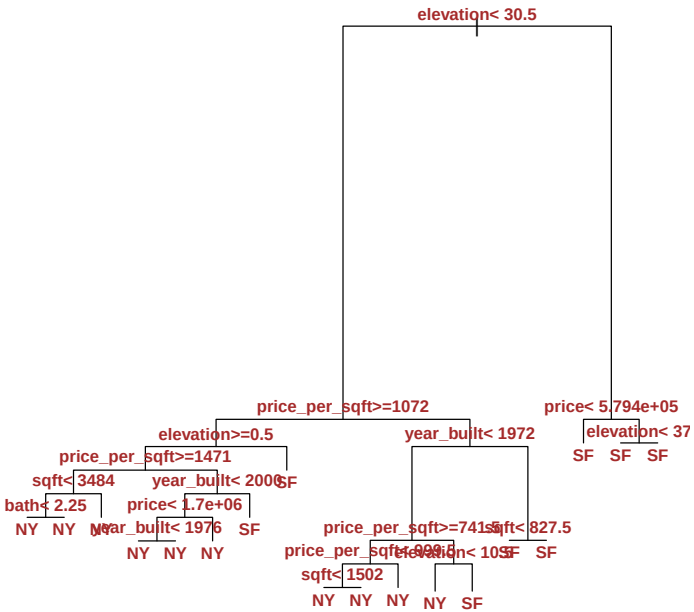
- created by and for biostatisticians
- functional language (like JavaScript)
- open source
- mature
- lots of machine learning packages
- R2D3[8]

[8] http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

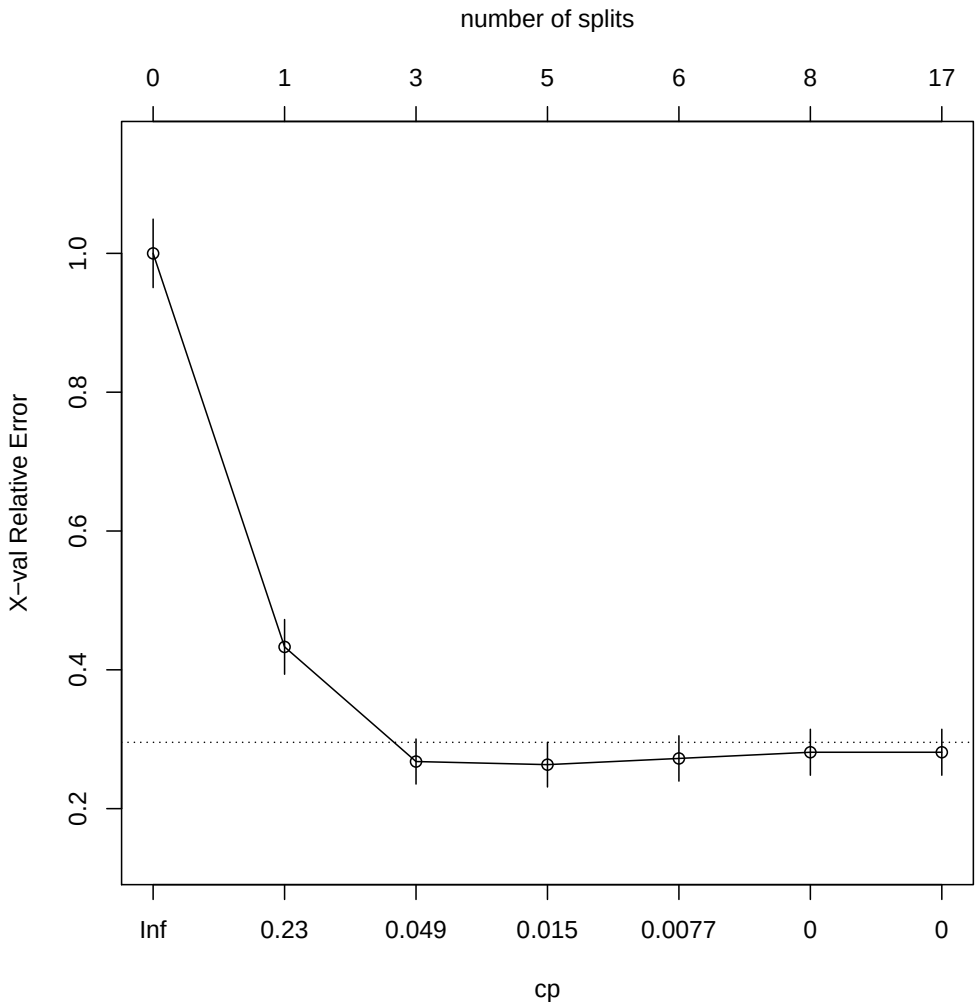
# Fitting Decision Trees

## Using the `rpart` R library

a complex tree



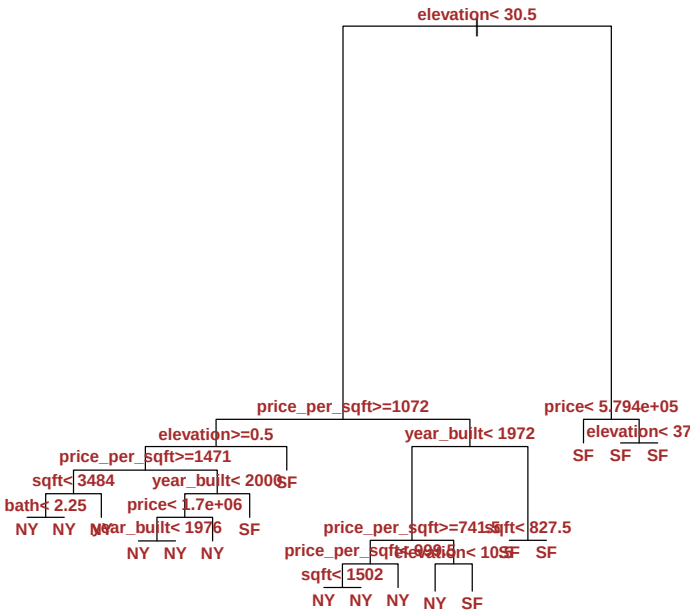
# Avoiding Overfitting (Too Much Complexity)



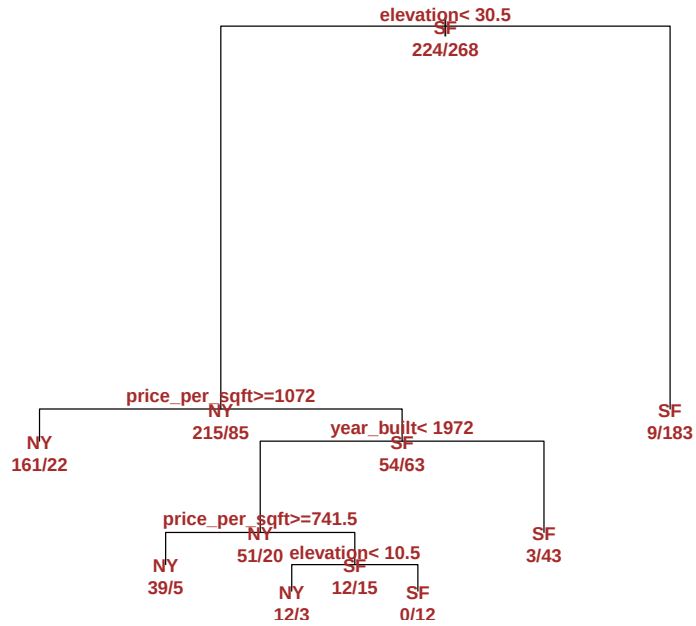
# Fitting Decision Trees

## Using the `rpart` R library

### a complex tree

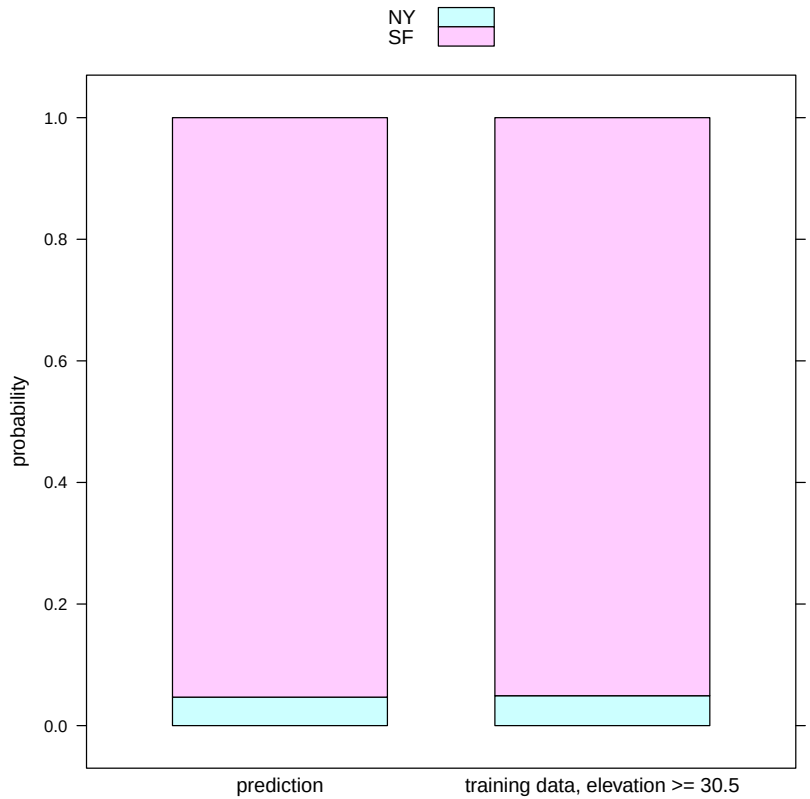


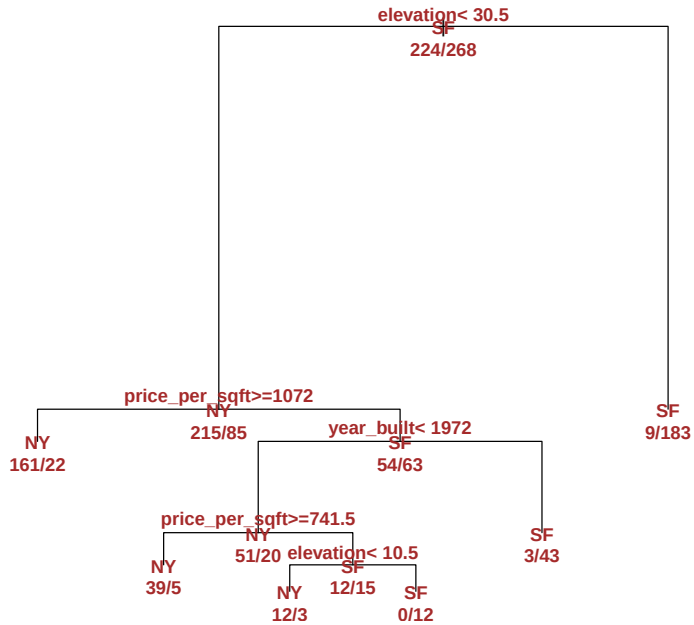

### the optimal tree



# Prediction

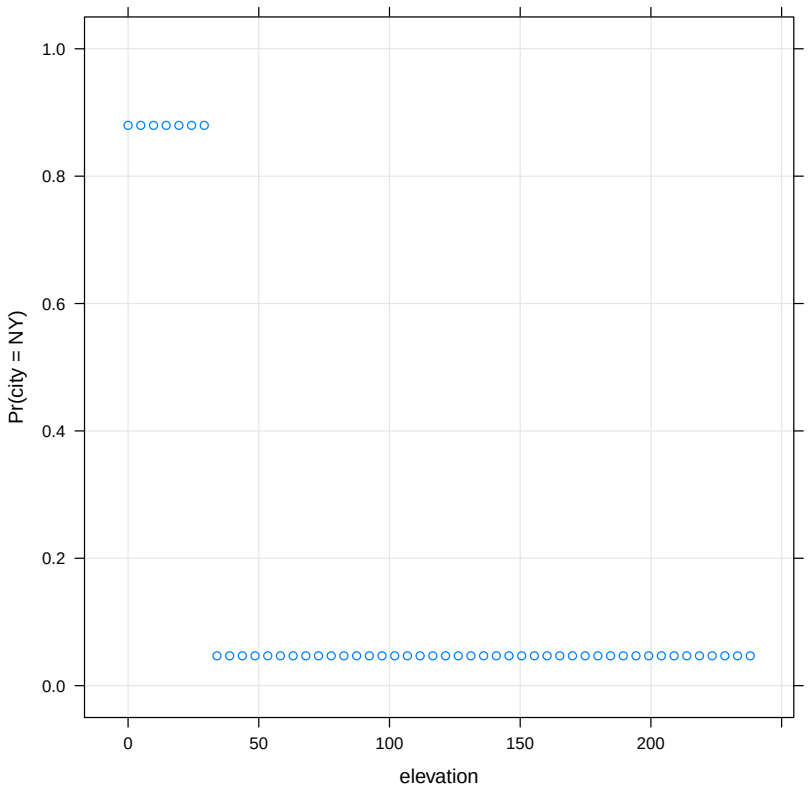
at “the average of traning data”

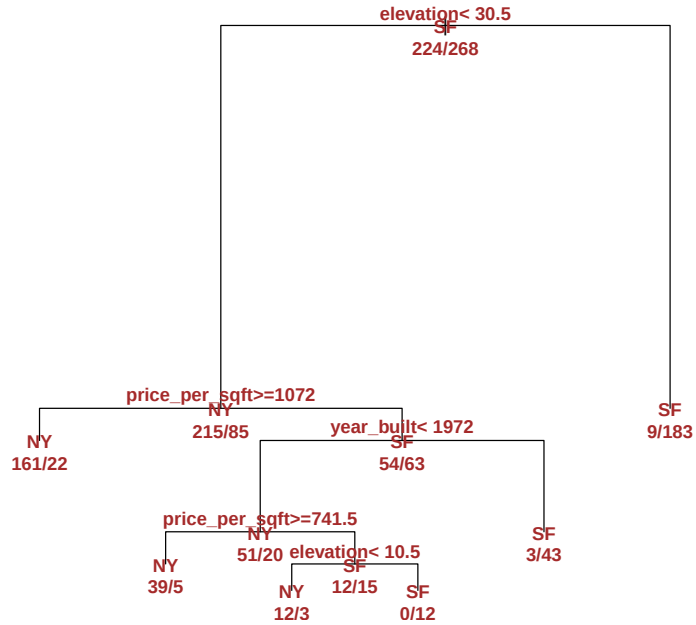


# Prediction

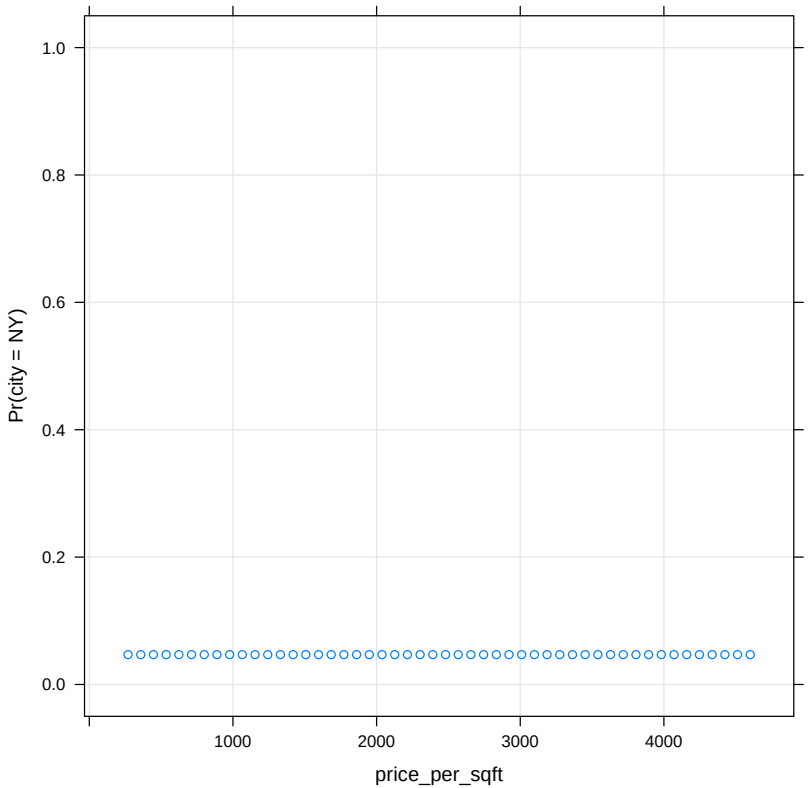
at varying elevation

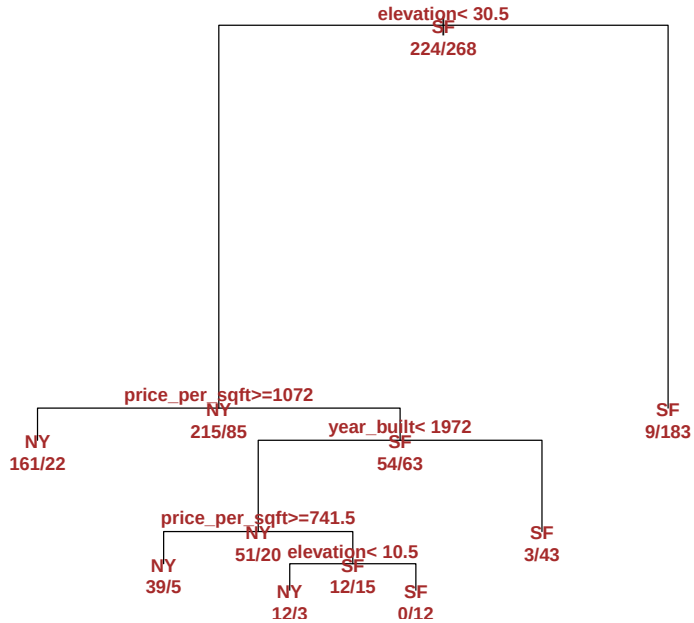


# Prediction

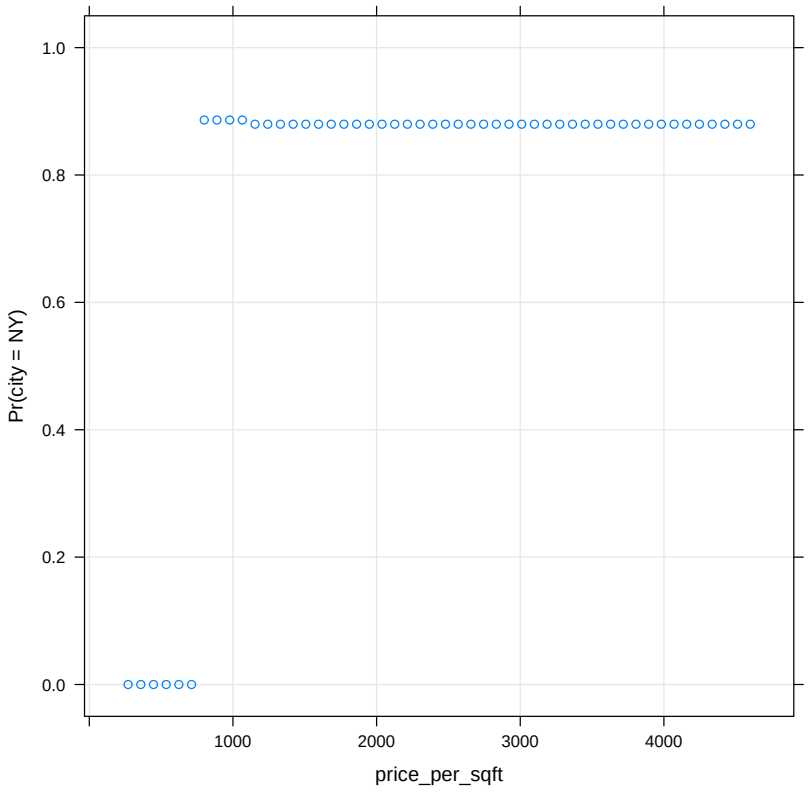
at varying price/sqft and 30m elevation

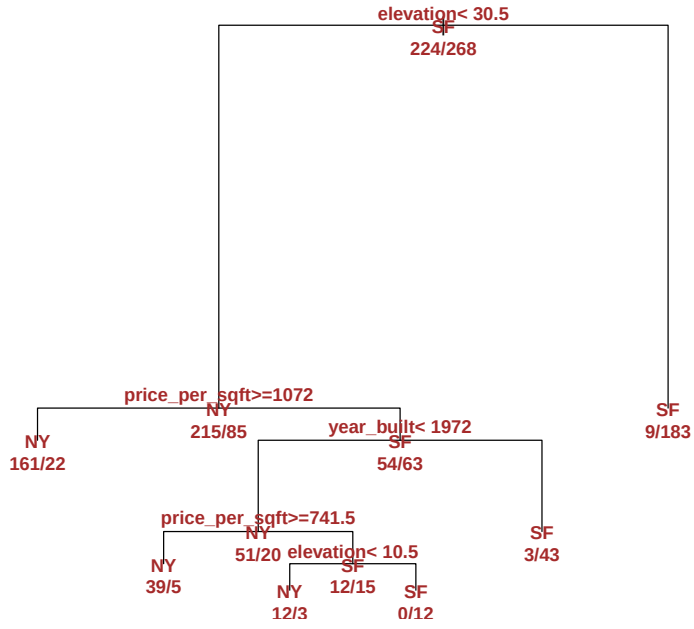


# Prediction

at varying price/sqft and average (40m) elevation



# Conclusion: Machine Learning and You

1. doing it
   - `Hello World!` is easy but useless
   - obtaining skills takes years
   - rewarding
2. understanding it
   - learn concepts not cooking
   - collaboration, interpretation