Actuarial

Data Analytics / Predictive Modeling Seminar Part 2

Matthew Morton FSA, MAAA

Ben Williams

ILTCI

Agenda

- Introduction
- Overview of Seminar
- “Traditional” Experience Study
- “Traditional” vs. “Predictive Modeling”
- Types of Predictive Modeling

Overview of Seminar

Welcome to the first ever

ILTCI Predictive Modeling Seminar

Three part series providing an in depth introduction to predictive modeling

Agenda

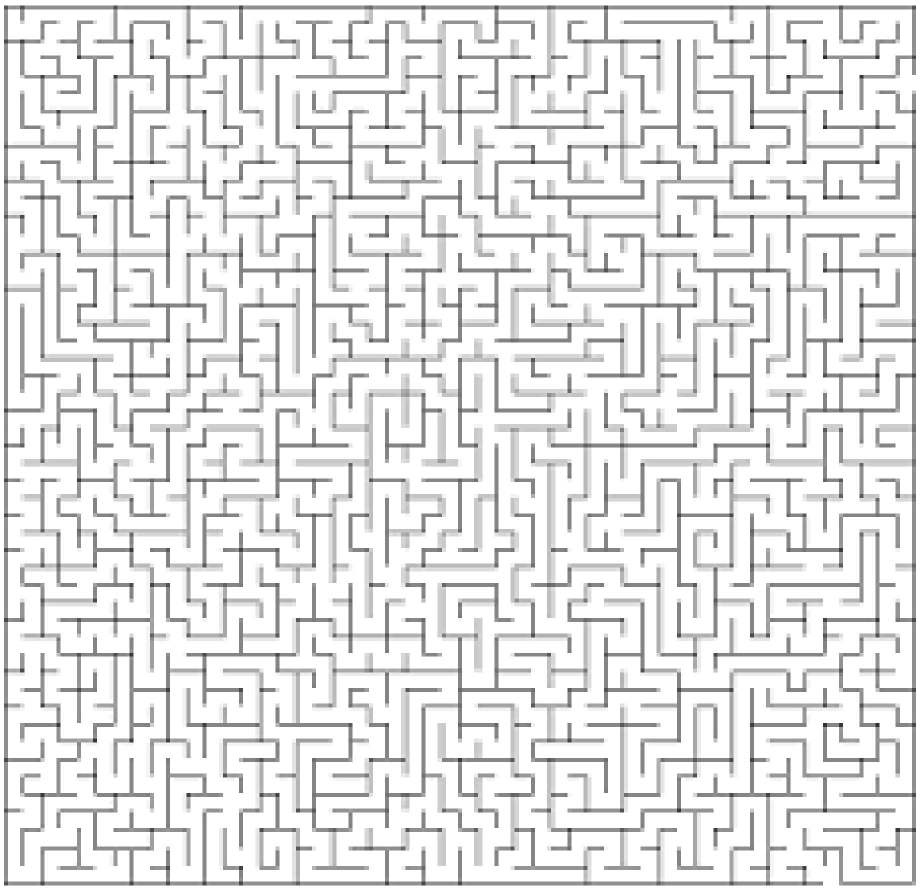
Sunday; Part 1: Background

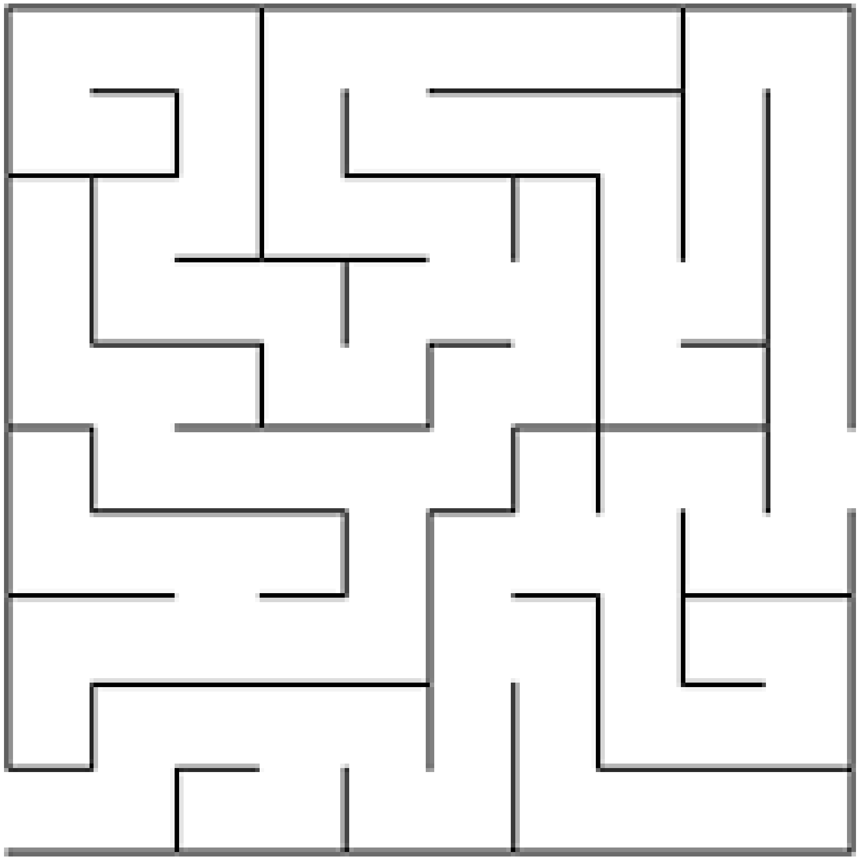
Monday; Part 2: Conference session

Wednesday; Part 3: Hands on experience

Overview of Seminar

Goal of this Session





Traditional Experience Study

Determine goal

- What are we measuring?
- Why are we measuring?

Data and reasonability review

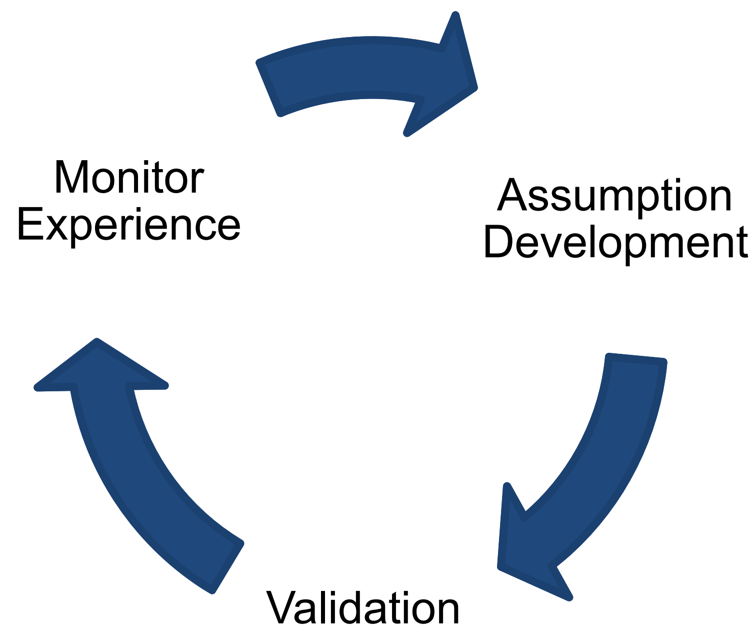
- Quality review
- Completeness
- General patterns and relationships

Develop assumptions

- Iterations
- Analysis of change

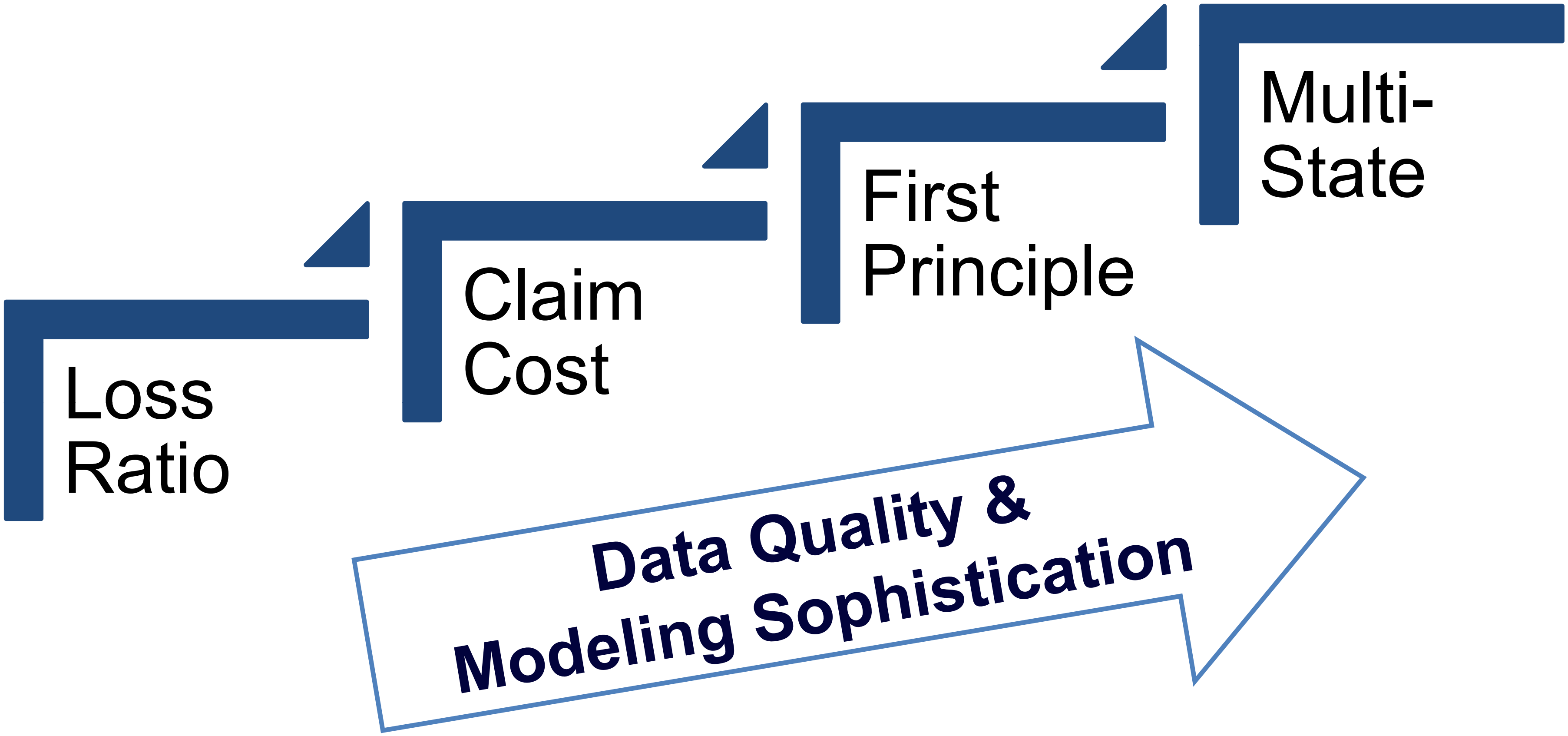
Validation

- Tests
- Business review



Traditional Experience Study

Determine goal



Traditional Experience Study

Data and reasonability review

- Summary of business (demographics)
- Completeness
- Financial reconciliation
- Volume of information
- Granular cell checks or audits

Traditional Experience Study

Assumption development / review

- Source of information
  - Company data
  - Industry data
  - Population data
  - Actuarial judgment
- Methodology & analysis toolset
- Degree of rigor

Traditional Experience Study

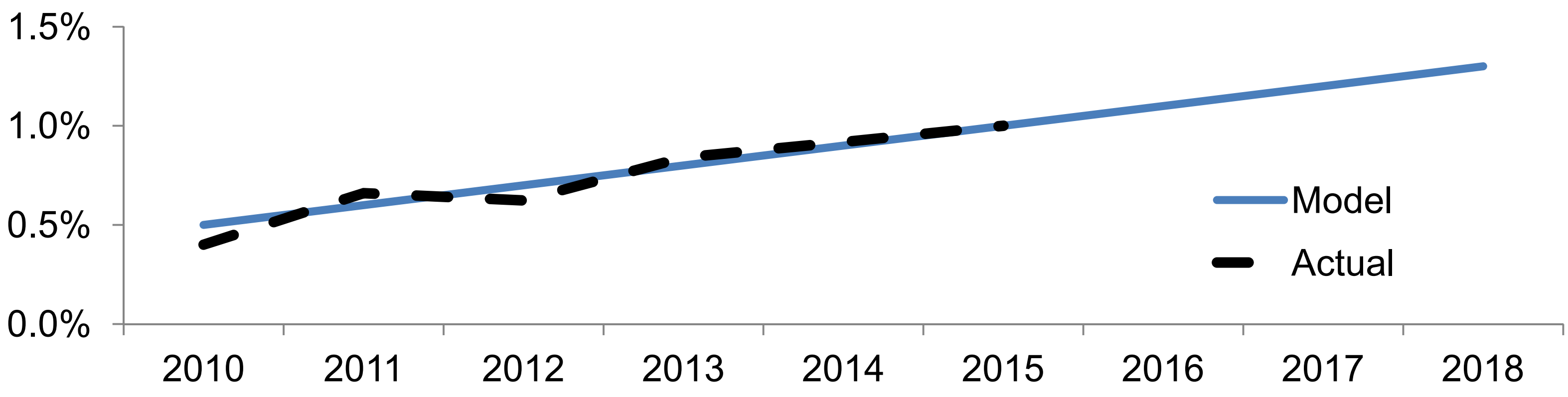
Assumption development / review

- Example – Incidence – Develop from data
- One approach
  - Develop ultimate attained age curve
  - Adjust for policyholder and benefit characteristic
  - Test to ensure fit…
  - Repeat.. test to ensure fit
  - Repeat.. test to ensure fit

Traditional Experience Study

Validation of Assumptions

- Reasonability
- Tests
  - Actual to expected analyses
  - Retrospective adequacy
  - Dynamic validation to projection
  - Key metric review
- Comparison to prior



Traditional Experience Study

Advantages

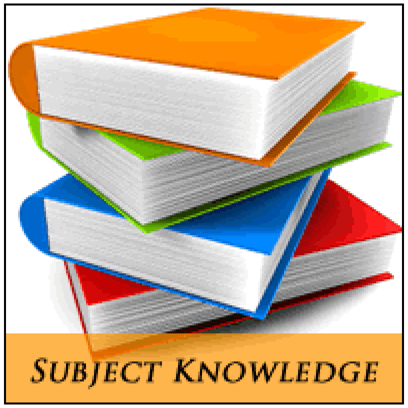
- Easy to understand
- Transparent
- Flexible

Disadvantages

- Interdependencies / Iterative
- Data grouping
- Time consuming

Traditional vs Predictive Modeling

- What inhibits a traditional modeler from using predictive modeling



Traditional vs Predictive Modeling

- Will PM help with the following questions:
  - Will it tell me what I don't know?
  - Would PM tell me what to assume in places we don't have data?
  - How should we handle an RPU?
  - Will it tell me what to assume for cost of care in 40 years?

Easy Answer: NO

Traditional vs Predictive Modeling

What is Predictive Modeling?

- We have a series of historical observations showing how input variables x (independent variables) are related to responses y (dependent variables) by some process

$$Y \longleftarrow \boxed{\text{Nature}} \longleftarrow X$$

- A predictive model is some function of the independent variables that mimics this process
- Predictive Modeling is the process of developing a predictive model

What is Predictive Modeling?

- There are two goals in fitting a predictive model
  - Prediction: to be able to predict responses for future input variables x
  - Information: to understand the process that associates response variables with input variables
- Note: <u>Just the same as the goal of developing an assumption!!!</u>

Traditional vs Predictive Modeling

How is Predictive Modeling different from Traditional Analysis?

- Traditional Analysis assumes a model structure, and compares Actual vs Expected (according to the model) on a one-way or a two-way basis. The model is iteratively modified (independent variables added or parameters changed) to improve the fit on this basis
- Predictive Modeling doesn't force parameters to take certain values*
- Predictive Modeling uses statistics** to determine which independent variables should be included, and what parameters they should take

*But it can

**And potentially other tests

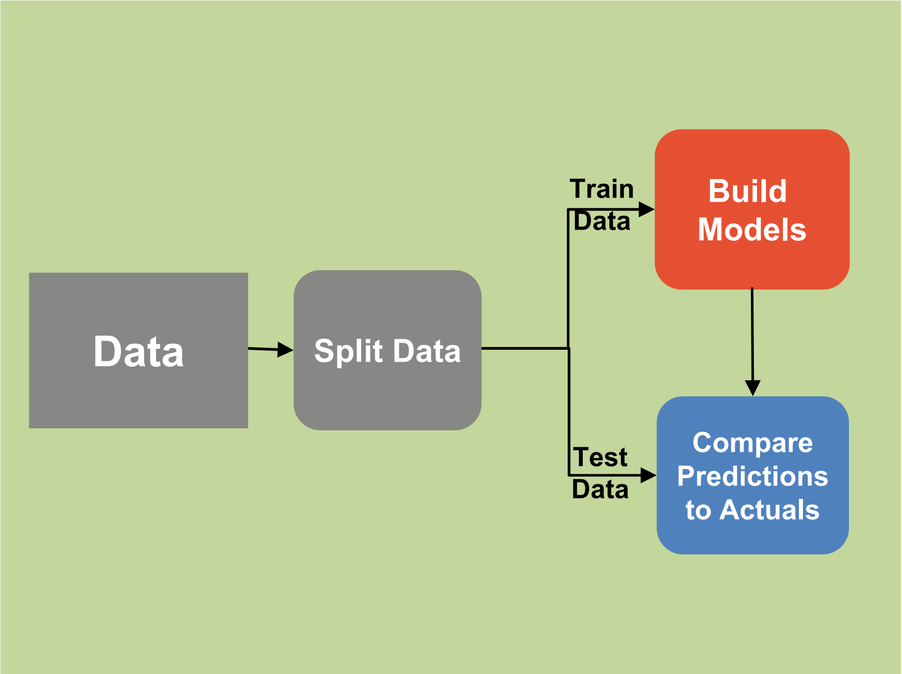
Traditional vs Predictive Modeling

- Why do Predictive Modeling?
- Remember our goals in fitting a predictive model
  - Prediction: to be able to predict responses for future input variables x
  - Information: to understand the process that associates response variables with input variables
- Predictive models can give
  - Better predictions of responses
  - A better understanding of the process

Traditional vs Predictive Modeling

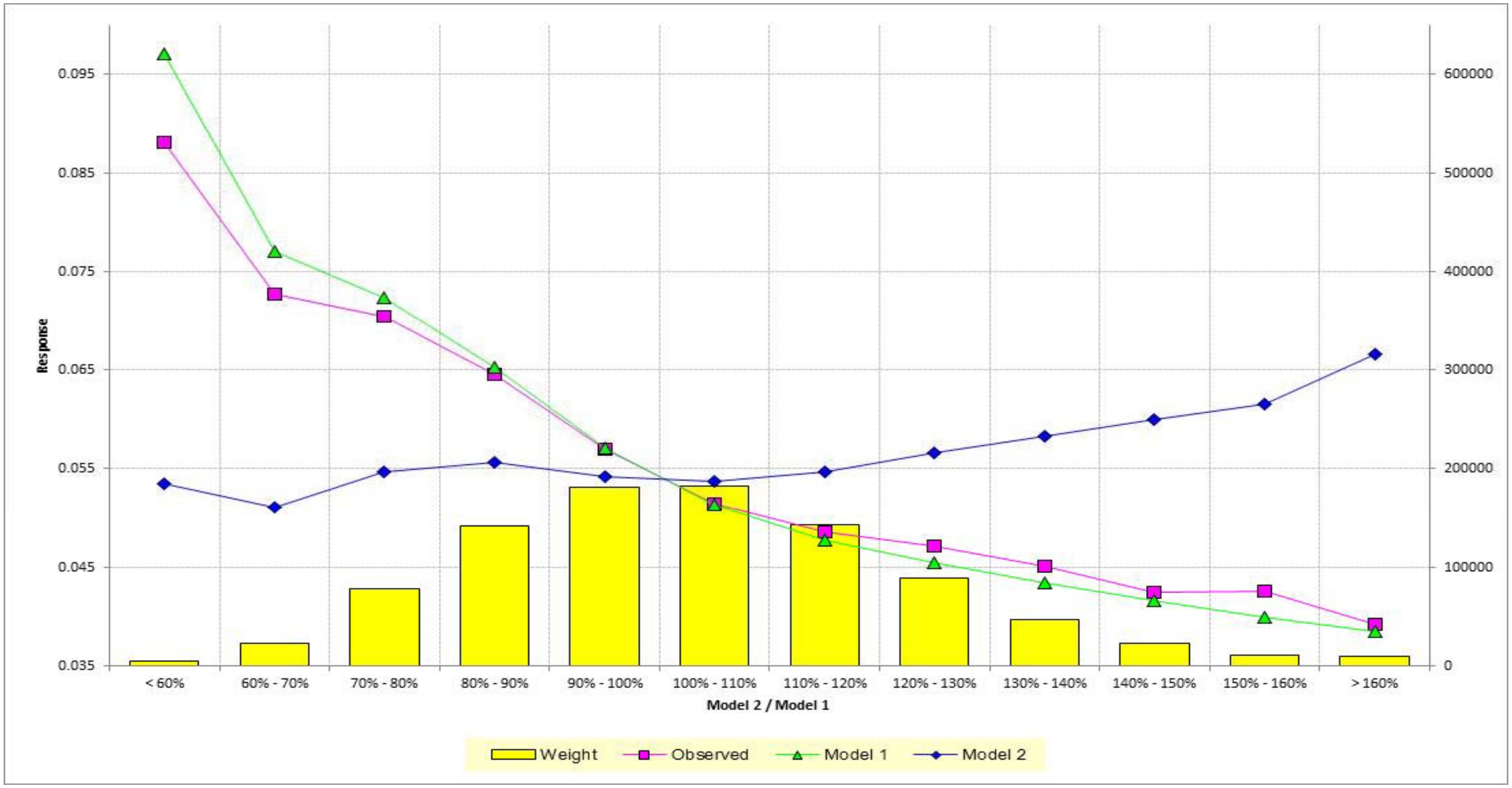
Better predictions?

- How do we show this?
- When modeling, we split the available data into two sets, training and testing
- We fit models on the training data
- Apply both of these models to the testing data



Better predictions?

- We can see which of the models gave predictions closer to the observed response



Traditional vs Predictive Modeling

Better understanding of the process?

- Predictive modeling tells us
  - Which factors <u>need</u> to be in a model according to some combination of criteria
  - The <u>true</u> effect of each independent variable included in the model (which can be different from the actual oneway effect, or the ratio of the actual to expected effects on a oneway basis, as it takes into account correlations between variables)
- (Arguably) not all predictive modeling methods will give a better understanding of the process (black box)

Types of Predictive Model

There are many types of predictive model

- Regression
- Decision Trees
- Neural Networks
- Genetic Algorithms
- Support Vector Machines
- K-nearest Neighbors

Types of Predictive Model

Many of these have different varieties. For example, Regression includes

- Ordinary Linear Regression
- Generalized Linear Models (GLM)
- Ridge regression
- Lasso
- Elastic Net

Types of Predictive Model

Regression

- The expected value of independent variable Y for a given combination of levels of dependent variables X is a function of X
- Fitting this kind of model involves determining the structure of the model function and solving for the parameters
- Outcome is a list of model parameters that have to be combined in some way (e.g. multiplicatively)

Types of Predictive Model

Regression

- Example output of a Regression model (a GLM)

Base	0.0004								
Gender		**Incurred Age**		**Duration**		**Marital Status**		**Premium Class**	
Female	1.0000	35-	0.1171	1	1.0000	Married	1.0000	Preferred	0.8682
Male	0.7560	36	0.1326	2	1.4224	Single	2.1227	Standard	1.0000
		37	0.1484	3	1.8732			Substandard	1.1006
		38	0.1641	4	2.3096				
		39	0.1796	5	2.6933				
		40	0.1947	6	2.9984				
		41	0.2092	7	3.2136				
		42	0.2231	8	3.3414				
		51	0.3293	17	2.7583				
		52	0.3425	18	2.6561				

Base	Gender	Incurred Age	Duration	Marital Status	Premium Class	Expected Mortality (per '000)
	Male	51	5	Single	Preferred	
0.0004	0.7560	0.3293	2.6933	2.1227	0.8682	0.4775

Types of Predictive Model

Regression

- Example: they can allow us to make statements like (all else being equal)
  - Incidence is 10% higher in single than married people
  - Duration impacts on incidence in a certain way
- **Pros:**
  - Flexible, easy to interpret and to explain
  - The result is a formula (which can be turned into a table)
- **Cons:** do not give good results if data is highly nonlinear (to some extent this can be overcome)

Types of Predictive Model

Generalized Linear Model (GLM)

- Has three components
  - An error distribution coming from the exponential family
  - A linear predictor function of dependent variables
  - A link function, which relates the linear predictor to the expected value of the response
- Parameters typically found by minimizing L = negative log likelihood for model structure
- Model structure developed by experiment (can be automated to some extent)
  - Factors are added, removed, combined and simplified, and statistics related to the fit of the model are studied
  - Not dissimilar to development of assumptions by traditional method, but aided by statistics

Types of Predictive Model

Generalized Linear Model (GLM)

- Widely used in P&C insurance for the reasons given previously (flexible, easy to interpret and to explain)
- GLMs will be used in the workshop after the conference to fit a model of incidence

Types of Predictive Model

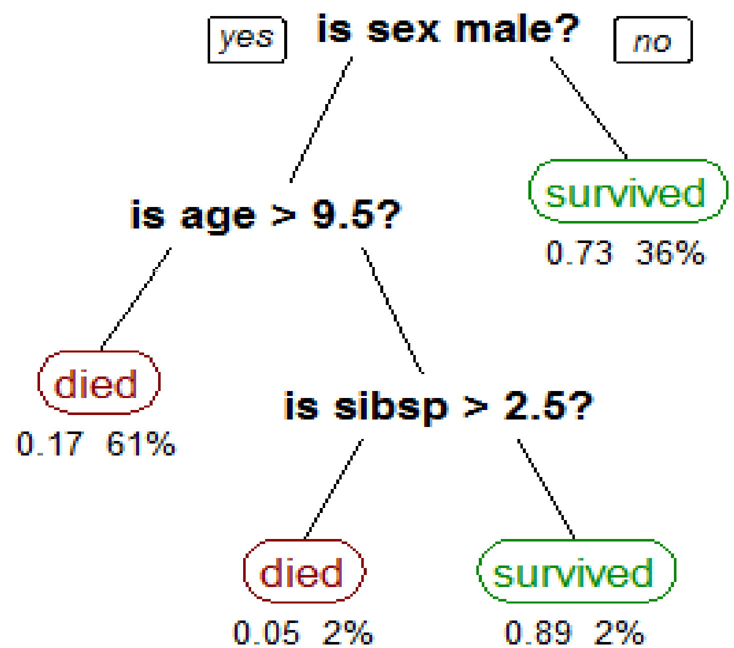
Penalized Regression

- Same model form as GLM, but parameters β are estimated differently
- Function minimized to find parameters is $L + \lambda.\text{Penalty}(\beta)$
  - $\lambda = 0$ means GLM
  - λ = infinity makes all parameters 0
  - Necessary to choose “best” value of λ
- Ridge Regression and Lasso have different penalty functions which lead to different properties
  - For example, Lasso is useful for understanding variable importance, useful when number of variables is large
- Elastic Net combines the penalty functions of Ridge Regression and Lasso

Decision Trees

- Determines a series of rules based on values of the independent variables that segment the data
- The process is recursive
- It stops when no further splitting will improve results, or some stopping condition is satisfied

Passengers of the Titanic



Decision Trees

Pros

- Outcome is a set of rules applying to different segments (easy to interpret, explain, and order)
- Good for identifying high-dimensional features of data, as in the Titanic example (and these features can be used as variables in other modeling techniques)

Cons

- Highly dependent on the data, and therefore doesn’t give predictions as good as some other techniques

Types of Predictive Model

Generalizations of Decision Trees

- To overcome this issue, generalizations of Decision Trees exist, such as
  - Random Forests
  - Gradient Boosted Trees
- These are examples of ensemble methods, which use combinations of different underlying models

Random Forests

- Roughly speaking, this involves
  - Taking a large number of random samples of the data (with replacement)
  - Fitting a simple tree on each sample
  - The model is an average of these trees

•The idea is that the combination of simple trees avoids overfitting to the data, and is more predictive than the single tree

- Output is a complex set of rules
- They can give very good predictions, but interpreting the model can be complicated (some people would argue with this statement)

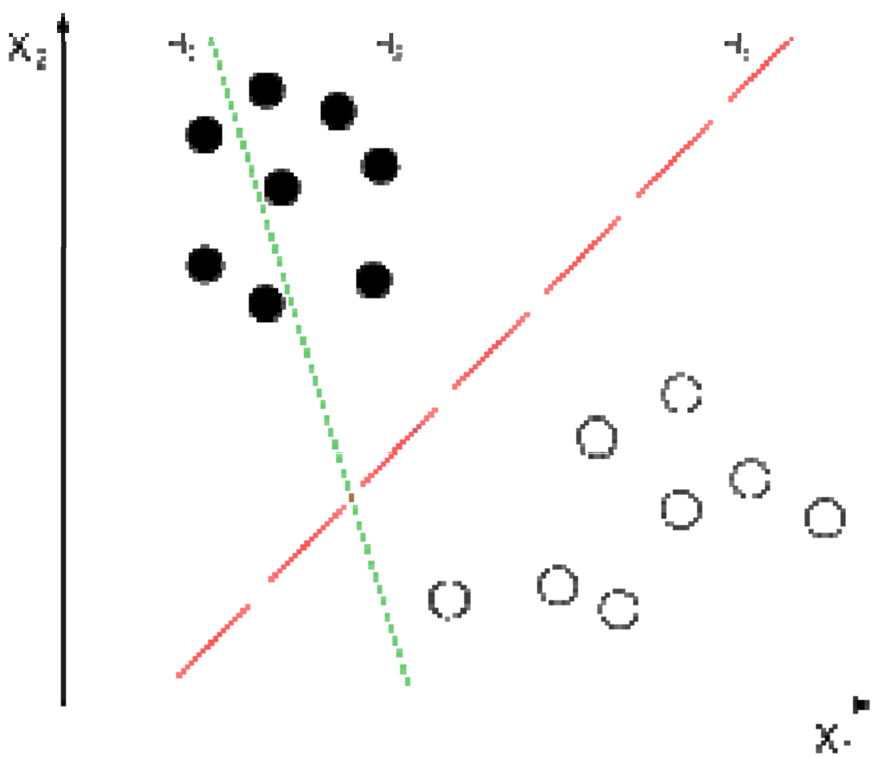
Gradient Boosted Trees

- Roughly speaking, this involves
  - Fit a simple tree on a random sample of the data
  - On another random sample
    - Calculate predictions according to previous tree
    - Calculate model residuals
    - Fit another simple tree on the residuals
  - Repeat the process
- Output is a complex combination of sets of rules
- They can give very good predictions, but interpreting the model can be complicated (some people would argue with this statement)

Types of Predictive Model

Support Vector Machines

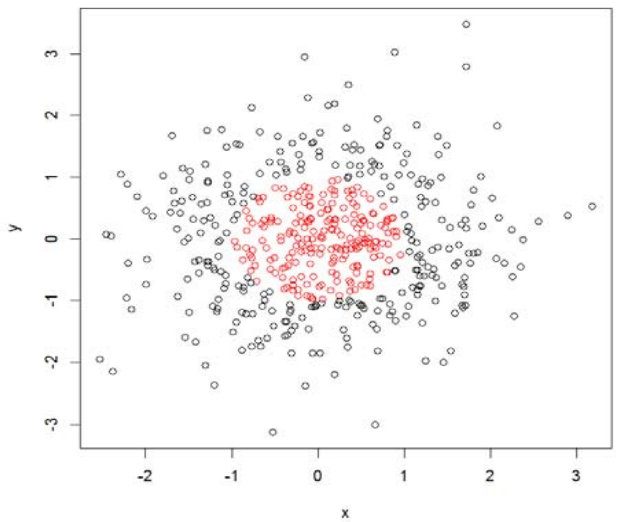
- Hyperplanes in high-dimensional space separate observations into different groups by
- Each different group gets a different prediction



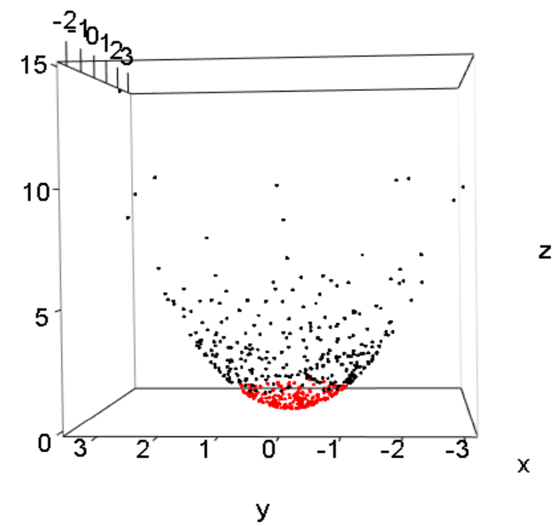
Support Vector Machines

- Modeling involves implicitly transforming data to aid search for hyperplanes, as below (red means low risk, black means high risk)

Original feature space



After transformation

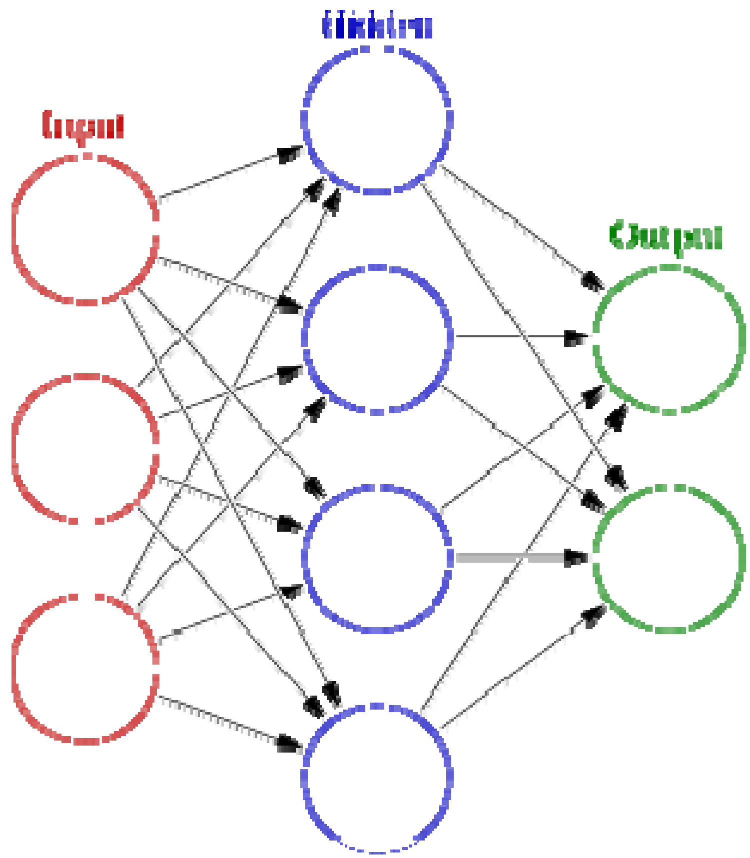


- Problem becomes more difficult as more dimensions are added

Types of Predictive Model

Neural Networks

- Inspired by biological neural networks (e.g. the brain)
- Predicted values calculated in stages by passing through a network of layers
- Value of a node given by a weighted sum of values in the layer before, transformed by a non-linear activation function
- Number/size of hidden layers chosen during modeling
- Weights estimated to minimize a loss function (e.g., negative log-likelihood)
- Can give very good predictions, but interpretation can be complicated (some people would argue with this statement)



Summary

- The goals of Predictive Modeling are the same as traditional assumption setting
  - Making predictions of future outcomes
  - Understanding the process
- Predictive Modeling <u>can</u> give demonstrably better results than traditional techniques
- There are many predictive modeling techniques
- Predictive Modeling is not necessarily a Black Box

Types of Predictive Modeling

- Possible Long Term Care Applications
  – Traditional actuarial assumption development
    - Incidence
    - Length of stay
    - Utilization
    - Lapse
    - Mortality (active vs disabled)
  – Could we determine other uses?

Types of Predictive Modeling

- Possible Long Term Care Applications
  - Underwriting
    - Can we quantify the most critical aspects of the UW process?
    - Could we determine better early knockout questions?
    - Could we determine who qualifies using less questions?
  - Claim intake
    - Can we quantify the most critical data collection to pay a claim?
    - Could we determine the right claims to manage closely?

Questions?