Overview

- Applications
  - Marketing: Direct mail advertising (Zahavi example)
  - Biomedical: finding predictive risk factors
  - Financial: predicting returns and bankruptcy

- Role of management
  - Setting goals
  - Coordinating players

- Critical stages of modeling process
  - Picking the model \(\leftarrow\) My research interest
  - Validation

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Predicting Health Risk

- Who is at risk for a disease?
  - Costs
    - False positive: treat a healthy person
    - False negative: miss a person with the disease
  - Example: detect osteoporosis without need for x-ray

- What sort of predictors, at what cost?
  - Very expensive: Laboratory measurements, "genetic"
  - Expensive: Doctor reported clinical observations
  - Cheap: Self-reported behavior

- Missing data
  - Always present
  - Are records with missing data like those that are not missing?

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Predicting Stock Market Returns

- Predicting returns on the S&P 500 index
  - Extrapolate recent history
  - Exogenous factors

- What would distinguish a good model?
  - Highly statistically significant predictors
  - Reproduces pattern in observed history
  - Extrapolate better than guessing, hunches

- Validation
  - Test of the model yields sobering insight
Predicting the Market

- Build a regression model
  - Response is return on the value-weighted S&P
  - Use standard forward/backward stepwise
  - Battery of 12 predictors
- Train the model during 1992-1996
  - Model captures most of variation in 5 years of returns
  - Retain only the most significant features (Bonferroni)
- Predict what happens in 1997
- Another version in Foster, Stine & Waterman

Historical patterns?

Fitted model predicts...

What happened?
Over-confidence?

- Over-fitting
  - DM model fits the training data too well – better than it can predict when extrapolated to future.
  - Greedy model-fitting procedure
    “Optimization capitalizes on chance”
- Some intuition for the phenomenon
  - Coincidences
    • Cancer clusters, the “birthday problem”
  - Illustration with an auction
    • What is the value of the coins in this jar?

Auctions and Over-fitting

- Auction jar of coins to a class of students
- Histogram shows the bids of 30 students
- Some were suspicious, but a few were not!
- Actual value is $3.85
- Known as “Winner’s Curse”
- Similar to over-fitting: best model like high bidder

Roles of Management

Management determines whether a project succeeds…

- Whose data is it?
  - Ownership and shared obligations/rewards
- Irrational expectations
  - Budgeting credit: “How could you miss?”
- Moving targets
  - Energy policy: “You’ve got the old model.”
- Lack of honest verification
  - Stock example… Given time, can always find a good fit.
  - Rx marketing: “They did well on this question.”
What are the costs?

- Symmetry of mistakes?
  - Is over-predicting as costly as under-predicting?
  - Managing inventories and sales
  - Visible costs versus hidden costs
- Does a false positive = a false negative?
  - Classification
    - Credit modeling, flagging “risky” customers
  - Differential costs for different types of errors
    - False positive: call a good customer “bad”
    - False negative: fail to identify a “bad”

Back to a real application…

How can we avoid some of these problems?

I’ll focus on

* statistical modeling aspects (my research interest),
and also
* reinforce the business environment.

Predicting Bankruptcy

- “Needle in a haystack”
  - 3,000,000 months of credit-card activity
  - 2244 bankruptcies
  - Best customers resemble worst customers
- What factors anticipate bankruptcy?
  - Spending patterns? Payment history?
  - Demographics? Missing data?
  - Combinations of factors?
    - Cash Advance + Las Vegas = Problem
- We consider more than 100,000 predictors!

Stages in Modeling

- Having framed the problem, gotten relevant data...
- Build the model
  Identify patterns that predict future observations.
- Evaluate the model
  When can you tell if its going to succeed…
  - During the model construction phase
    - Only incorporate meaningful features
  - After the model is built
    - Validate by predicting new observations
Building a Predictive Model

So many choices…

- **Structure**: What type of model?
  - Neural net (projection pursuit)
  - CART, classification tree
  - Additive model or regression spline (MARS)

- **Identification**: Which features to use?
  - Time lags, “natural” transformations
  - Combinations of other features

- **Search**: How does one find these features?
  - Brute force has become cheap.

My Choices

- Simple structure
  - Linear regression with nonlinear via interactions
  - All 2-way and many 3-way, 4-way interactions

- Rigorous identification
  - Conservative standard error
  - Comparison of conservative t-ratio to adaptive threshold

- Greedy search
  - Forward stepwise regression
  - Coming: Dynamically changing list of features
  - Good choice affects where you search next.

Bankruptcy Model: Construction

- **Context**
  - Identify current customers who might declare bankruptcy

- Split data to allow validation, comparison
  - Training data
    - 600,000 months with 450 bankruptcies
  - Validation data
    - 2,400,000 months with 1786 bankruptcies

- Selection via **adaptive thresholding**
  - Analogy: Compare sequence of t-stats to Sqrt(2 log p/q)
  - Dynamic expansion of feature space

Bankruptcy Model: Fitting

- Where should the fitting process be stopped?

[Residual Sum of Squares graph]
Bankruptcy Model: Fitting

- Our adaptive selection procedure stops at a model with 39 predictors.

Bankruptcy Model: Validation

- The validation indicates that the fit gets better while the model expands. Avoids over-fitting.

Lift Chart

- Measures how well model classifies sought-for group

\[
Lift = \frac{\% \text{ bankrupt in DM selection}}{\% \text{ bankrupt in all data}}
\]

- Depends on rule used to label customers
  - Very high probability of bankruptcy
  - Lots of lift, but few bankrupt customers are found.
  - Lower rule
  - Lift drops, but finds more bankrupt customers.
- Tie to the economics of the problem
  - Slope gives you the trade-off point

Example: Lift Chart

- Model vs. Random
**Bankruptcy Model: Lift**

- Much better than diagonal!

![Lift Diagram]

**Calibration**

- Classifier assigns \( \text{Prob}(\text{"BR"}) \) rating to a customer.
- Weather forecast
- Among those classified as 2/10 chance of "BR", how many are BR?
- Closer to diagonal is better.

![Calibration Chart]

**Bankruptcy Model: Calibration**

- Over-predicts risk near claimed probability 0.3.

![Calibration Chart]

**Modeling Bankruptcy**

- Automatic, adaptive selection
  - Finds patterns that predict new observations
  - Predictive, but not easy to explain
- Dynamic feature set
  - Current research
  - Information theory allows changing search space
  - Finds more structure than direct search could find
- Validation
  - Remains essential only for judging fit, reserve more for modeling
  - Comparison to rival technology (we compared to C4.5)
Wrap-Up Data Mining

- Data, data, data
  - Often most time consuming steps
  - Cleaning and merging data
  - Without relevant, timely data, no chance for success.

- Clear objective
  - Identified in advance
  - Checked along the way, with “honest” methods

- Rewards
  - Who benefits from success?
  - Who suffers if it fails?