

The Independent Sign Bias: Gaining Insight from Multiple Linear Regression



Michael J. Pazzani and Stephen D. Bay
University of California, Irvine

Background



- Knowledge Discovery in Databases: The process of identifying valid, novel, useful, and understandable patterns in data

$$Y = b_0 + b_1x_1 + b_2x_2 \dots + b_nx_x$$

- “Drowning in data, but starving for knowledge”

Modeling Salaries

■ Social Science Professors

$$\text{Salary} = 45,647 - 66Y_{aT} + 1784Y_{sD} - 346Y_{sH}$$

■ BaseBall Players

$$\begin{aligned} \text{Salary} = & -180 + 10\text{runs} + 5\text{hits} + 0.9\text{obp} \\ & + 15\text{hr} + 14\text{rbi} - 0.8\text{ave} - 18\text{db} - 39\text{tr} \end{aligned}$$

Do the models make sense?

Applications



■ Credit Scoring

- Explanations of credit rejection are important**

■ Medical “algorithms”

- Models for predicting dementia levels from diagnostic tests**
- Models must be acceptable to administrator**

Goals



- Identify conditions under which linear models of data prove credible.
- Produce linear models that
 - are as accurate as standard regression techniques
 - are more acceptable to people knowledgeable about the domain

Outline



- Why are the signs wrong?
- The Independent Sign Bias and Constrained Regression
- Accuracy
- Subject Ratings
- Conclusions

Why are the signs wrong?

- computational error
 - numerical (rounding, truncation)
- variance in estimates
- coefficients do not differ significantly from zero
- multicollinearity: predictor variables are highly correlated
- true sign is reversed when other variables are considered

$$Y = X\beta + \varepsilon$$

$$\mathbf{b} = (\mathbf{X}'\mathbf{X})^{-1} \mathbf{X}'\mathbf{Y}$$

The Independent Sign Bias



Hypothesis:

Models are more acceptable when the sign of each variable in the regression equation is the same as the sign of the variable in isolation

Constrained Regression

■ Multiple Linear Regression

$$\text{Salary} = -180 + 10\text{runs} + 5\text{hits} + 0.9\text{obp} \\ + 15\text{hr} + 14\text{rbi} - 0.8\text{ave} - 18\text{db} - 39\text{tr}$$

■ Independent Sign Regression (ISR)

$$\text{minimize } \|\mathbf{Xb} - \mathbf{Y}\| \quad \text{subject to } \mathbf{Cb} > \bar{\mathbf{0}}$$

$$\text{Salary} = -207 + 15\text{runs} + 0.8\text{hits} + 11\text{hr} + 11\text{rbi} \\ + 0.33\text{ave} + 5\text{db}$$

Forward Selection

■ Forward Selection

$$\text{Salary} = -114 + 16\text{runs} + 17\text{rbi} - 59\text{tr}$$

■ Independent Sign Forward Regression (ISFR)

- add variables as long as constraint is not violated

$$\text{Salary} = -148 + 15\text{runs} + 15\text{rbi}$$

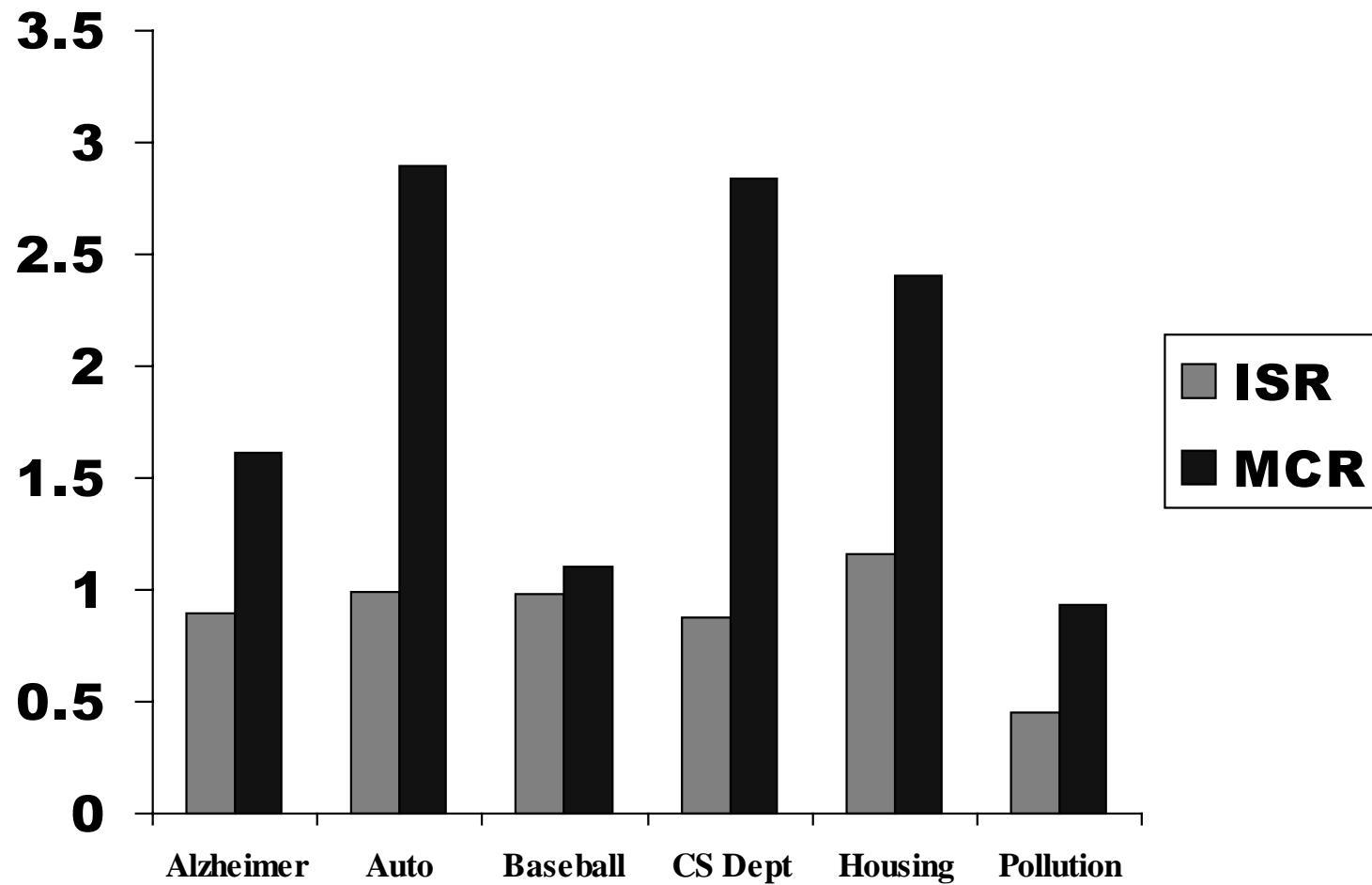
Constrained Regression



■ Mean Coefficient Regression (MCR)

$$\text{Salary} = -162 + 4\text{runs} + 2\text{hits} + 1.1\text{obp} \\ + 10\text{hr} + 3\text{rbi} + 1.2\text{ave} + 9\text{db} + 16\text{tr}$$

Accuracy of Regression



MLR violations:

7

4

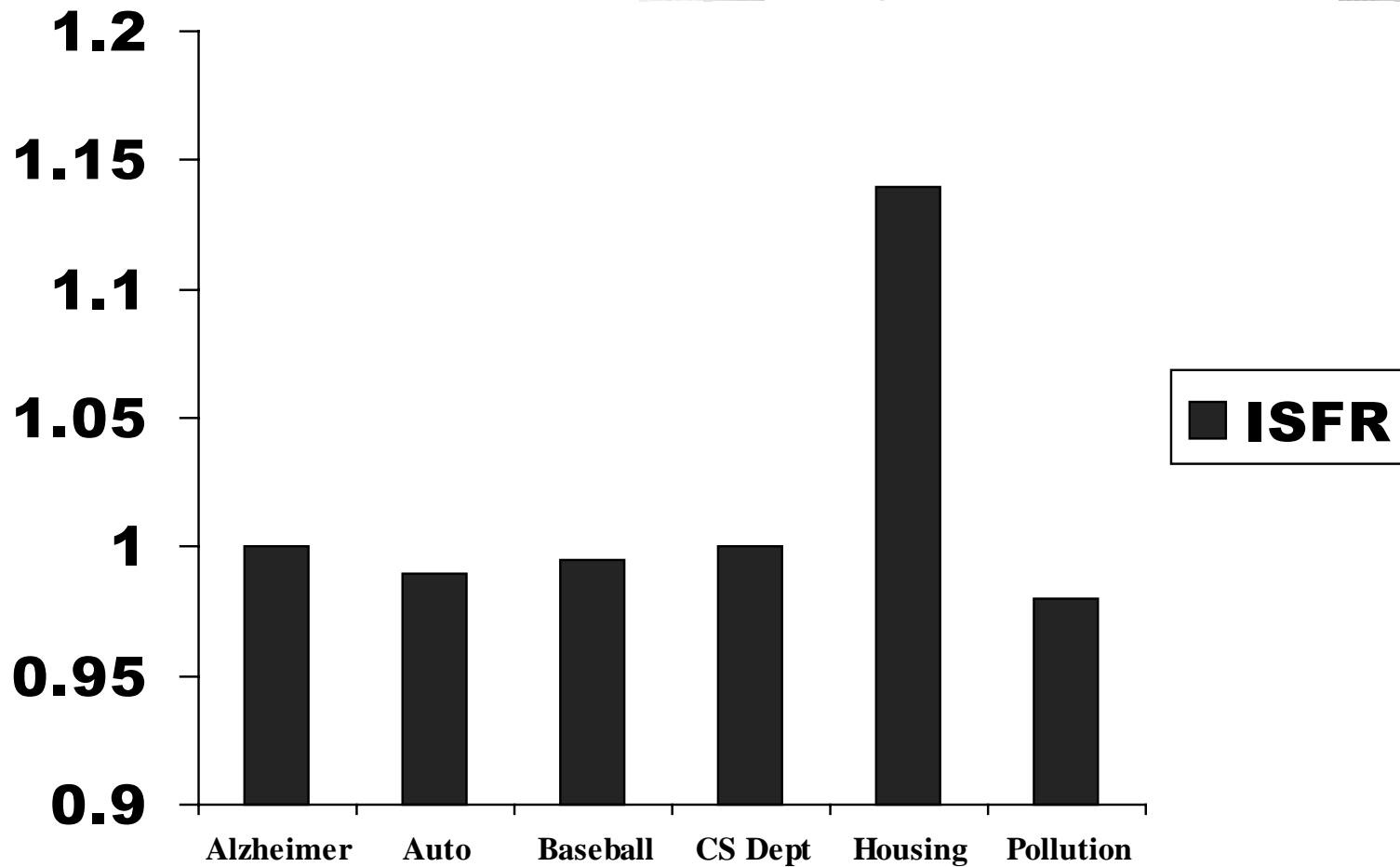
3

1

3

5

Accuracy: Forward Selection



FS violations:

0

1

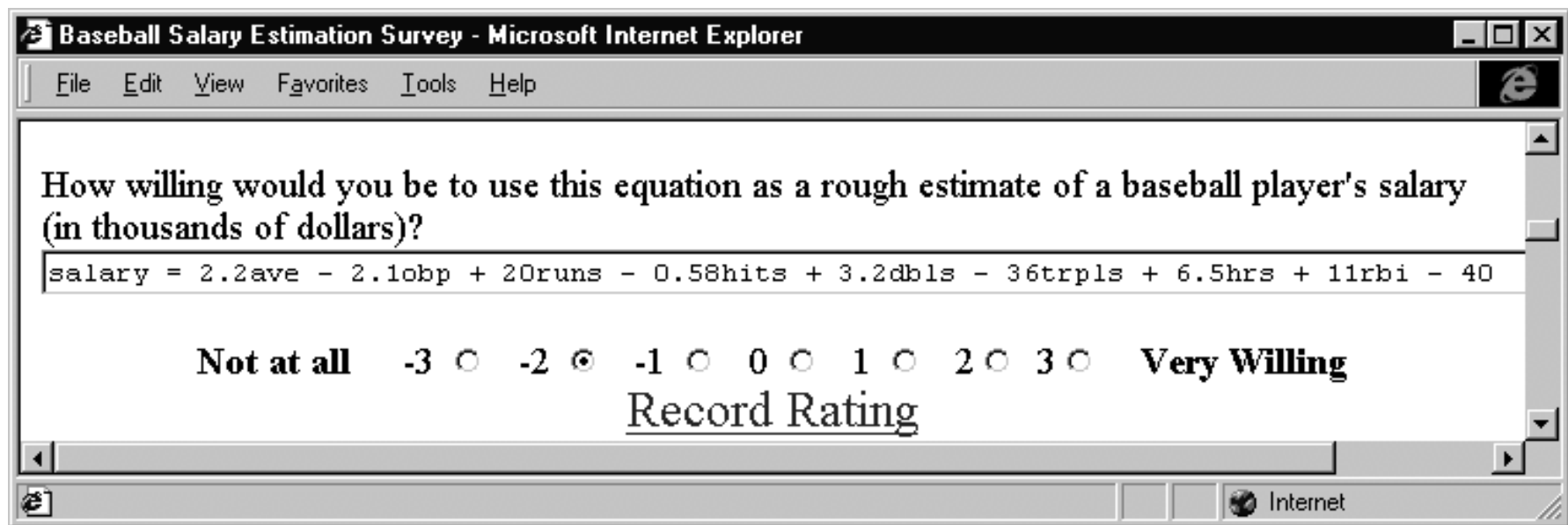
1

0

0

2

Baseball Salary Experiment



The screenshot shows a web browser window with the title "Baseball Salary Estimation Survey - Microsoft Internet Explorer". The address bar is empty. The menu bar includes "File", "Edit", "View", "Favorites", "Tools", and "Help". The main content area contains the following text:

How willing would you be to use this equation as a rough estimate of a baseball player's salary (in thousands of dollars)?

$$\text{salary} = 2.2\text{ave} - 2.1\text{obp} + 20\text{runs} - 0.58\text{hits} + 3.2\text{dbls} - 36\text{trpls} + 6.5\text{hrs} + 11\text{rbi} - 40$$

Below the equation is a horizontal scale for rating willingness. The scale is labeled "Record Rating" and ranges from "Not at all" to "Very Willing". The ratings are represented by radio buttons:

Not at all -3 ☐ -2 ☒ -1 ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ Very Willing

The browser's status bar at the bottom shows "Internet".

47 Subjects

Experiment Results

Regression Algorithm	Mean Rating
Multiple Linear Regression	-0.816
Independent Sign Regression	0.603
Mean Coefficient Regression	0.851
Stepwise Forward Regression	-1.09
Independent Sign Forward Regression	-0.113

ISR > MLR

MCR > MLR

ISFR > SFR

*$F(4,184)=22.11$
 $p < 0.0001$*

*All differences significant
with Tukey-Kramer test at
0.05 level*

Biasing KDD to improve understandability



■ Related Work

- Clark, P. & Matwin, S. (1993). *Using Qualitative Models to Guide Inductive Learning*. MLC 49-56.**
- Monotonicity Constraints: Pazzani, Subramani and Shankle. Proc. Cog Sci 1996.**

Conclusions



- The independent sign bias affects the willingness of subjects to use linear models
- new constrained regression routines
 - as accurate as unconstrained regression
 - more acceptable to users