

Supervised Learning: Introduction

Noah Simon & Ali Shojaie

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University of Washington

A Simple Example

- ▶ Suppose we have $n = 500$ kids for whom we have $p = 3$ measurements: height, weight, and shoe size.
- ▶ We wish to predict these kids' 1600-meter run times using these measurements.

A Simple Example

Run Time	Height	Weight	Shoe Size
y_1	x_{11}	x_{12}	x_{13}
y_2	x_{21}	x_{22}	x_{23}
.	.	.	.
.	.	.	.
.	.	.	.
y_n	x_{n1}	x_{n2}	x_{n3}

Notation:

- ▶ n is the number of observations.
- ▶ p the number of variables/features/predictors.
- ▶ y is a n -vector containing response/outcome for each of n observations.
- ▶ X is a $n \times p$ data matrix.

Linear Regression on a Simple Example

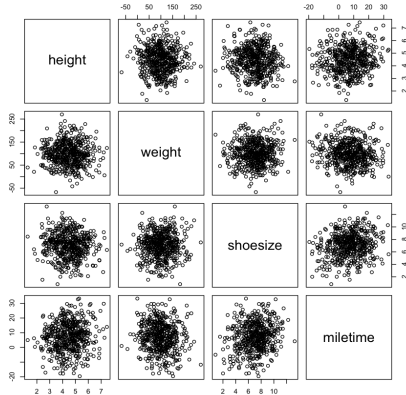
- ▶ You can perform linear regression to develop a model to predict run time using height, weight, and shoe size:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon$$

where y is run time, X_1, X_2, X_3 are height, weight, and shoe size, and ϵ is a **noise term**.

- ▶ You can look at the coefficients, p-values, and t-statistics for your linear regression model in order to interpret your results.
- ▶ You learned everything (or most of what) you need to analyze this data set in AP Statistics!

A Relationship Between the Variables?



Linear Model Output

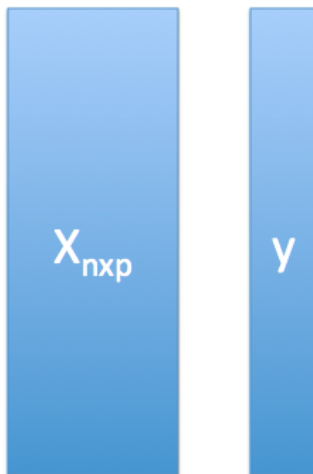
	Estimate	Std. Error	T-Stat	P-Value
Intercept	-2.265831	2.644654	-0.857	0.39199
height	1.074814	0.414789	2.591	0.00985 **
weight	-0.021155	0.008482	-2.494	0.01295 *
shoesize	0.955222	0.214449	4.454	1.04e-05 ***

$\text{RunTime} \approx -2.27 + 1.07 \times \text{Height} - 0.021 \times \text{Weight} + 0.96 \times \text{ShoeSize}.$

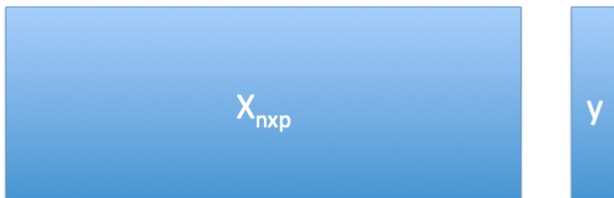
Low-Dimensional Versus High-Dimensional

- ▶ The data set that we just saw is **low-dimensional**: $n \gg p$.
- ▶ Lots of the data sets coming out of modern biological techniques are **high-dimensional**: $n \approx p$ or $n \ll p$.
- ▶ This poses statistical challenges! AP Statistics no longer applies.

Low Dimensional



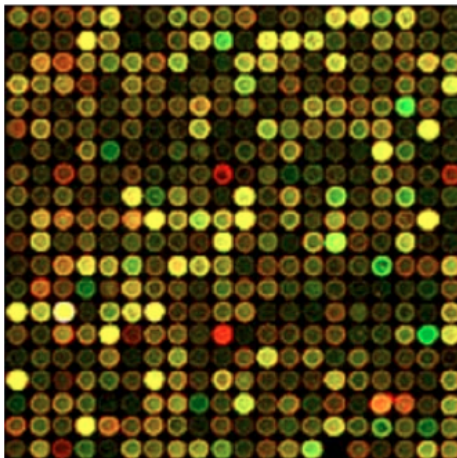
High Dimensional



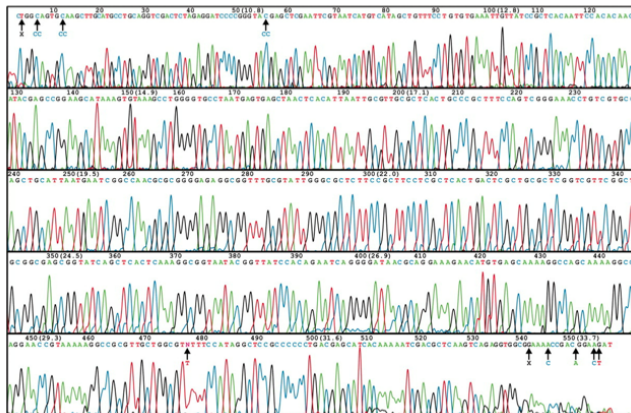
What Goes Wrong in High Dimensions?

- ▶ Suppose that we included many additional predictors in our model, such as
 - ▶ 50-yard dash time
 - ▶ Age
 - ▶ Zodiac symbol
 - ▶ Favorite color
 - ▶ Mother's birthday, in base 2
- ▶ Some of these predictors are useful, others aren't.
- ▶ If we include too many predictors, we will **overfit** the data.
- ▶ **Overfitting**: Model looks great on the data used to develop it, but will perform very poorly on future observations.
- ▶ When $p \approx n$ or $p > n$, overfitting is guaranteed unless we are very careful.

Gene Expression Data



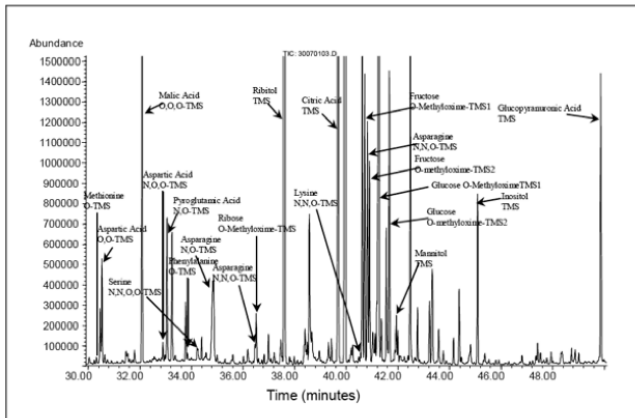
DNA Sequence Data



DNase Hypersensitivity Data



Metabolomic Data



High-Dimensional Omics Analyses

For most omics analyses, we have many more variables than observations.... i.e. $p \gg n$.

- ▶ **Predict** risk of diabetes on the basis of DNA sequence data.... using $n = 1000$ patients and $p = 3000000$ variables.
- ▶ **Cluster** tissue samples on the basis of DNase hypersensitivity... using $n = 200$ cell types and $p = 1000000000$ variables.
- ▶ **Identify** genes whose expression is associated with survival time... using $n = 250$ cancer patients and $p = 20000$ variables.

Why Does Dimensionality Matter?

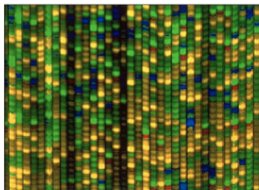
- ▶ Classical statistical techniques, such as linear regression, *cannot* be applied.
- ▶ Even very simple tasks, like identifying variables that are associated with a response, must be done with care.
- ▶ High risks of **overfitting**, **false positives**, and more.

This course: Statistical machine learning tools for **big – mostly high-dimensional – data**.

Statistical Machine Learning



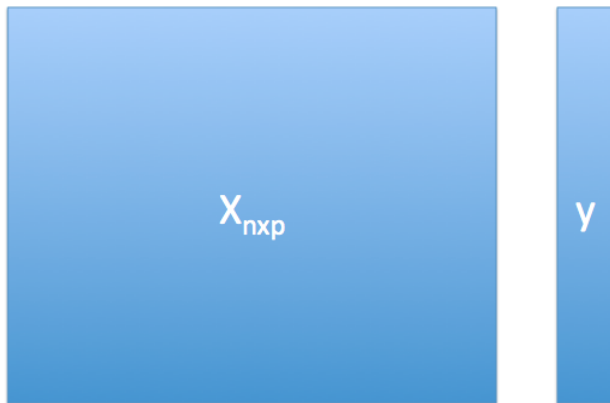
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Supervised and Unsupervised Learning

- ▶ **Statistical machine learning** can be divided into two main areas: **supervised** and **unsupervised**.
- ▶ **Supervised Learning:** Use a data set X to **predict** or **detect association with** a response y .
 - ▶ Regression
 - ▶ Classification
 - ▶ Hypothesis Testing
- ▶ **Unsupervised Learning:** Discover the signal in X , or detect associations within X .
 - ▶ Dimension Reduction
 - ▶ Clustering

Supervised Learning



Unsupervised Learning



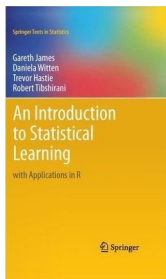
$X_{n \times p}$

This Course

- ▶ We will cover the **big ideas** in **supervised learning** for big data.
- ▶ The best way to use these methods: learn R.



“Course Textbook” . . . with applications in R



- ▶ Available for (free!) download from www.statlearning.com.
- ▶ An accessible introduction to statistical machine learning, with an R lab at the end of each chapter!!
- ▶ We will go through some of these R labs in class.
- ▶ To learn more, go through them on your own!

Let's Try Out Some R!

Chapter 2 R lab
www.statlearning.com