An Introduction to the Data Science Statistics Concentration

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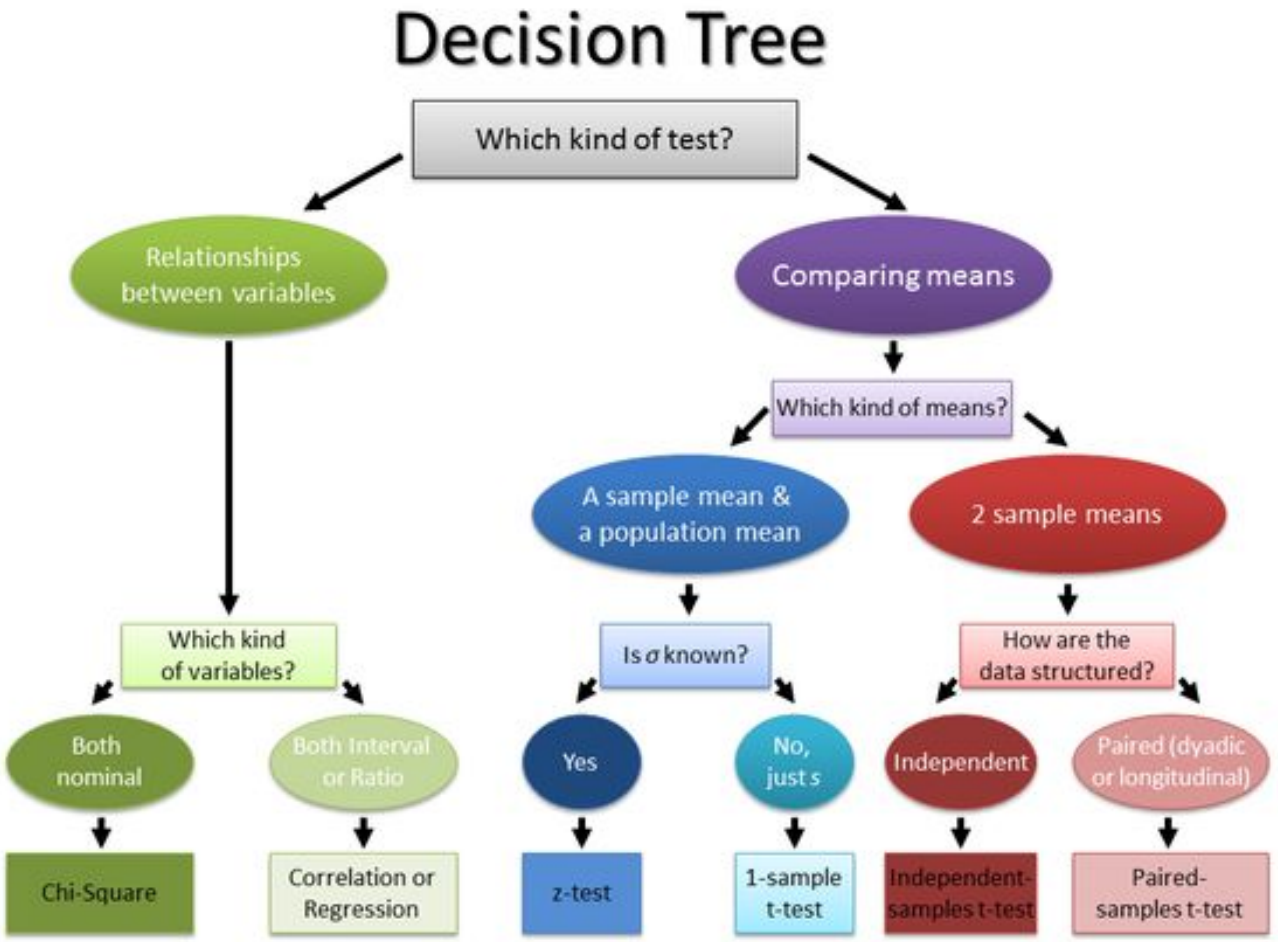
Data science

- What is data science?
- Data science is statistics + computer science with a focus on communication
- What is statistics?
- My opinion: data science is what statistics should have been – the statistics community dropped the ball!

Statistical Modeling

- Drawing conclusions based on data while accounting for random variation.
- Goal: Make **inference** about the state of the world using **data**.
- Most statistics courses are taught as a recipe.
    - If your data are X then do Y.
    - Where is the creativity? Science?

What people think statistics is



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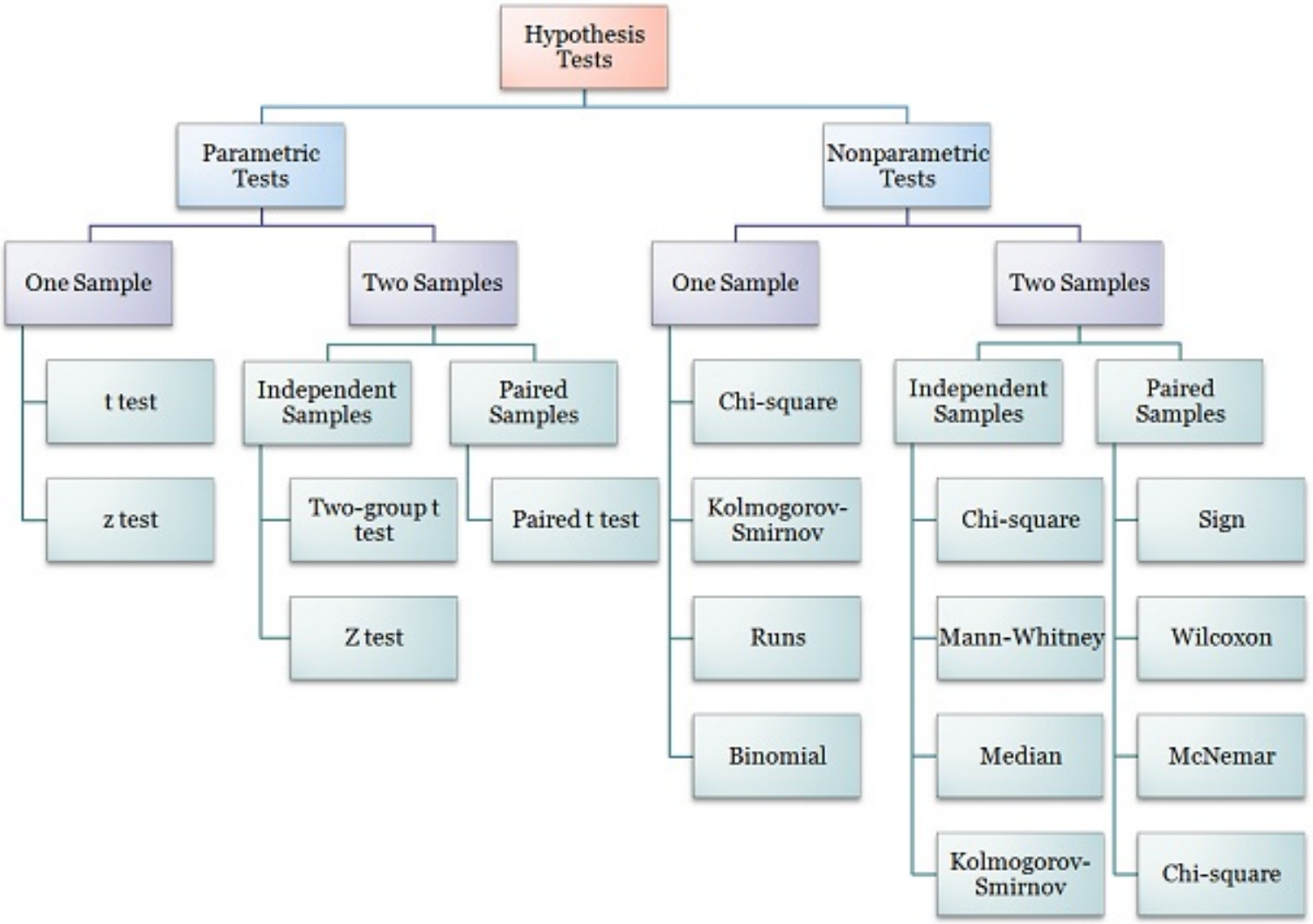

What statistics actually is

- The creative process of turning data into insights using mathematics
- The mathematics that allow for understanding using data
- Constructive and dynamic
- Collaborative: Opportunity to work with experts in multiple fields

Problem with traditional statistics

- Where is the science?
- Don’t we know something about the world other than our data is X?
- How do we add this knowledge into our modeling?

Scientifically Motivated Statistical Modeling

- Probabilistic modeling.
- Model encodes our understanding of the scientific process of interest.
- Model accounts for as much uncertainty as possible.
- Model results in a probability distribution.
- Update model with data.
- Use the model to generate parameter estimates given data.

Scientifically Motivated Statistical Modeling

- Criticize the model
    - Does the model fit the data well?
    - Do the predictions make sense?
    - Are there subsets of the data that don't fit the model well?
- Make inference using the model.
- If the model fits the data, use the model fit for prediction or inference.

Data Science Statistics – What you will learn

- Focus on the mathematical underpinnings for data science
- Programming languages and data frameworks change
  - Today it's python/R
  - Tomorrow it's (probably) Julia
- Not everything is big data and most problems don't require deep learning and instead require careful thought

Data science statistics - What you will learn

- Understanding the first principles ensures your expertise will never become obsolete
  - The models and programming frameworks will change in the future
  - The mathematics and statistics underlying these will always be the same

Data science statistics - What you will learn

- There is a desperate need for people that can think statistically
  - There are many, many more software engineers than data scientists
  - Why?
  - Statistical thinking is hard and takes time to learn

Data science statistics

- Core courses
  - Introduction to Mathematical Statistics
  - Statistical forecasting and prediction
  - Bayesian Methods
- Possible electives
  - Nonparametric methods
  - Experimental Design
  - Analysis of categorical data

Mathematical Statistics

- Statistical properties
  - What happens to the model inference/prediction as you get more data?
  - Are the estimates unbiased?
    - On average, are the estimates equal to the “true” value?
  - Are the estimates consistent?
    - As you get more data, do the estimates converge to the “true” value
- Estimation and testing

Mathematical Statistics

- Sufficient statistics
  - The backbone of distributed computing platforms
  - Hadoop, Apache Spark, MapReduce, etc.
- Decision Theory
  - How to make decisions under uncertainty
  - Formal definition of loss and risk

Statistical Forecasting and Prediction

- Modeling of data that is dependent on time
  - Temperature today is more likely to be like yesterday than the same day last year
  - Retail sales today more likely to be like yesterday than last month
- Fundamentals of “time series” data analysis
- Robust understanding of autocorrelation, autoregression, and moving averages
- Fundamental for finance, business forecasting, ecological monitoring, etc.

Bayesian Methods

- Understanding model building, regularization, classification and prediction.
- Formal modeling of uncertainty
  - Estimates of how reliable a prediction is
- Inclusion of prior (scientific) knowledge
  - Add knowledge about the real world
- Constructive model building
  - Customize the analysis to specific challenges and problems
  - Not just “data mining”
  - Iterative model building and improvement

Other statistics courses

- Nonparametric statistics
  - What to do when assumptions are not met
  - bootstrapping and resampling methods
  - Foundation for deep learning and ML models
- Experimental statistics
  - A/B testing – how internet ads are tested
  - Scientific testing
- Analysis of categorical data
  - Generalized linear models
  - Count data
  - Logistic regression

Jobs in Data Science Statistics

- A Data Science Statistics concentration will prepare you for all jobs in data science
- Strongly recommend learning from experts
    - Much of the work of applied statisticians and data scientists is translating knowledge from experts in a domain area into mathematical models and computer code