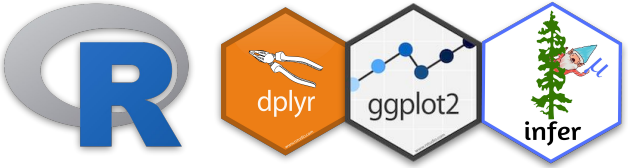
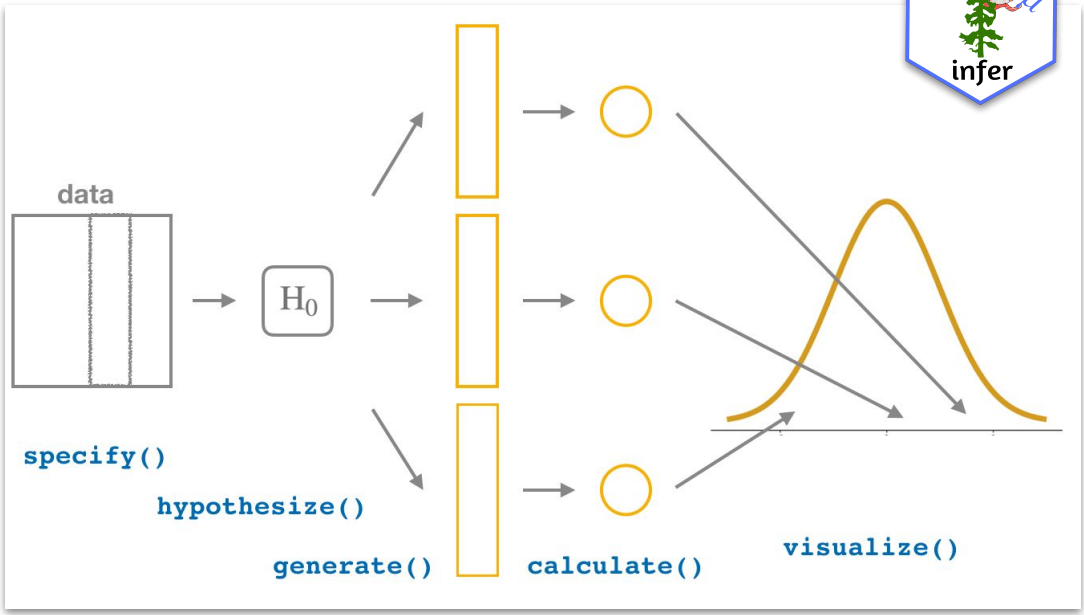
Optimize



A/B Testing

& Statistical Inference

Special Topic: Website Optimization



Matt Dancho & David Curry

Business Science Learning Lab

Learning Lab Structure

- **Presentation**
  (20 min)
- **Demo's**
  (30 min)
- **Pro-Tips**
  (15 mins)

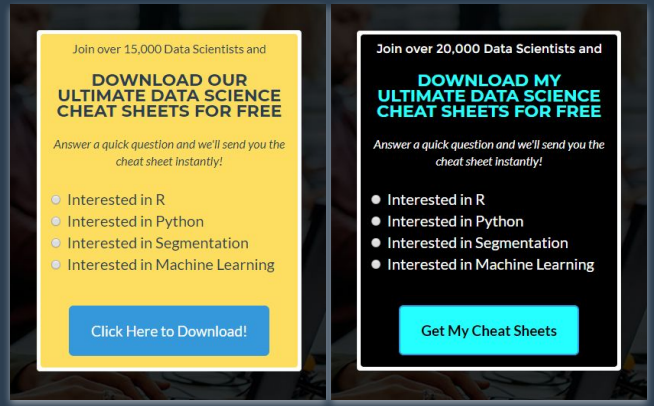
Matt Dancho

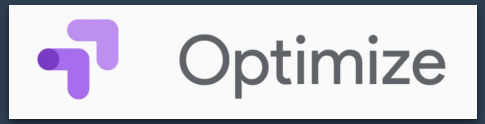
Founder of Business Science, Matt designs and executes educational courses and workshops that deliver immediate value to organizations. His passion is **up-leveling future data scientists** coming from **untraditional backgrounds**.

David Curry

Founder of Sure Optimize, David works with businesses to help improve website performance and SEO using data science. His passion is **ethical Machine Learning initiatives**.

Agenda





- **Business Case Study**
  - Website Optimization
  - A/B Testing
- **30-Min Demo**
  - A/B Test Analysis in R w/ infer
- **A/B Testing**
  - What is it?
  - What can you do?
- **Pro-Tips & Learning Guide**
  - Recap + Pro-Tips
  - Learning Plan
- **Google Optimize**
  - Free tool for A/B Testing
- **Statistical Inferences**
  - 80/20 Concepts
  - R package infer

Learning Labs PRO

Every 2-Weeks

1-Hour Course

Recordings + Code + Slack

$19/month

university.business-science.io

Lab 23
BigQuery & Conversion Funnel

Lab 22
SQL for Time Series

Lab 21
SQL for Data Science

Lab 20
Explainable Machine Learning

Lab 19
Using Customer Credit Card History for Networks Analysis

Lab 18
Time Series Anomaly Detection with anomalize

Lab 17
Anomaly Detection with H2O Machine Learning

Continuous Learning
Jet Fuel for your Brain

Website Optimization

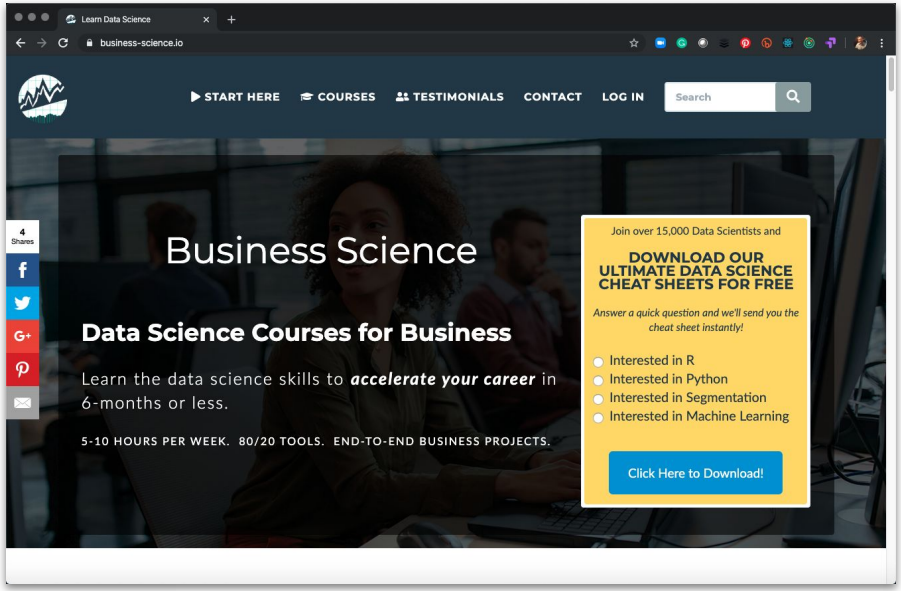
Business Case

Business Science Website

Email Signup

- Email is critical to **my business**
- Way to connect with **my people**
- Relationship + Value = **Trust**
- Email is the **1st Step** towards building trust

https://www.business-science.io/



Tracking Conversions

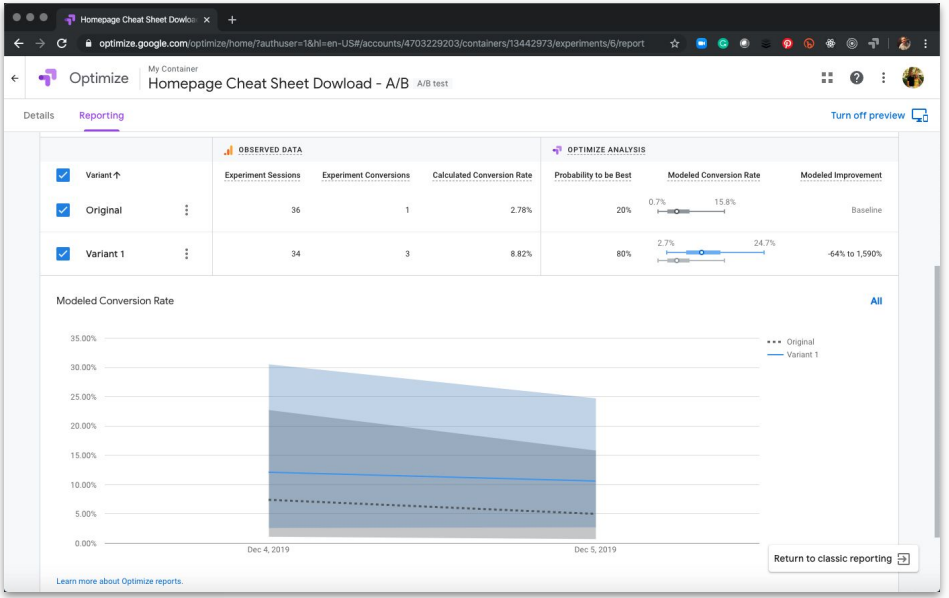
For Business Science

1. Google made a new tool **Google Optimize** that helps with A/B Testing for websites

2. **All-in-one tool** which helps streamline the A/B test process

3. **Integrates** with Google Tag Manager & Google Analytics

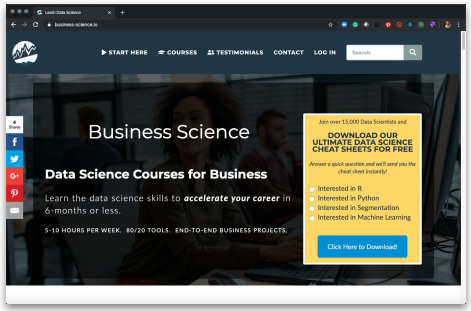
4. **Other types of Conversions**
    - **Email Marketing** - Test email variants



A/B Testing

80/20 Concepts

What is A/B Testing?



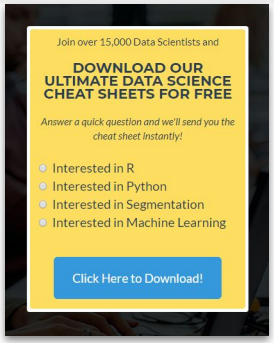
50%

Control

1700/week

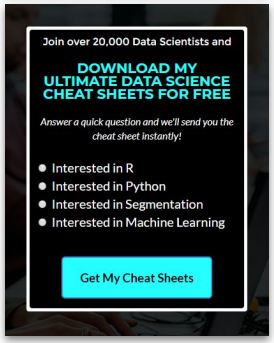
Variant

50%



2.5%

1700/wk x 2.5% = 43 emails/wk



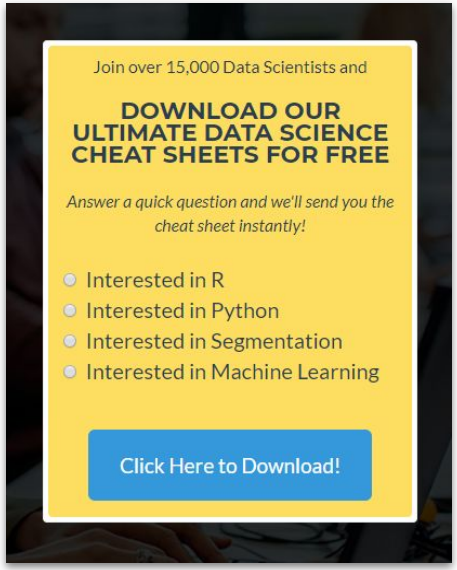
7.5%

3X Improvement

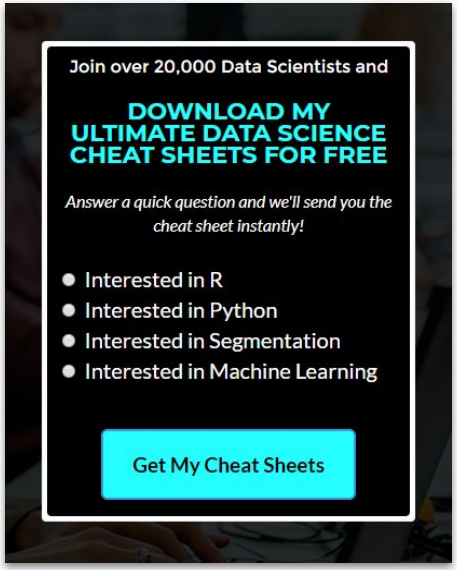
Versus Control

1700/wk x 7.5% = **128 emails/wk**

Small Change, Big Effect



2.5% Conv.
42 emails/week



7.5% Conv.
128 emails/week

What Can You A/B Test?

Website

How to optimize?

Improving your website using **statistically significant results**

- Solve pain points
- Improve ROI from web traffic
- Reduce bounce rate
- Improve customer experience
- Achieve better results

Blog

What interests your prospective subscribers?

Finding content & topics that **connect you** to your people.

- Improve web traffic & click rates
- Optimize title (traffic)
- Optimize image (traffic)
- Optimize content (click)

Email

What interests your current subscribers?

Finding content & topics that **grow your relationship** with your people.

- Improve Open & Click Rates
- Optimize title (traffic)
- Optimize image (click)
- Optimize content (click)

A/B Test Tools

Google Optimize

Pros - Fast & Easy to Set Up

Cons:

- Web Only (No Email)
- No advanced ML

R Ecosystem

Pros:

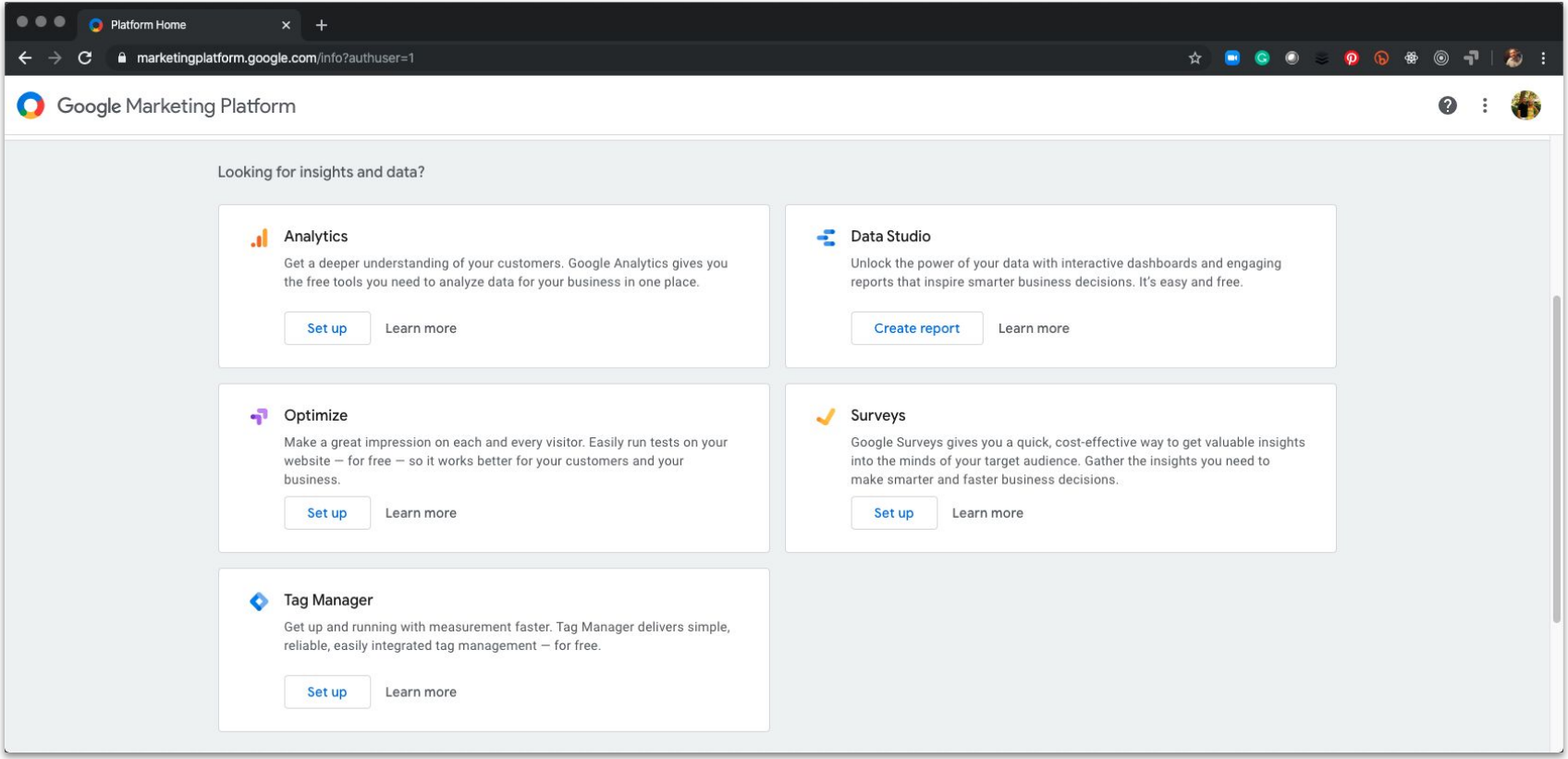
- Any Data (Email, Web, Other)
- Answer more questions:
  - What correlates to success?
- Apply advanced tools
  - Machine Learning

Cons: Learn R Ecosystem

Google Optimize

Concepts & Short Demo

Google Marketing Platform

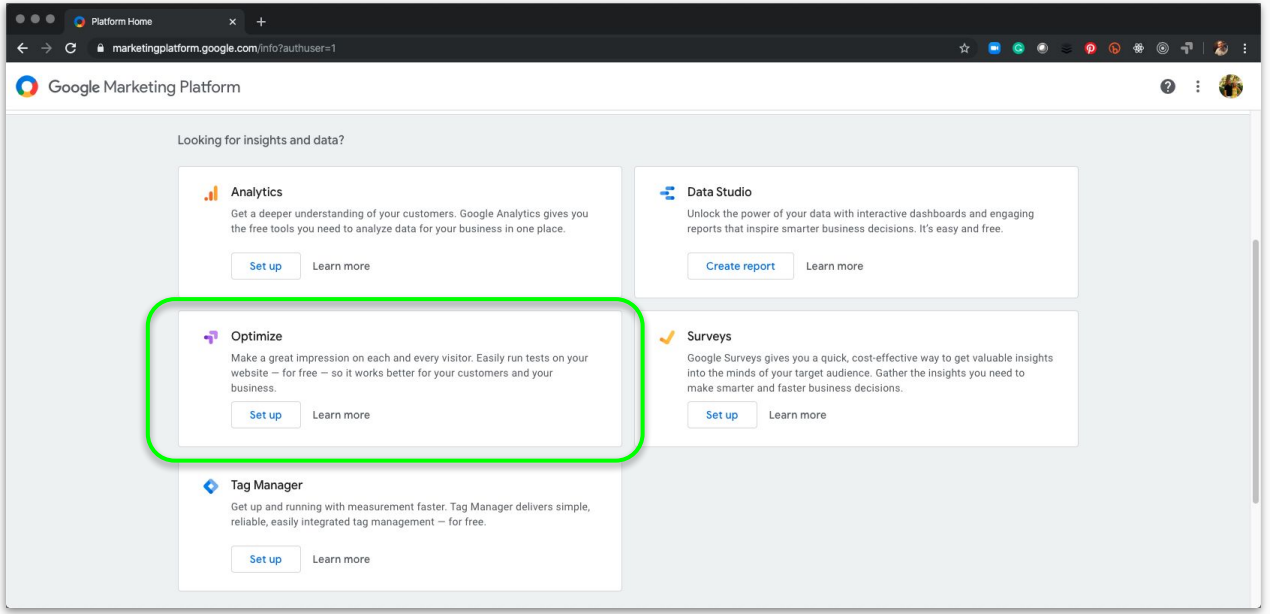


Google Optimize

Run A/B Tests

Integrates with:

- Google Analytics
- Google Tag Manager
- And more



DEMO

Statistical Inference

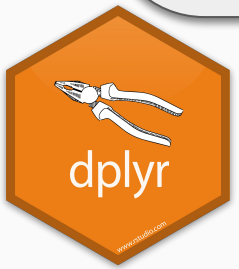
80/20 Data Concepts

Infer R Package

```
# A tibble: 290,585 x 7
   user_id timestamp           group     landing_page converted label              visit_count
     <dbl> <dttm>              <chr>     <chr>            <dbl> <chr>                    <dbl>
 1  922696 2017-01-02 13:42:05 treatment new_page             0 treatment-new_page           1
 2  781507 2017-01-02 13:42:15 control   old_page             0 control-old_page             1
 3  737319 2017-01-02 13:42:21 control   old_page             0 control-old_page             1
 4  818377 2017-01-02 13:42:26 treatment new_page             0 treatment-new_page           1
 5  725857 2017-01-02 13:42:27 treatment new_page             0 treatment-new_page           1
 6  762651 2017-01-02 13:42:28 treatment new_page             0 treatment-new_page           1
 7  722516 2017-01-02 13:42:34 treatment new_page             0 treatment-new_page           1
 8  688937 2017-01-02 13:42:41 treatment new_page             0 treatment-new_page           1
 9  781125 2017-01-02 13:42:45 treatment new_page             0 treatment-new_page           1
10  799109 2017-01-02 13:42:45 control   old_page             0 control-old_page             1
# … with 290,575 more rows
```

Infer R Package

```
# A tibble: 290,585 x 7
   user_id timestamp           group     landing_page converted label              visit_count
     <dbl> <dttm>              <chr>     <chr>            <dbl> <chr>                    <dbl>
 1  922696 2017-01-02 13:42:05 treatment new_page             0 treatment-new_page           1
 2  781507 2017-01-02 13:42:15 control   old_page             0 control-old_page             1
 3  737319 2017-01-02 13:42:21 control   old_page             0 control-old_page             1
 4  818377 2017-01-02 13:42:26 treatment new_page             0 treatment-new_page           1
 5  725857 2017-01-02 13:42:27 treatment new_page             0 treatment-new_page           1
 6  762651 2017-01-02 13:42:28 treatment new_page             0 treatment-new_page           1
 7  722516 2017-01-02 13:42:34 treatment new_page             0 treatment-new_page           1
 8  688937 2017-01-02 13:42:41 treatment new_page             0 treatment-new_page           1
 9  781125 2017-01-02 13:42:45 treatment new_page             0 treatment-new_page           1
10  799109 2017-01-02 13:42:45 control   old_page             0 control-old_page             1
# … with 290,575 more rows
```




```
# A tibble: 46 x 5
   label           date                count conversion  prop
   <chr>           <dttm>              <int>      <dbl> <dbl>
 1 control-old_page 2017-01-02 00:00:00  2859        359 0.126
 2 control-old_page 2017-01-03 00:00:00  6590        750 0.114
 3 control-old_page 2017-01-04 00:00:00  6578        802 0.122
 4 control-old_page 2017-01-05 00:00:00  6427        792 0.123
 5 control-old_page 2017-01-06 00:00:00  6606        762 0.115
 6 control-old_page 2017-01-07 00:00:00  6604        799 0.121
 7 control-old_page 2017-01-08 00:00:00  6687        795 0.119
 8 control-old_page 2017-01-09 00:00:00  6628        793 0.120
 9 control-old_page 2017-01-10 00:00:00  6654        751 0.113
10 control-old_page 2017-01-11 00:00:00  6688        795 0.119
# … with 36 more rows
```

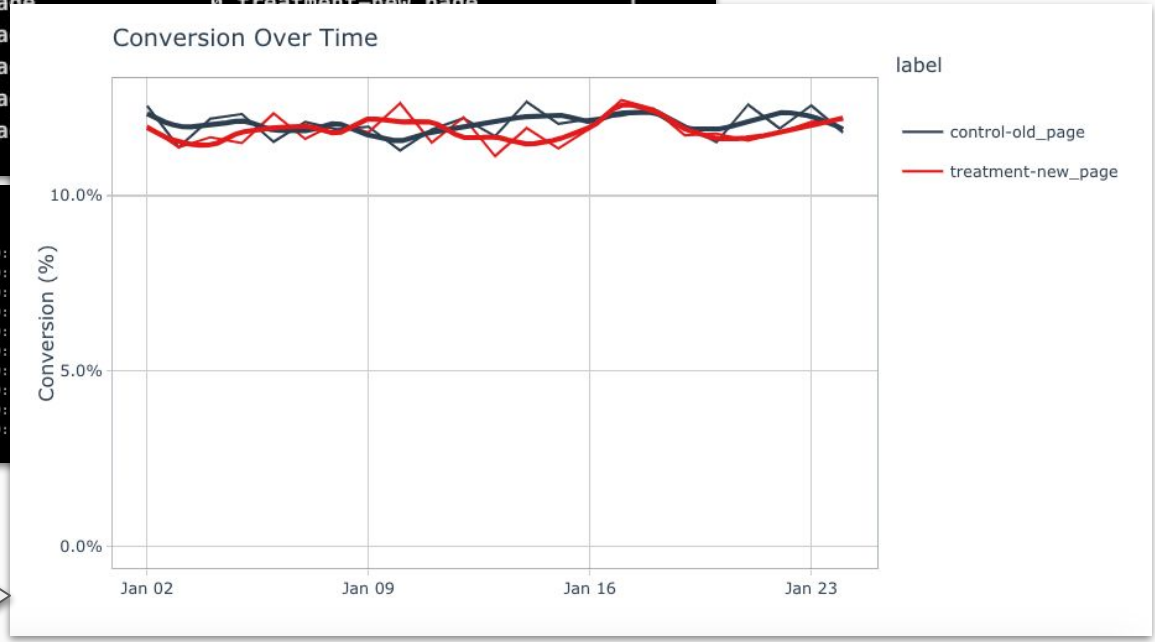
Infer R Package

```
# A tibble: 290,585 x 7
   user_id timestamp           group     landing_page converted label              visit_count
     <dbl> <dttm>              <chr>     <chr>            <dbl> <chr>                    <dbl>
 1  922696 2017-01-02 13:42:05 treatment new_page             0 treatment-new_page           1
 2  781507 2017-01-02 13:42:15 control   old_page             0 control-old_page             1
 3  737319 2017-01-02 13:42:21 control   old_page             0 control-old_page             1
 4  818377 2017-01-02 13:42:26 treatment new_page             0 treatment-new_page           1
 5  725857 2017-01-02 13:42:27 treatment new_page             0 treatment-new_page           1
 6  762651 2017-01-02 13:42:28 treatment new_page             0 treatment-new_page           1
 7  722516 2017-01-02 13:42:34 treatment new_pa
 8  688937 2017-01-02 13:42:41 treatment new_pa
 9  781125 2017-01-02 13:42:45 treatment new_pa
10  799109 2017-01-02 13:42:45 control   old_pa
# … with 290,575 more rows
```

```
# A tibble: 46 x 5
   label           date
   <chr>           <dttm>
 1 control-old_page 2017-01-02 00:00:
 2 control-old_page 2017-01-03 00:00:
 3 control-old_page 2017-01-04 00:00:
 4 control-old_page 2017-01-05 00:00:
 5 control-old_page 2017-01-06 00:00:
 6 control-old_page 2017-01-07 00:00:
 7 control-old_page 2017-01-08 00:00:
 8 control-old_page 2017-01-09 00:00:
 9 control-old_page 2017-01-10 00:00:
10 control-old_page 2017-01-11 00:00:
# … with 36 more rows
```

dplyr

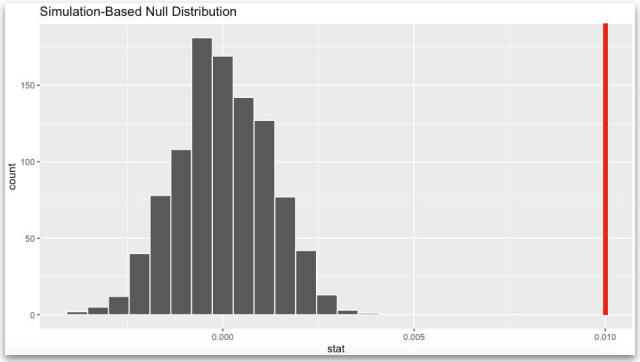
ggplot2



Types of Statistical Inference Tests

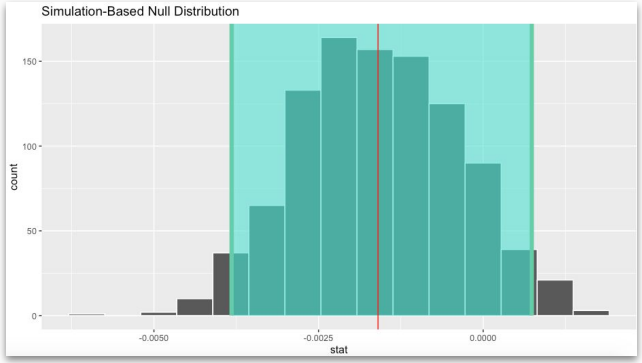
Hypothesis (Permutation)

Probability of a conversion more extreme than 1.0%

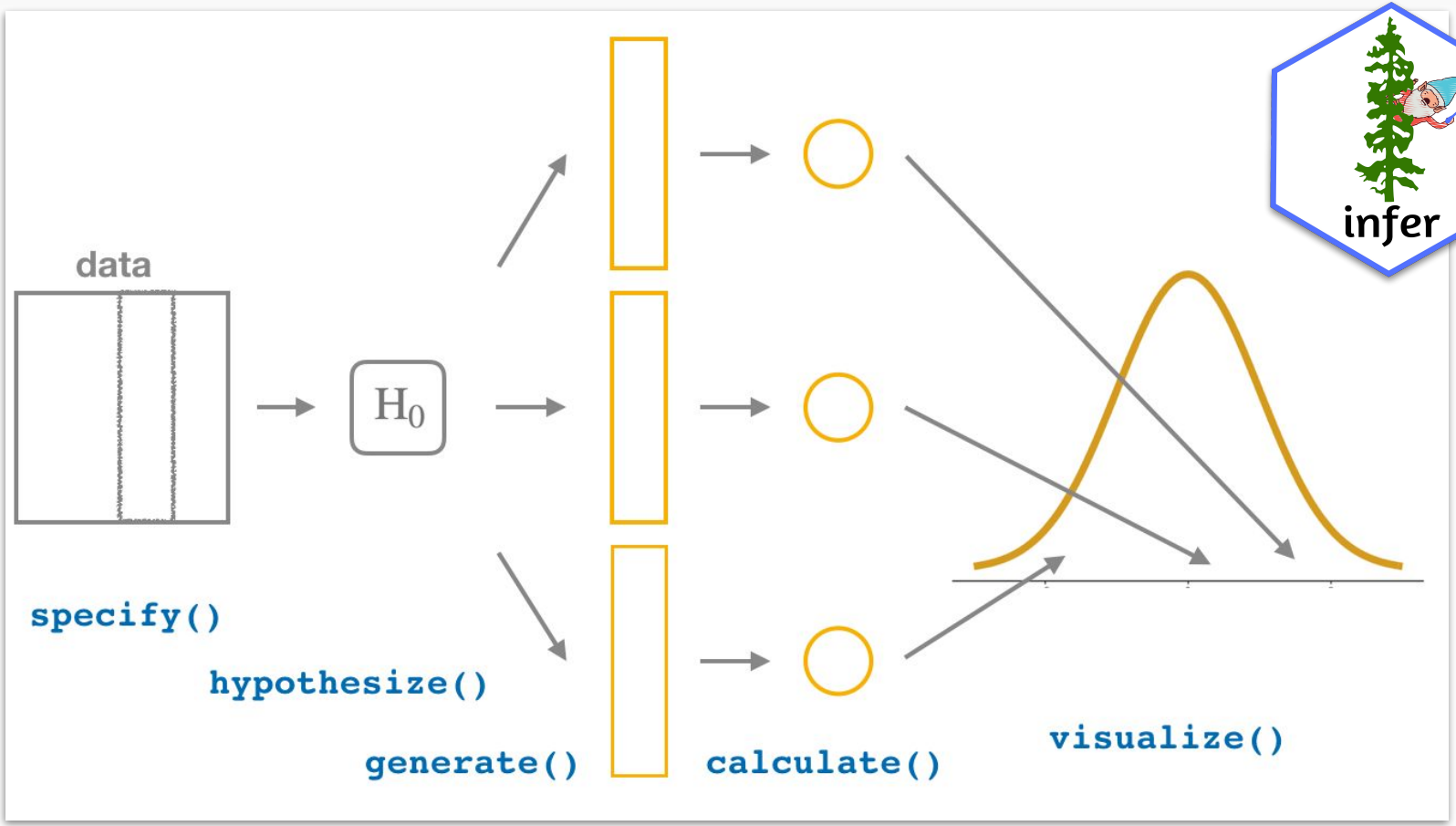


Confidence Interval (Bootstrap)

95% of time the difference in conversion is within this **Confidence Interval** window



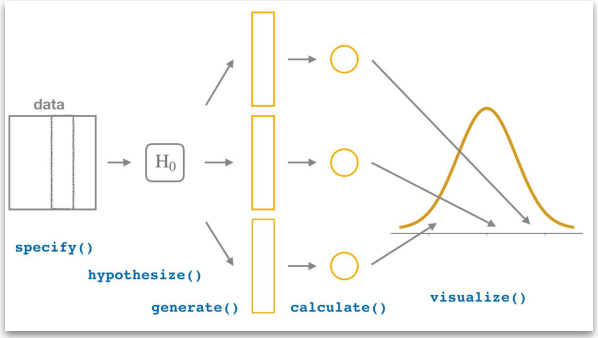
Infer R Package



Infer Workflow

specify()

Specify the variables in the A/B Test




```
> comparison_1_tbl %>%
+
+     # Infer
+     specify(prop ~ label)
Response: prop (numeric)
Explanatory: label (factor)
# A tibble: 46 x 2
    prop label
   <dbl> <fct>
 1 0.126 control-old_page
 2 0.114 control-old_page
 3 0.122 control-old_page
 4 0.123 control-old_page
 5 0.115 control-old_page
 6 0.121 control-old_page
 7 0.119 control-old_page
 8 0.120 control-old_page
 9 0.113 control-old_page
10 0.119 control-old_page
# … with 36 more rows
```

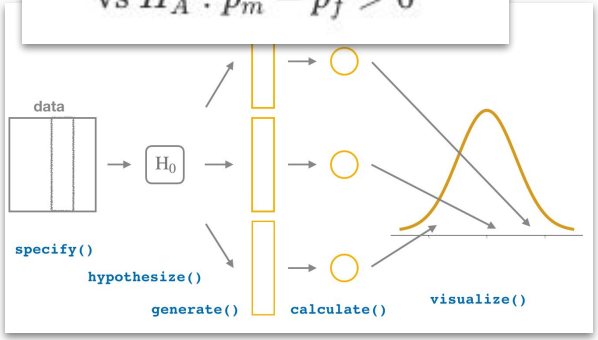
Infer Workflow

hypothesize()

For Hypothesis Testing Only

(Not for Bootstrap CI Estimation)

$$H_0 : p_m - p_f = 0$$
$$\text{vs } H_A : p_m - p_f > 0$$



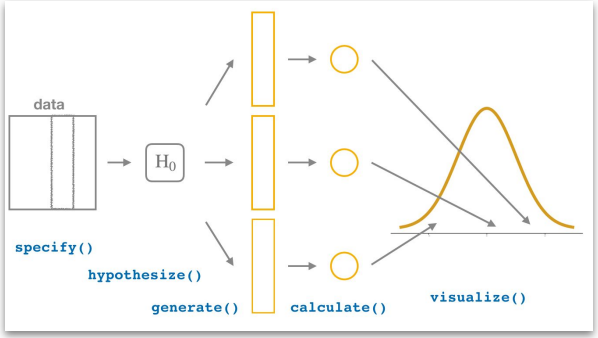

```
> comparison_1_tbl %>%
+
+     # Infer
+     specify(prop ~ label) %>%
+     hypothesize(null = "independence")
Response: prop (numeric)
Explanatory: label (factor)
Null Hypothesis: independence
# A tibble: 46 x 2
    prop label
   <dbl> <fct>
 1 0.126 control-old_page
 2 0.114 control-old_page
 3 0.122 control-old_page
 4 0.123 control-old_page
 5 0.115 control-old_page
 6 0.121 control-old_page
 7 0.119 control-old_page
 8 0.120 control-old_page
 9 0.113 control-old_page
10 0.119 control-old_page
# … with 36 more rows
```

Infer Workflow

generate()

Make **permutations** or **bootstrap** replicates

```
> comparison_1_tbl %>%
+
+     # Infer
+     specify(prop ~ label) %>%
+     hypothesize(null = "independence") %>%
+     generate(reps = 1000, type = "permute")
Response: prop (numeric)
Explanatory: label (factor)
Null Hypothesis: independence
# A tibble: 46,000 x 3
# Groups:   replicate [1,000]
    prop label             replicate
   <dbl> <fct>                 <int>
 1 0.126 control-old_page          1
 2 0.125 control-old_page          1
 3 0.119 control-old_page          1
 4 0.113 control-old_page          1
 5 0.113 control-old_page          1
 6 0.119 control-old_page          1
 7 0.122 control-old_page          1
 8 0.119 control-old_page          1
 9 0.126 control-old_page          1
10 0.117 control-old_page          1
# … with 45,990 more rows
```

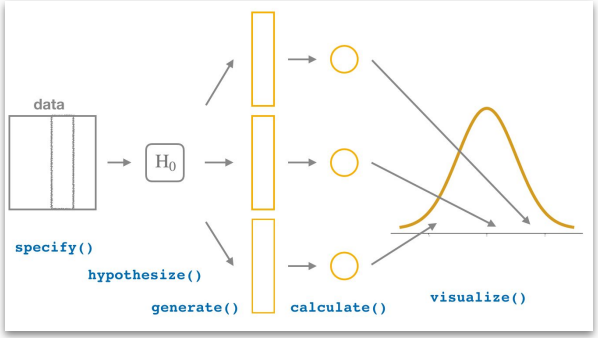


Infer Workflow

calculate()

Apply a summary statistic:

- “diff in means” for difference in means



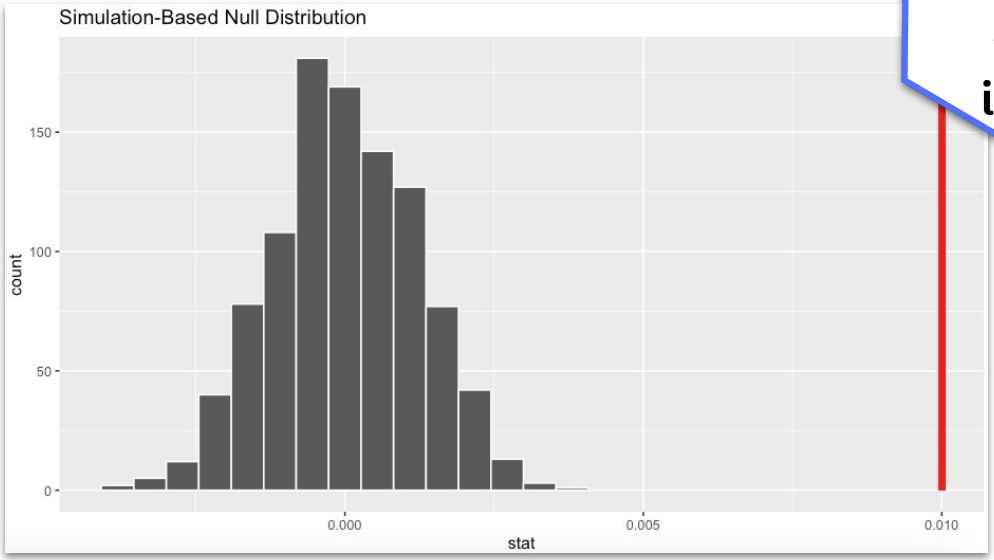

```
> comparison_1_tbl %>%
+
+     # Infer
+     specify(prop ~ label) %>%
+     hypothesize(null = "independence") %>%
+     generate(reps = 1000, type = "permute") %>%
+     calculate(stat = "diff in means",
+               order = c("treatment-new_page", "control-old_page"))
# A tibble: 1,000 x 2
   replicate        stat
       <int>       <dbl>
 1         1  0.000822
 2         2 -0.00131
 3         3 -0.000462
 4         4  0.00197
 5         5  0.0000738
 6         6  0.00156
 7         7  0.000606
 8         8  0.00172
 9         9  0.00173
10        10 -0.00000660
# … with 990 more rows
```

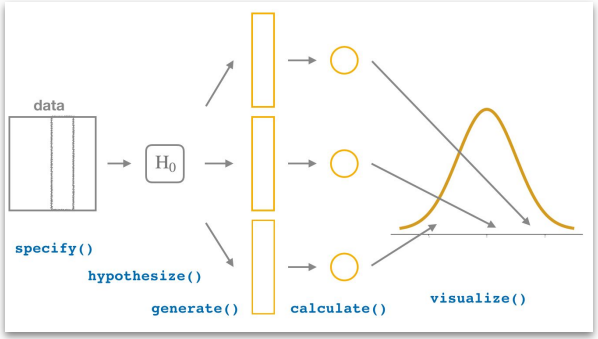
Infer Workflow

visualize()

- View the probability of a value more extreme

```
193  comp_1_diff_means_permuted_tbl %>%
194      visualize() +
195      shade_p_value(obs_stat = 0.01, direction = "right")
196
```



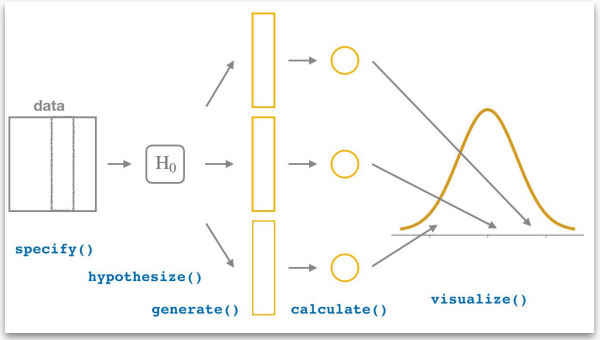


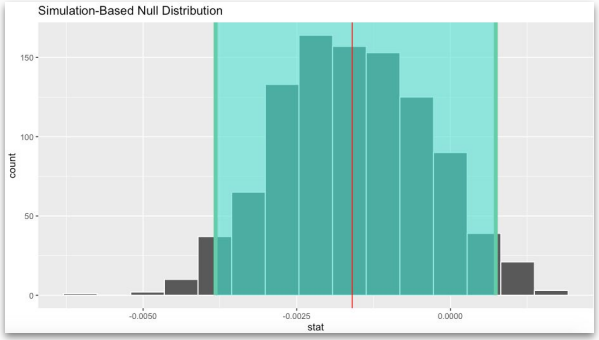

```
> comp_1_diff_means_permuted_tbl %>%
+     get_p_value(obs_stat = 0.01, direction = "right")
# A tibble: 1 x 1
  p_value
    <dbl>
1       0
```

What about Confidence Intervals?

Bootstrap Workflow

Just **skip hypothesize()** and **set generate(type = “bootstrap”)**



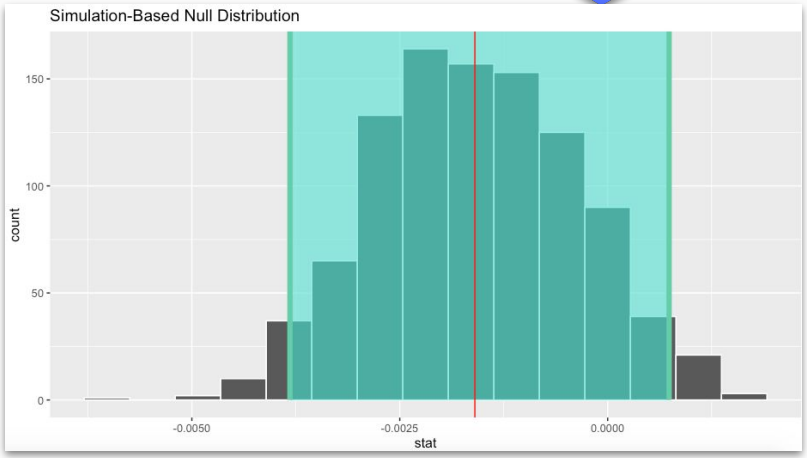


Infer Workflow

Bootstrap

- Skip hypothesize()
- Set generate(type = ”bootstrap”)

```
205 comp_1_diff_bootstrap_tbl <- comparison_1_tbl %>%
206
207     # Infer
208     specify(prop ~ label) %>%
209
210     # Remove Hypothesis:
211     # hypothesize(null = "independence") %>%
212
213     # Change generate(): type = "boostrap"
214     generate(reps = 1000, type = "bootstrap") %>%
215     calculate(stat = "diff in means",
216               order = c("treatment-new_page", "control-old_page"))
```




```
> bootstrap_ci_tbl
# A tibble: 1 x 2
    `2.5%`   `97.5%`
     <dbl>     <dbl>
1 -0.00380 0.000720
```

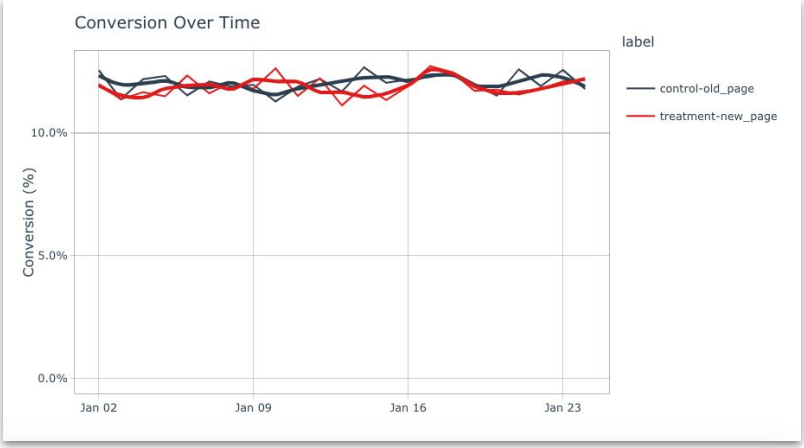
30-Min Demo

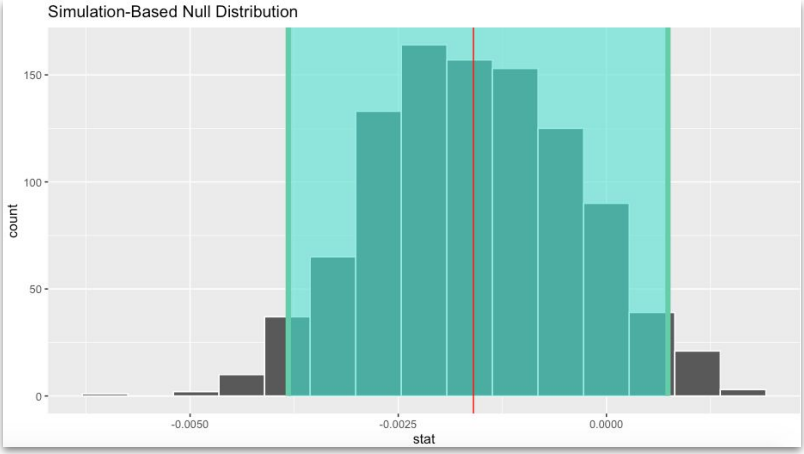
A/B Testing

PRO-TIPS

Yeahhhhhh!

Pro-Tips





#1. Visualize Over Time

If conversion aggregation by day, **run for at least 2 weeks**

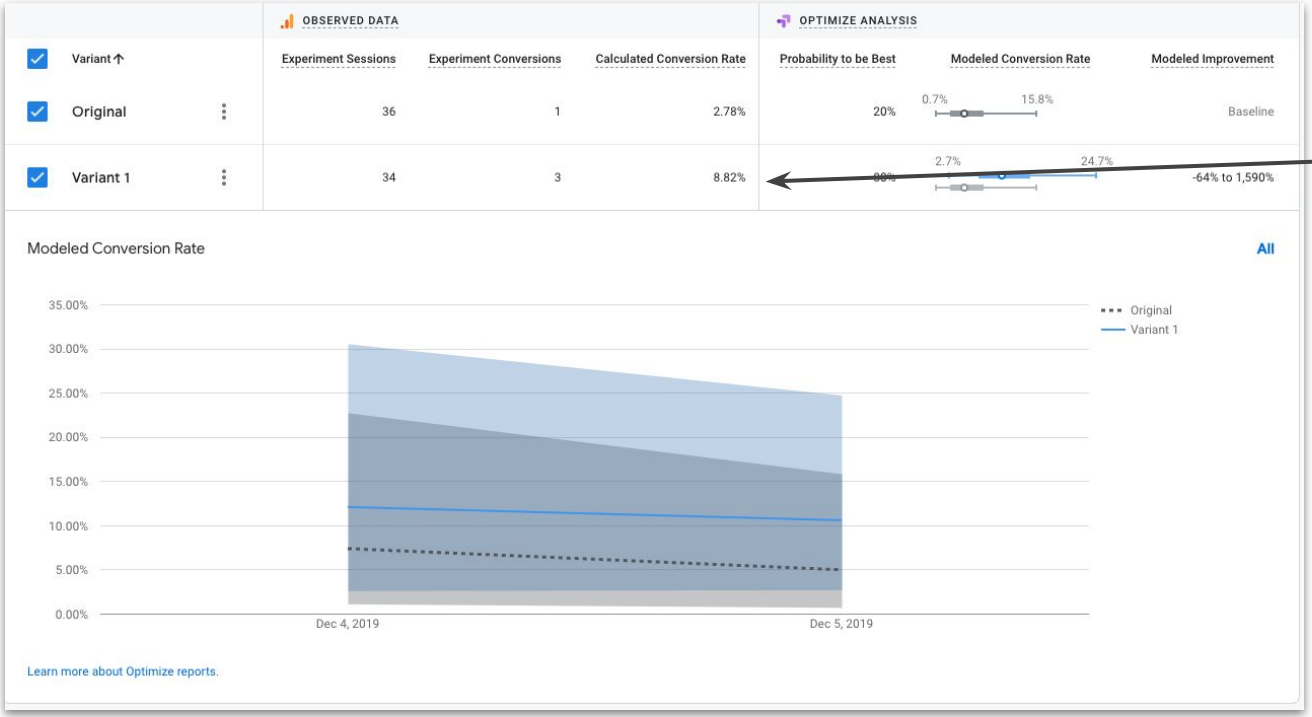
Don't just go off of mean: Outliers, changes in rates, can affect .

#2. Use Bootstrap for Confidence Intervals

Explain: 95% of time the range is between -0.38% and +0.01% with the mean of -0.16%.

Use Significance: Say with significance that we should or should not make the change.

Pro-Tips



Can I trust this number?

Absolutely not.

I haven't run for 2 weeks.

I don't know if this trend will persist.

What We Just Did

And how WE did it!

A/B Testing Workflow

Step-By-Step

Google Optimize

Perform A/B Testing

dplyr & ggplot2

A/B Test Data Wrangling and Visualization

infer

Hypothesis Testing & Confidence Interval Estimation

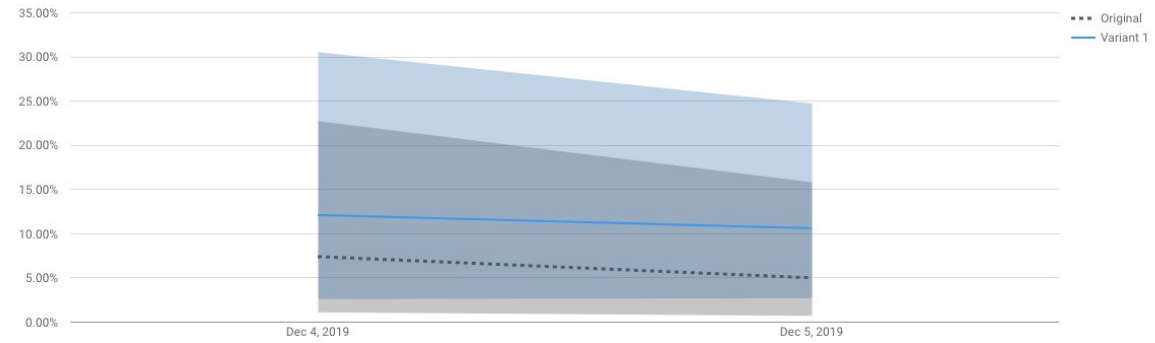
Google Optimize

Optimize

	OBSERVED DATA			OPTIMIZE ANALYSIS		
Variant ↑	Experiment Sessions	Experiment Conversions	Calculated Conversion Rate	Probability to be Best	Modeled Conversion Rate	Modeled Improvement
Original	36	1	2.78%	20%	0.7% 15.8%	Baseline
Variant 1	34	3	8.82%	80%	2.7% 24.7%	-64% to 1,590%

Modeled Conversion Rate

All

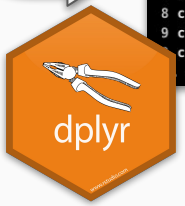


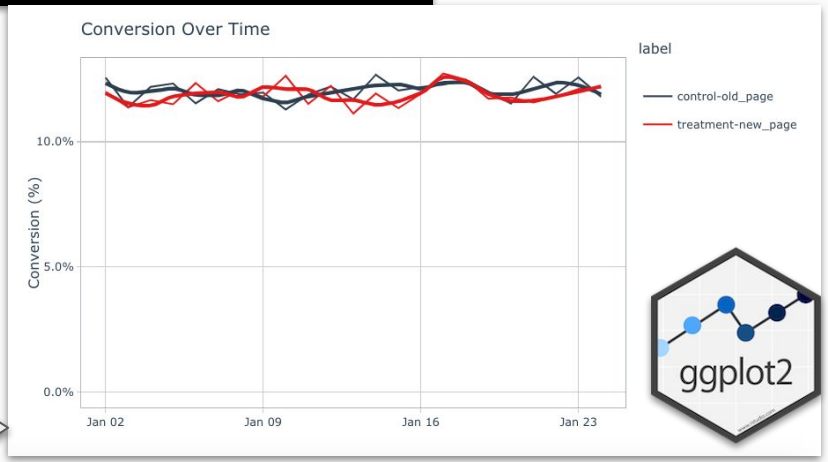
Learn more about Optimize reports.

dplyr & ggplot2

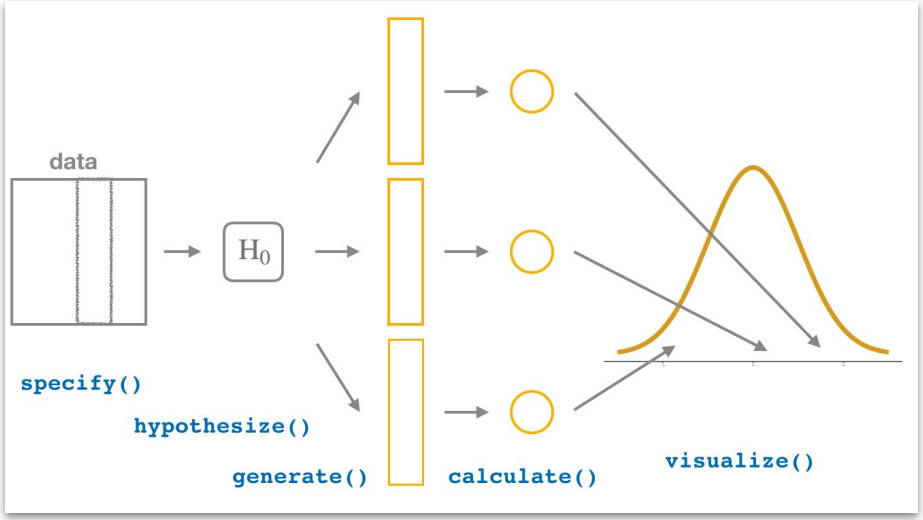
```
# A tibble: 290,585 x 7
   user_id timestamp           group     landing_page converted label              visit_count
     <dbl> <dttm>              <chr>     <chr>            <dbl> <chr>                    <dbl>
 1  922696 2017-01-02 13:42:05 treatment new_page             0 treatment-new_page           1
 2  781507 2017-01-02 13:42:15 control   old_page             0 control-old_page             1
 3  737319 2017-01-02 13:42:21 control   old_page             0 control-old_page             1
 4  818377 2017-01-02 13:42:26 treatment new_page             0 treatment-new_page           1
 5  725857 2017-01-02 13:42:27 treatment new_page             0 treatment-new_page           1
 6  762651 2017-01-02 13:42:28 treatment new_page             0 treatment-new_page           1
 7  722516 2017-01-02 13:42:34 treatment new_page             0 treatment-new_page           1
 8  688937 2017-01-02 13:42:41 treatment new_page             0 treatment-new_page           1
 9  781125 2017-01-02 13:42:45 treatment new_page             0 treatment-new_page           1
10  799109 2017-01-02 13:42:45 control   old_page             0 control-old_page             1
# … with 290,575 more rows
```

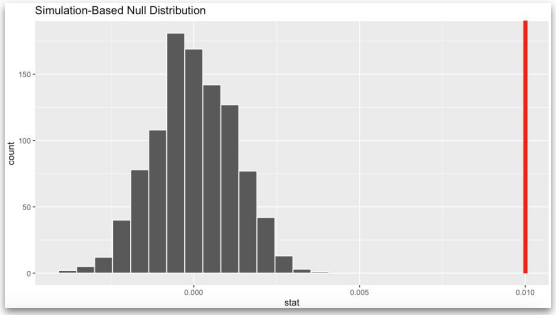
```
# A tibble: 46 x 5
   label           date                count conversion  prop
   <chr>           <dttm>              <int>      <dbl> <dbl>
 1 control-old_page 2017-01-02 00:00:00  2859        359 0.126
 2 control-old_page 2017-01-03 00:00:00  6590        750 0.114
 3 control-old_page 2017-01-04 00:00:00  6578        802 0.122
 4 control-old_page 2017-01-05 00:00:00  6427        792 0.123
 5 control-old_page 2017-01-06 00:00:00  6606        762 0.115
 6 control-old_page 2017-01-07 00:00:00  6604        799 0.121
 7 control-old_page 2017-01-08 00:00:00  6687        795 0.119
 8 control-old_page 2017-01-09 00:00:00  6628        793 0.120
 9 control-old_page 2017-01-10 00:00:00  6654        751 0.113
   control-old_page 2017-01-11 00:00:00  6688        795 0.119
  with 36 more rows
```

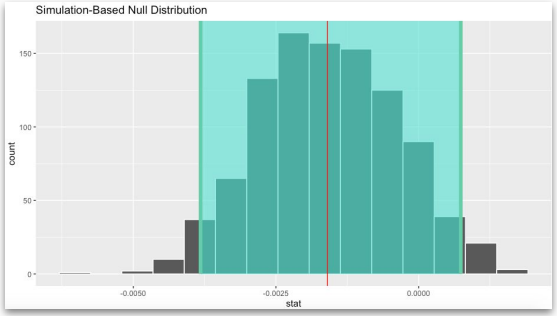




Infer Workflow





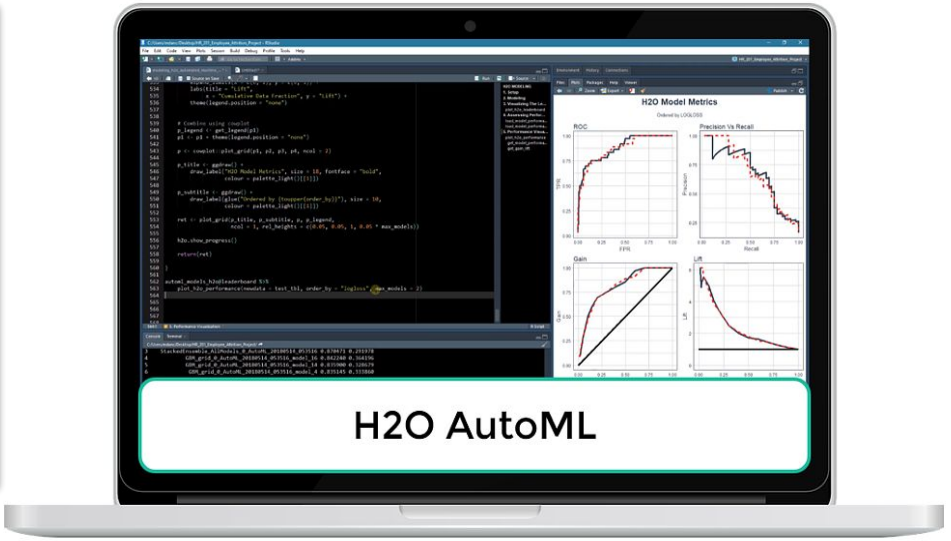


A lot more to learn... Advanced ML

H2O.ai

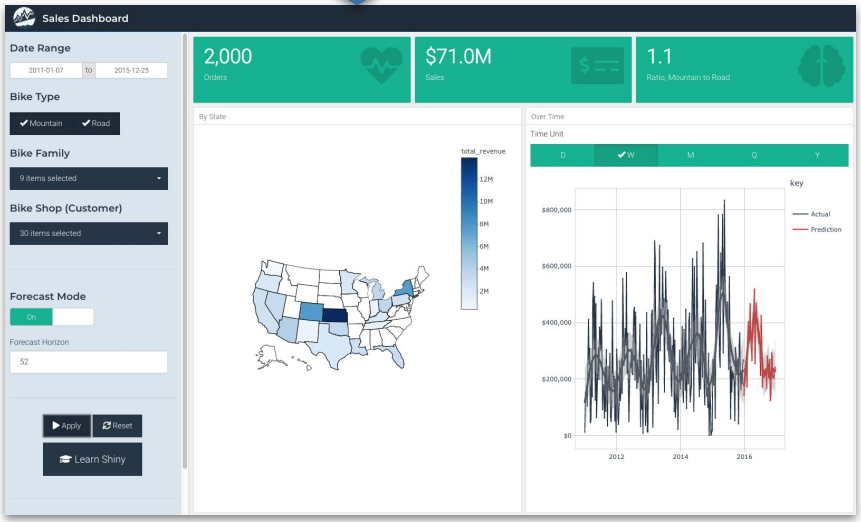
201

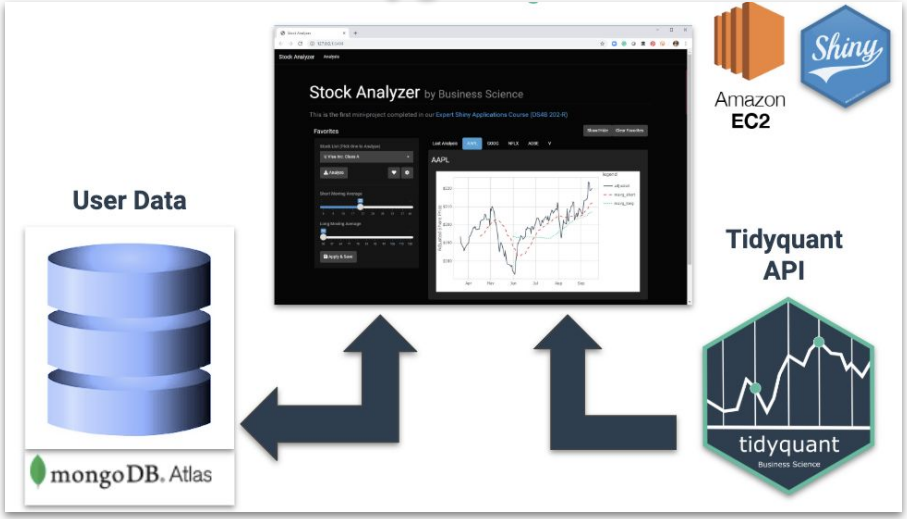
```
> h2o.predict(h2o_model, newdata = as.h2o(credit_card_group_tbl)) %>%
+   as_tibble()
  |======================================================================
  |======================================================================
# A tibble: 1,125 x 7
   predict      p1        p2        p3      p4        p5   Other
   <fct>     <dbl>     <dbl>     <dbl>   <dbl>     <dbl>   <dbl>
 1 Other   0       0.0000704 0.0228    0       0         0.977
 2 Other   0.0232  0.0000717 0.0000553 0       0.00376   0.973
 3 Other   0       0.0000737 0.0238    0       0.000107  0.976
 4 Other   0.00643 0.0000724 0.0000558 0.00343 0.000105  0.990
 5 Other   0       0.0000720 0.0000555 0       0.000104  1.000
 6 3       0       0.0000704 0.909     0       0.000102  0.0909
 7 3       0       0.0000761 0.995     0       0.000110  0.00491
 8 1       0.984   0.0000735 0.0000567 0.00349 0.000106  0.0127
 9 Other   0.195   0.0000602 0.0000464 0.00285 0.0000870 0.802
10 Other   0       0.0000737 0.0000568 0       0         1.000
# … with 1,115 more rows
```



A lot more to learn... Web Apps

102 & 202A





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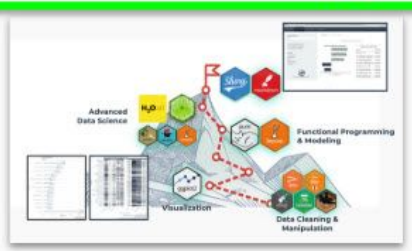
R-TRACK

LEARNING LABS PRO



Do Business Projects
Climb the Hill

Build Production-Ready
Web Apps

Complete 1-Hour Courses
Continuous Education

Start

1

2

3

Finish

Analysis Courses
101 & 201

App Development Courses
102

Learning Labs PRO

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4-Course R-Track System

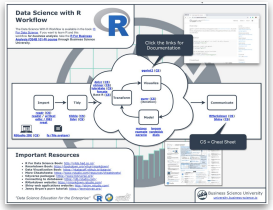
Business Analysis with R
(DS4B 101-R)

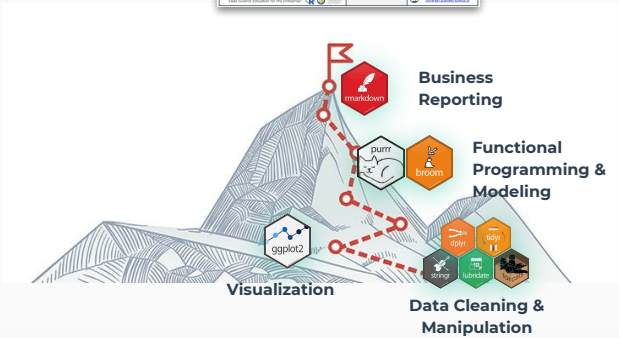
Data Science For Business with R
(DS4B 201-R)

Web Apps & Shiny Developer
(DS4B 102-R + DS4B 202A-R)

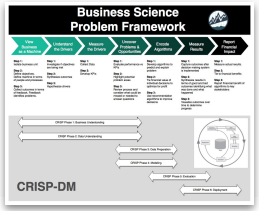
Project-Based Courses with Business Application

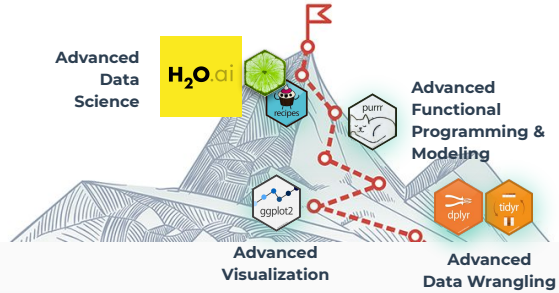
Data Science Foundations
7 Weeks



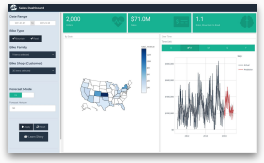


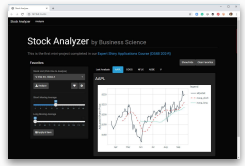
Machine Learning & Business Consulting
10 Weeks





Web Application Development
12 Weeks





Key Benefits

- Fundamentals - Weeks 1-5 (25 hours of Video Lessons)
  - Data Manipulation (dplyr)
  - Time series (lubridate)
  - Text (stringr)
  - Categorical (forcats)
  - Visualization (ggplot2)
  - Programming & Iteration (purrr)
  - 3 Challenges

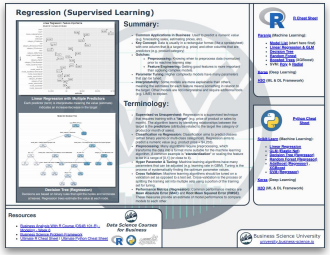
- **Machine Learning - Week 6 (8 hours of Video Lessons)**
  - **Clustering (3 hours)**
  - **Regression (5 hours)**
  - **2 Challenges**

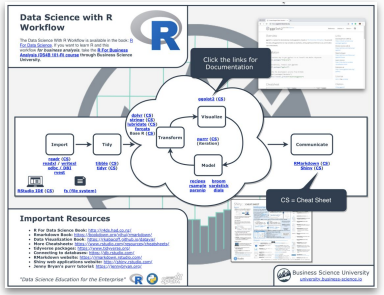
- Learn Business Reporting - Week 7
  - RMarkdown & plotly
  - 2 Project Reports:
    1. Product Pricing Algo
    2. Customer Segmentation

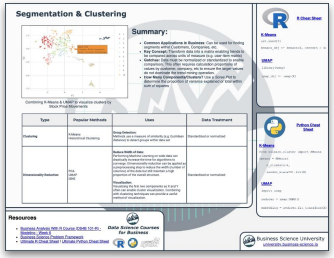
Business Analysis with R (DS4B 101-R)

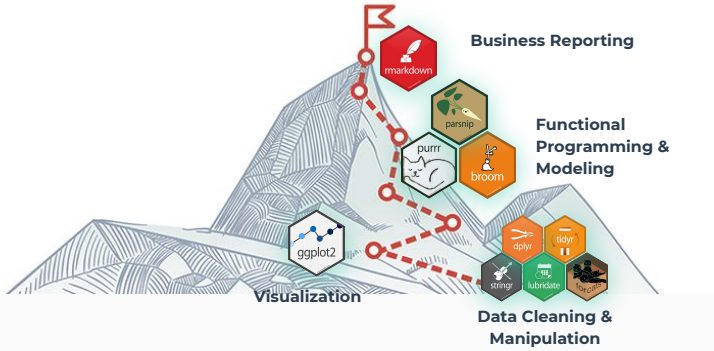
Data Science Foundations

7 Weeks









Key Benefits

End-to-End Churn Project

Understanding the Problem & Preparing Data - Weeks 1-4

- Project Setup & Framework
- Business Understanding / Sizing Problem
- Tidy Evaluation - rlang
- EDA - Exploring Data -GGally, skimr
- Data Preparation - recipes
- Correlation Analysis
- 3 Challenges

Machine Learning - Weeks 5, 6, 7

- **H2O AutoML - Modeling Churn**
- **ML Performance**
- **LIME Feature Explanation**

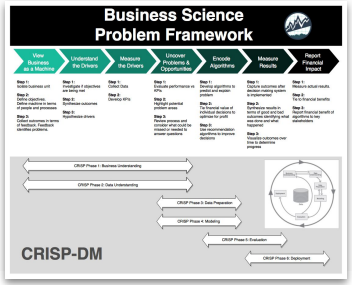
Return-On-Investment - Weeks 7, 8, 9

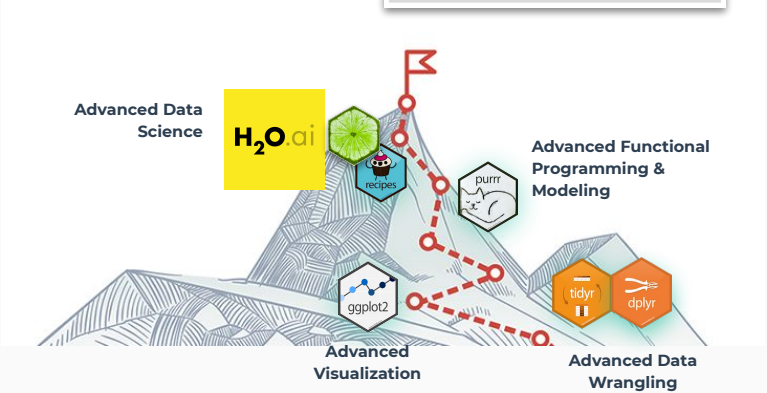
- **Expected Value Framework**
- **Threshold Optimization**
- **Sensitivity Analysis**
- **Recommendation Algorithm**

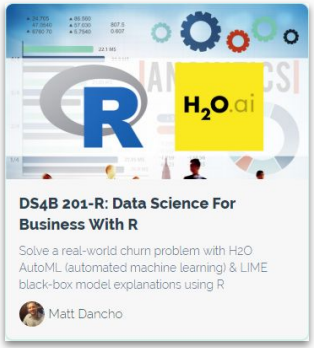
Data Science For Business (DS4B 201-R)

Machine Learning & Business Consulting

10 Weeks







Key Benefits

Learn Shiny & Flexdashboard
- Build Applications
- Learn Reactive Programming
- Integrate Machine Learning

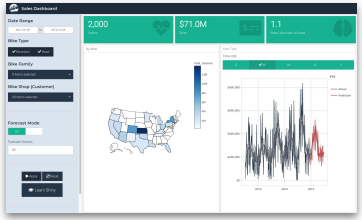
App #1: Predictive Pricing App
- Model Product Portfolio
- XGBoost Pricing Prediction
- Generate new products instantly

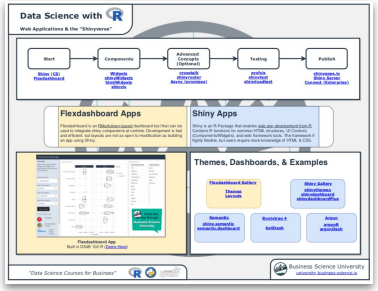
App #2: Sales Dashboard with Demand Forecasting
- Model Demand History
- Segment Forecasts by Product & Customer
- XGBoost Time Series Forecast
- Generate new forecasts instantly

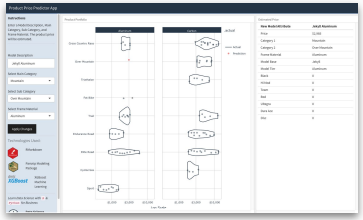
Shiny Apps for Business (DS4B 102-R)

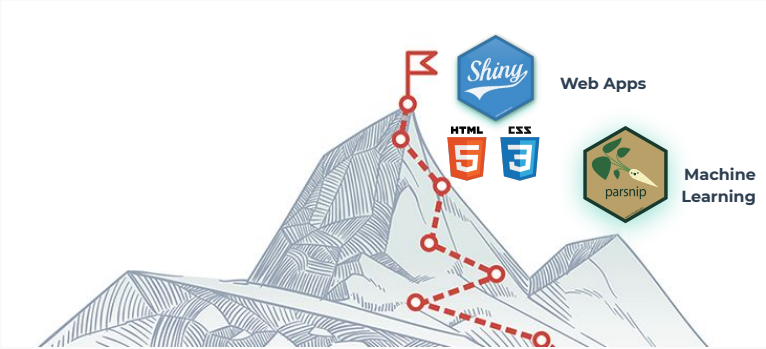
Web Application Development

4 Weeks









Key Benefits

Frontend + Backend + Production Deployment

Frontend for Shiny
- Bootstrap

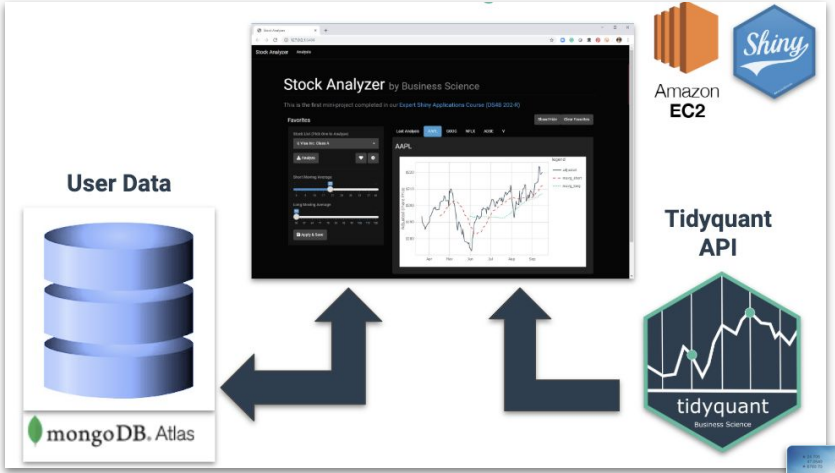
Backend for Shiny
- MongoDB
- Dynamic UI
- User Authentication
- Store & Write User Data

Production Deployment
- AWS
- EC2 Server
- VPC Connection
- URL Routing

Shiny Apps for Business (DS4B 202A-R)

Web Application Development

6 Weeks



aws

docker git Bootstrap mongoDB.

15% OFF PROMO Code: learninglabs

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Matt Dancho

DS4B 102-R: Shiny Web Applications For Business (Level 1)

Build a predictive web application using Shiny, Flexdashboard, and XGBoost

Matt Dancho

DS4B 201-R: Data Science For Business With R

Solve a real-world churn problem with H2O AutoML (automated machine learning) & LIME black-box model explanations using R

Matt Dancho

DS4B 202A-R: Expert Shiny Developer with AWS

Learn how to build Scalable Data Science Applications using R, Shiny, and AWS Cloud Technology.

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