Anomaly Detection

For Time Series

Difficulty: **Intermediate**

Matt Dancho & David Curry

Business Science Learning Lab

Learning Lab Structure

- **Presentation**
  (30 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**.

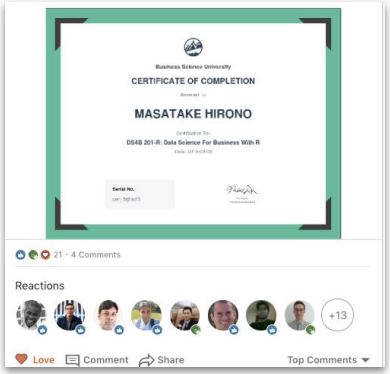
Success Story

Masatake Hirono

- Took 201
- Completed the 10-Week Course
- **Landed a Job at one of the most Prestigious Management Consulting Firms**

"This course showed me how to place data analytics in real business settings."

#Business Science Success



Agenda

- **Business Case Study**
  - Google Analytics
  - Web Traffic
  - Anomalies
- **30-Min Demo**
  - Web traffic
  - data.table
  - anomalize
- **Anomalies**
  - 3 Types
  - Algorithms
- **Pro-Tips:**
  - Tactics to Improve Forecasts
- **Time Series Anomaly Detection**
  - Anomalize Software
  - 80/20 Concepts
  - 3 Key Functions
  - Game Plan

Learning Labs PRO

Every 2-Weeks

1-Hour Course

Recordings + Code + Slack

$19/month

university.business-science.io

Lab 17
Anomaly Detection with H2O Machine Learning

Lab 16
R's Optimization Toolchain, Part 2 - Nonlinear Programming

Lab 15
R's Optimization Toolchain, Part 1 - Linear Programming

Lab 14
Customer Churn Survival Analysis

Lab 13
Wrangling 4.6M Rows of Financial Data w/ data.table

Lab 12
How I built anomalize

Continuous Learning
Jet Fuel for your Brain

Anomaly Detection

Business Case

Anomalous Web Traffic

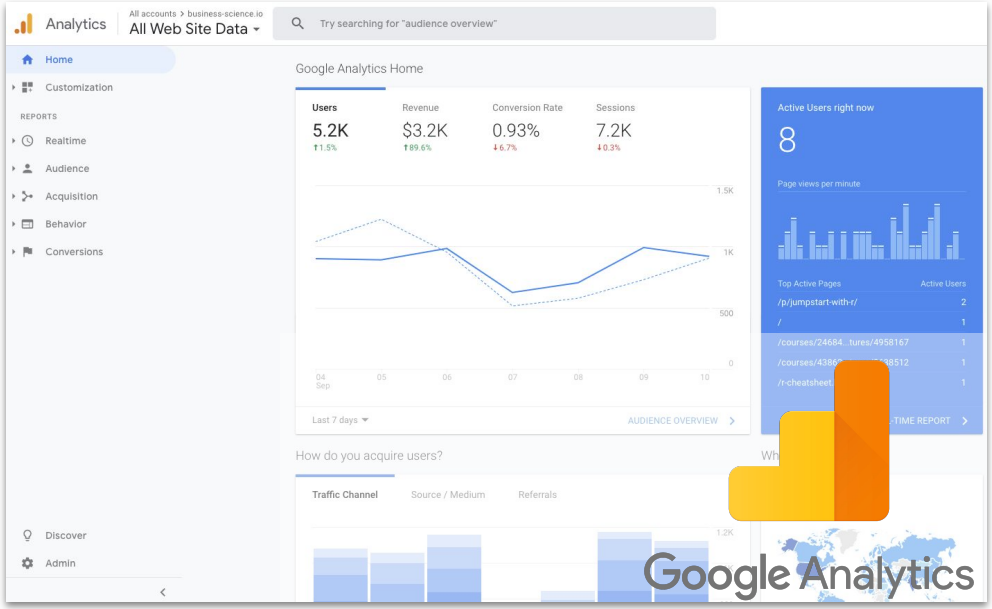
Revenue & Web Traffic

Consumers **spend billions** online every year

Web-based companies can use web-traffic to **forecast cashflow**

Anomalies:

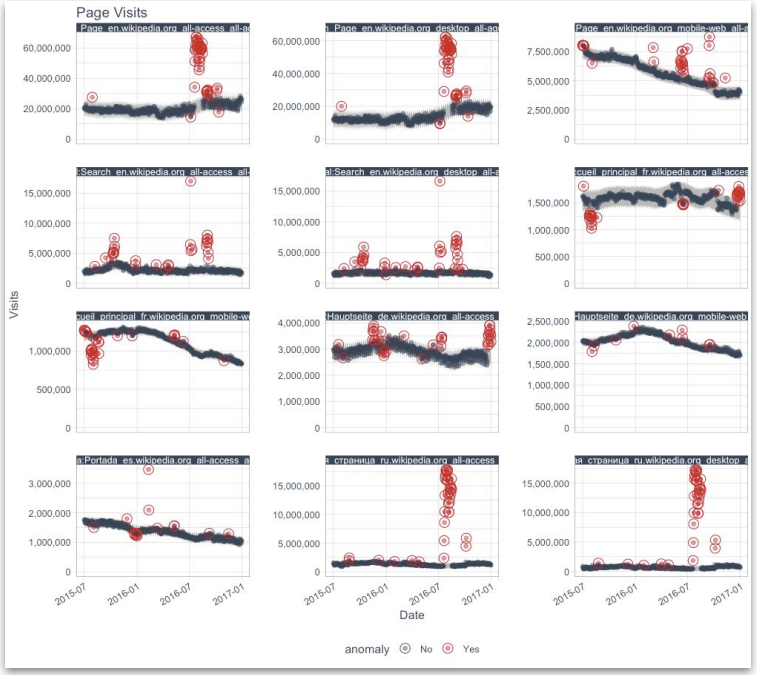
- Can flag important **events**
- Can impact the **forecast accuracy**



Anomalous Web Traffic

Key Issues

1. **1000's** of web pages
2. Scaling the data preparation (**cleaning of anomalies**) for forecasting
3. **Linking events** to anomalous data



What are Anomalies?

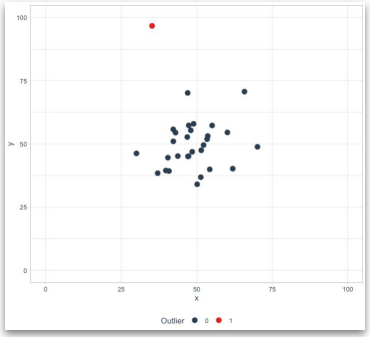
Recap from Lab 17

Types of Anomalies

1

Point Anomalies

Single Point

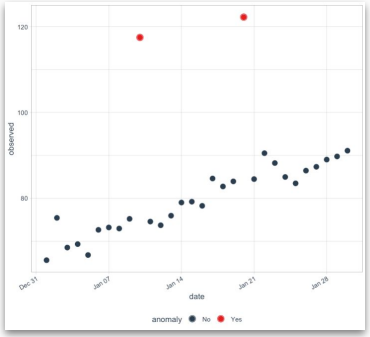


H2O Isolation Forest
H2O K-Means

2

Contextual

Time Series



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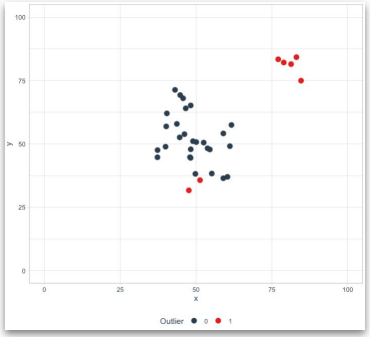
3

Collective

Cluster of Points



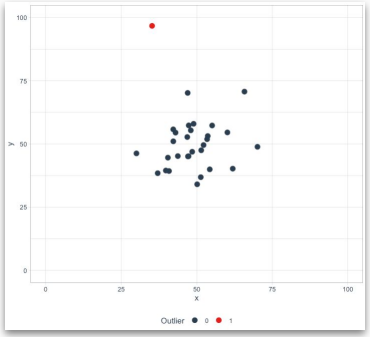
H2O Isolation Forest
H2O K-Means

Types of Anomalies

1

Point Anomalies

Single Point



H2O Isolation Forest
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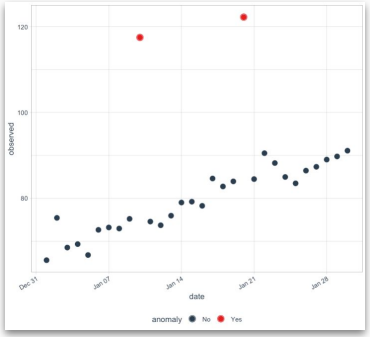

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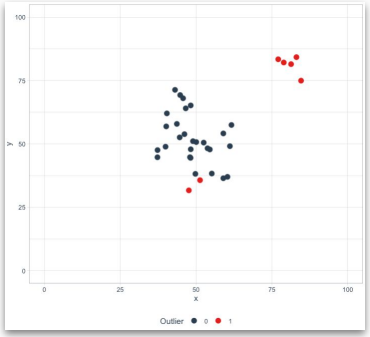


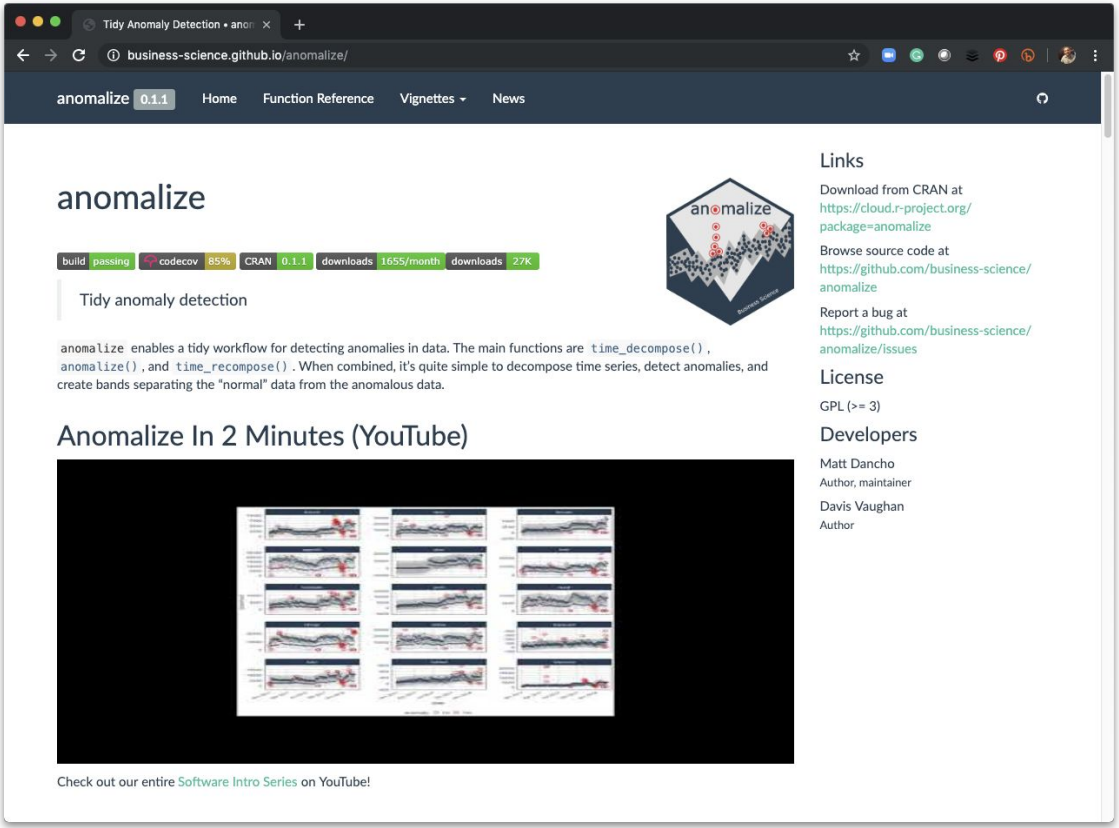
H2O Isolation Forest
H2O K-Means

Time Series Anomaly Detection

Software

Time Series Anomaly Detection

Anomalize enables a simple workflow for **scalable** anomaly detection for time series



https://business-science.github.io/anomalize/

Anomalize

80/20 Concepts & Important Operations

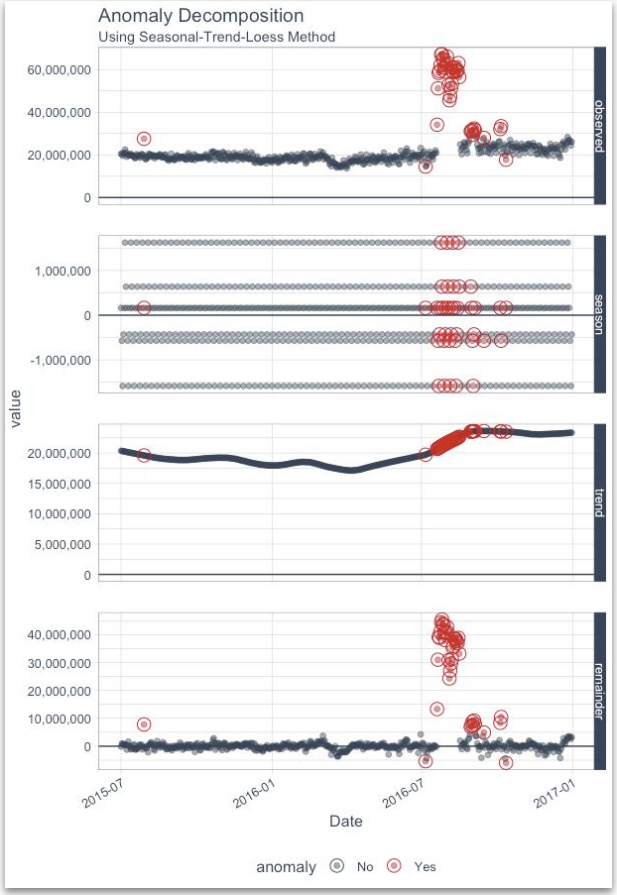
1. STL Method

Algorithm Internal Process

- Uses **STL Decomposition** to decompose time series into *seasonal, trend & remainder*
- The key is the **remainders (residuals)**
- Uses **IQR or GESD** to detect anomalies

Key Concept

Outliers have **have abnormal residuals (remainders)**



Observed

\- **Seasonal Component**

\- **Trend Component**

Remaining Component (remainder)

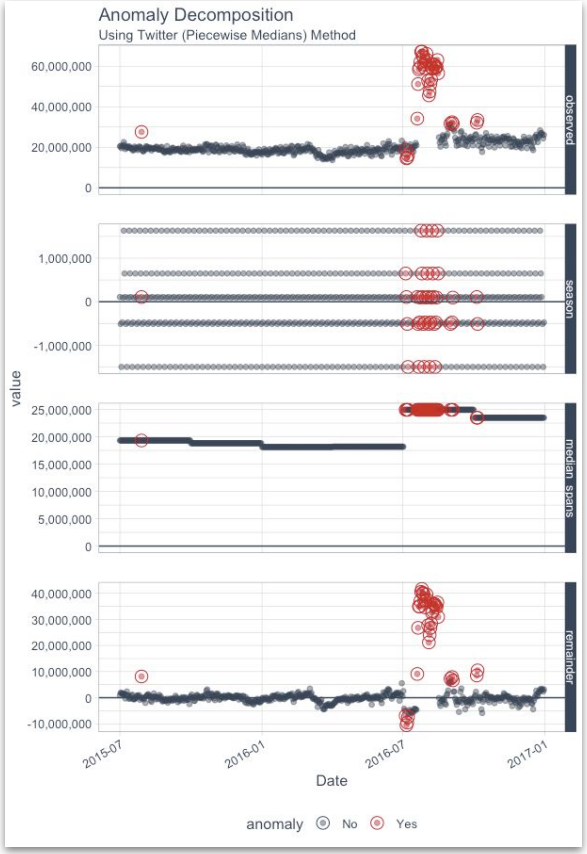
2. Twitter Method

Algorithm Internal Process

- Uses **Piecewise Medians Decomposition** to decompose time series into *seasonal, trend & remainder*
- The key is the **remainders (residuals)**
- Uses **IQR or GESD** to detect anomalies

Key Concept

Only difference is using Piecewise Medians vs LOESS Trend



Observed

Seasonal Component

Median Component

Remaining Component (remainder)

Implementation

3-Step Process:

1. time_decompose()

Uses **STL or Twitter** to decompose time series into *seasonal, trend & remainder*

2. anomalize()

Uses **IQR or GESD** to detect anomalies

3. time_recompose()

Calculates outlier boundaries

```
143 wikipedia_main_page_tbl %>%
144     # Step 1 - STL Decomposition
145     time_decompose(
146         target   = Visits,
147         method   = "stl", # stl or twitter
148         merge    = TRUE,
149         frequency = "1 week",
150         trend     = "3 months"
151     ) %>%
152     # Step 2 - Detect Anomalies in Remainder (Residual Analysis)
153     anomalize(
154         target = remainder,
155         method = "iqr", # iqr or gesd
156         alpha  = 0.05
157     ) %>%
158     # Step 3 - Add Boundaries separating the anomaly lower and upper limits
159     time_recompose() %>%
160
```

Gameplan

Workflow & Tools

Web Forecasting

Workflow

data.table & ggplot2

Exploratory Data Analysis

anomalize

Anomaly Detection

Data Cleaning

parsnip, purrr & ggplot2

Forecast Web Traffic

30-Min Demo

Web Traffic Anomaly Detection & Forecasting

Secret Tactics for

Forecasting with Anomalies

Use these tips to
increase your forecasting performance

Pro Tip

Clean Your Anomalies

Option 1

Flag Anomalies

Just add the “Anomaly (Y/N)” as a Flag in your model

Pro

Predicts well when future has anomalies that are **similar to past** anomalies

Con

May reduce forecasting accuracy

Option 2

Clean Anomalies

Replace Anomaly Values with Trend + Seasonal Components

Pro

Improves Forecasting Performance

Con

Doesn’t predict well when future has anomalies

Pro Tip

Clean Your Anomalies

Option 1

Flag Anomalies

Just add the “Anomaly (Y/N)” as a Flag in your model

```
> mape_flagged_anoms
# A tibble: 1 x 1
  `mean(mape)`
         <dbl>
1        0.284
```

Option 2

Clean Anomalies

Replace Anomaly Values with Trend + Seasonal Components

```
> mape_cleaned_anoms
# A tibble: 1 x 1
  `mean(mape)`
         <dbl>
1        0.139
```

51%

Improvement

Data Science Transformational

Skills that are needed to do what we just did

Web Forecasting

Step-By-Step

data.table & ggplot2

Exploratory Data Analysis

101 & Lab 13

anomalize

Anomaly Detection

Data Cleaning

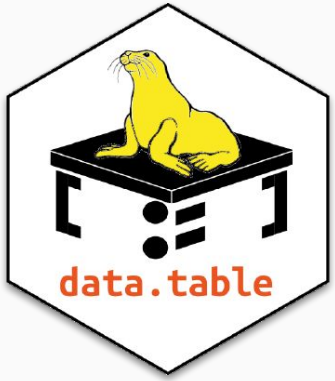
Lab 18

parsnip, purrr & ggplot2

Forecast Web Traffic

101 & 201

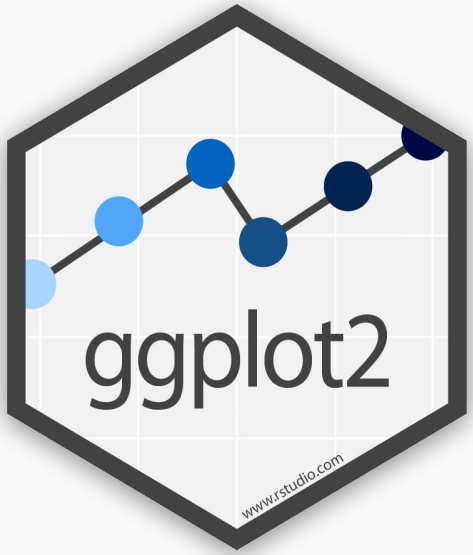
data.table - wrangling 80M rows



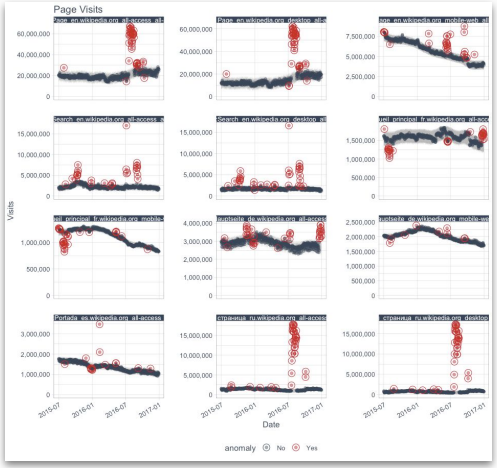
Pro-Tip:
Learn *dplyr* first


```
26  # 3.2 Setup in Long Format ----
27  page_visits_dt <- melt(
28      page_visits_dt,
29      id.vars      = c("Page"),
30      measure.vars = setdiff(names(page_visits_dt), "Page")
31  )
32
33  names(page_visits_dt) <- c("Page", "Date", "Visits")
34  # page_visits_dt$Date <- anytime::anydate(page_visits_dt$Date)
35  setkey(page_visits_dt, "Page")
36
37  page_visits_dt %>% glimpse()
38
39
40  # 3.3 Prep & Functions ----
41  page_visit_counts_dt <- page_visits_dt %>%
42      .[, .(visits_sum    = sum(Visits, na.rm = TRUE),
43            visits_mean   = mean(Visits, na.rm = TRUE),
44            visits_median = median(Visits, na.rm = TRUE),
45            visits_count  = sum(Visits > 0)),
46        keyby = .(Page)] %>%
47      .[, ratio := visits_mean / (visits_median + 1)]
48
49  page_visit_counts_dt %>% glimpse()
```

101 & 201
Lab 13



101 & 201




```
# AFTER CLEANING ----
pages_most_visited_anom_tbl %>%
  ggplot(aes(Date, visits_cleaned)) +
  geom_point(alpha = 0.5, color = palette_light()[[1]]) +
  facet_wrap(~ Page, ncol = 3, scales = "free_y") +
  expand_limits(y = 0) +
  scale_y_continuous(labels = scales::comma) +
  theme_tq()
```

ggplot2 & purrr


```
21      })) %>%
22
23      # Apply model to training set
24      mutate(model = map(split, .f = function(split) {
25          trn_tbl <- split %>%
26              training() %>%
27              timetk::tk_augment_timeseries_signature() %>%
28              select(-diff)
29
30          model <- linear_reg(mixture = 0.5) %>%
31              set_engine("glmnet") %>%
32              fit.model_spec(visits_cleaned ~ . - Date, data = trn_tbl)
33
34          return(model)
35      })) %>%
```

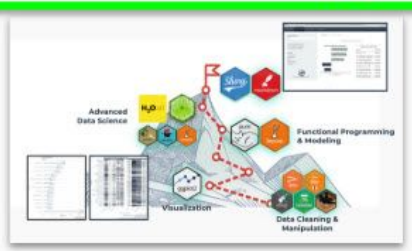
Business Science University

Our program that will TRANSFORM YOU in weeks, not years.

The program that will deliver YOUR Transformation

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

Everything is **Taken Care of** For You in Our Platform

3-Course R-Track System

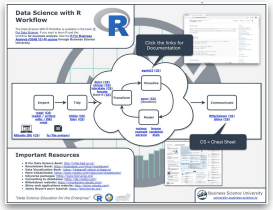
Business Analysis with R
(DS4B 101-R)

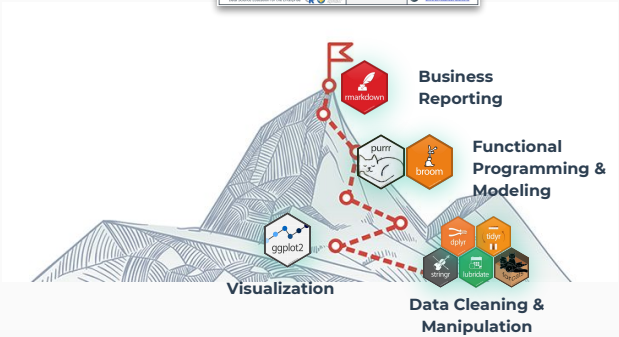
Data Science For Business with R
(DS4B 201-R)

R Shiny Web Apps For Business
(DS4B 102-R)

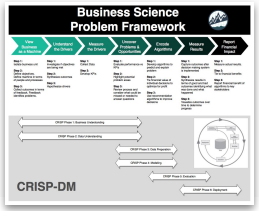
Project-Based Courses with Business Application

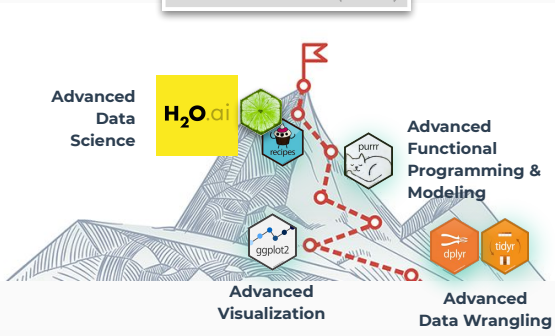
Data Science Foundations
7 Weeks



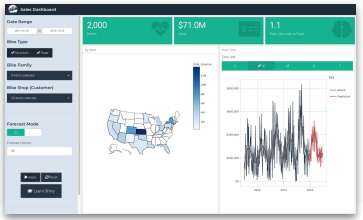


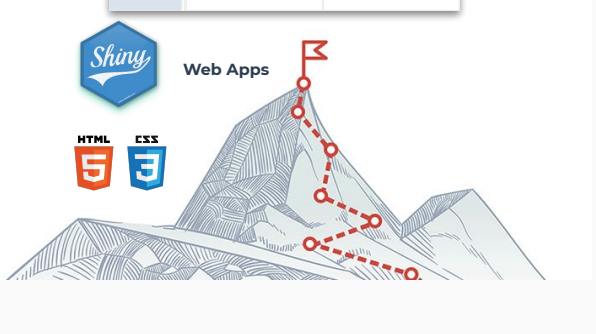
Machine Learning & Business Consulting
10 Weeks





Web Application Development
4 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

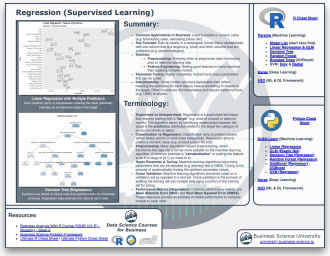
- **Machine Learning - Week 6 (8 hours of Video Lessons)**
  - **Clustering (3 hours)**
  - **Regression (5 hours)**
  - **2 Challenges**

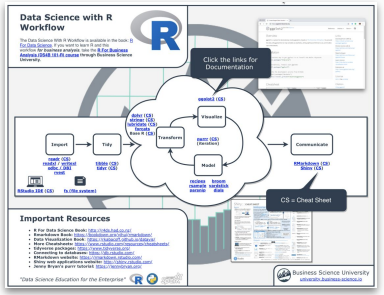
- Learn Business Reporting - Week 7
  - RMarkdown & plotly
  - 2 Project Reports:
    1. Product Pricing Algo
    2. Customer Segmentation

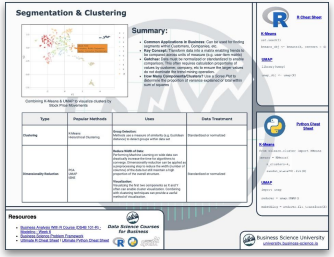
Business Analysis with R (DS4B 101-R)

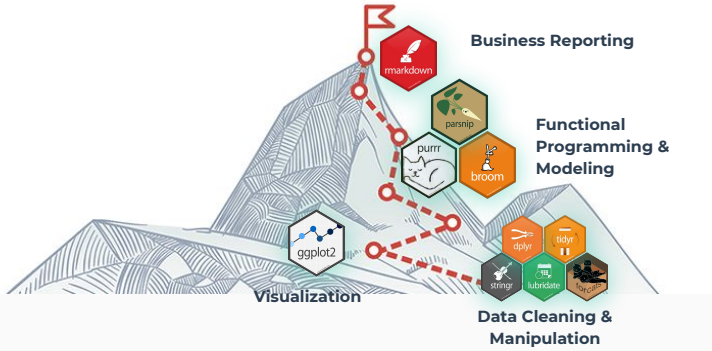
Data Science Foundations

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**

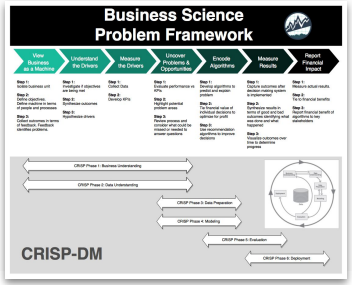
Return-On-Investment - Weeks 7, 8, 9

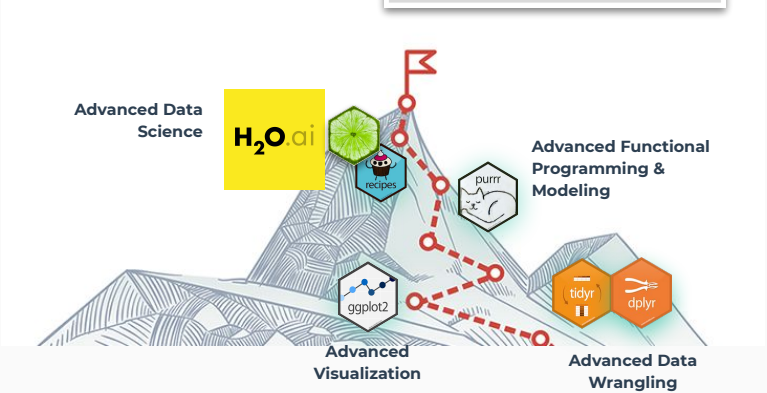
- **Expected Value Framework**
- **Threshold Optimization**
- **Sensitivity Analysis**
- **Recommendation Algorithm**

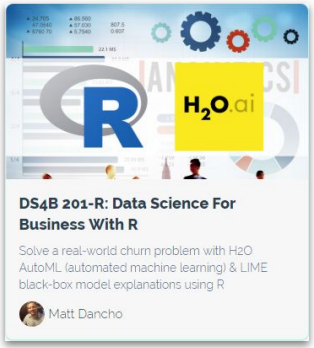
Data Science For Business (DS4B 201-R)

Machine Learning & Business Consulting

10 Weeks







Key Benefits

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

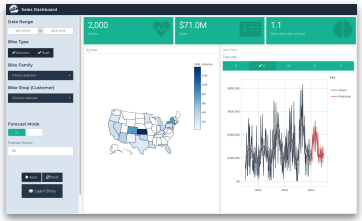
App #1: Predictive Pricing App
- Model Product Portfolio
- XGBoost Pricing Prediction
- Generate new products instantly

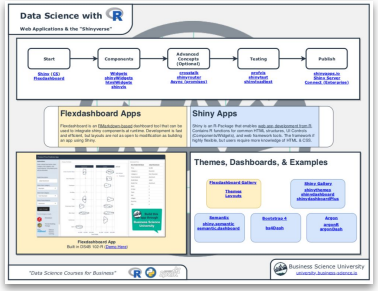
App #2: Sales Dashboard with Demand Forecasting
- Model Demand History
- Segment Forecasts by Product & Customer
- XGBoost Time Series Forecast
- Generate new forecasts instantly

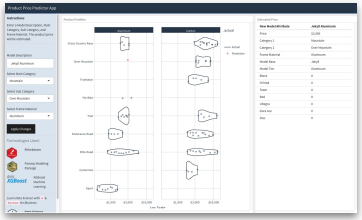
Shiny Apps for Business (DS4B 102-R)

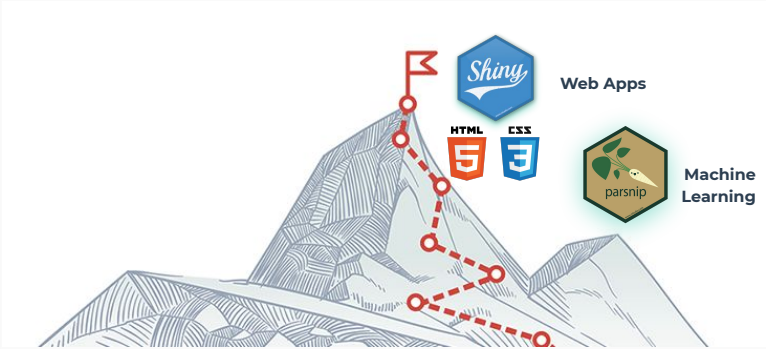
Web Application Development

4 Weeks









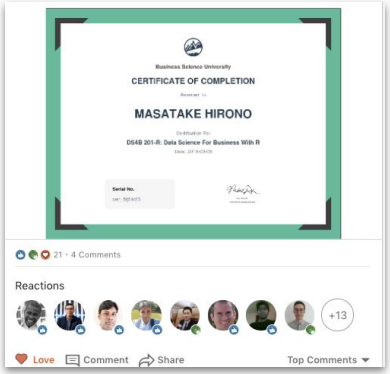
Success Story

Masatake Hirono

- Took DS4B 201-R
- Completed the 10-Week Course
- **Landed a Job at one of the most Prestigious Management Consulting Firms**

"This course showed me how to place data analytics in real business settings."

#Business Science Success



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