ML fundmentals - Company Segmentation

7/24/2020

Contents

Challenge Summary

Your organization wants to know which companies are similar to each other to help in identifying potential customers of a SAAS software solution (e.g. Salesforce CRM or equivalent) in various segments of the market. The Sales Department is very interested in this analysis, which will help them more easily penetrate various market segments.

You will be using stock prices in this analysis. You come up with a method to classify companies based on how their stocks trade using their daily stock returns (percentage movement from one day to the next). This analysis will help your organization determine which companies are related to each other (competitors and have similar attributes).

You can analyze the stock prices using what you've learned in the unsupervised learning tools including K-Means and UMAP. You will use a combination of `kmeans()` to find groups and `umap()` to visualize similarity of daily stock returns.

Objectives

Apply your knowledge on K-Means and UMAP along with dplyr, ggplot2, and purrr to create a visualization that identifies subgroups in the S&P 500 Index. You will specifically apply:

- Modeling: kmeans() and umap()
- Iteration: purrr
- Data Manipulation: dplyr, tidyr, and tibble
- Visualization: ggplot2 (bonus plotly)

Libraries

Load the following libraries.

```
# install.packages("plotly")

library(tidyverse)
library(tidyquant)
library(broom)
library(umap)
library(ggrepel) # Addon for ggplot, so that the labels do not overlap
```

Data

We will be using stock prices in this analysis. Although some of you know already how to use an API to retrieve stock prices I obtained the stock prices for every stock in the S&P 500 index for you already. The files are saved in the session_6_data directory.

We can read in the stock prices. The data is 1.2M observations. The most important columns for our analysis are:

- symbol: The stock ticker symbol that corresponds to a company's stock price
- date: The timestamp relating the symbol to the share price at that point in time
- adjusted: The stock price, adjusted for any splits and dividends (we use this when analyzing stock data over long periods of time)

```
# STOCK PRICES
sp_500_prices_tbl <- read_rds("sp_500_prices_tbl.rds")
sp_500_prices_tbl
```

```
## # A tibble: 1,225,765 x 8
##    symbol date        open  high   low close   volume adjusted
##    <chr>  <date>     <dbl> <dbl> <dbl> <dbl>    <dbl>    <dbl>
##  1 MSFT   2009-01-02  19.5  20.4  19.4  20.3 50084000     15.9
##  2 MSFT   2009-01-05  20.2  20.7  20.1  20.5 61475200     16.0
##  3 MSFT   2009-01-06  20.8  21    20.6  20.8 58083400     16.2
##  4 MSFT   2009-01-07  20.2  20.3  19.5  19.5 72709900     15.2
##  5 MSFT   2009-01-08  19.6  20.2  19.5  20.1 70255400     15.7
##  6 MSFT   2009-01-09  20.2  20.3  19.4  19.5 49815300     15.2
##  7 MSFT   2009-01-12  19.7  19.8  19.3  19.5 52163500     15.2
##  8 MSFT   2009-01-13  19.5  20.0  19.5  19.8 65843500     15.5
##  9 MSFT   2009-01-14  19.5  19.7  19.0  19.1 80257500     14.9
## 10 MSFT   2009-01-15  19.1  19.3  18.5  19.2 96169800     15.0
## # ... with 1,225,755 more rows
```

The second data frame contains information about the stocks the most important of which are:

- company: The company name
- sector: The sector that the company belongs to

```
# SECTOR INFORMATION
sp_500_index_tbl <- read_rds("sp_500_index_tbl.rds")
sp_500_index_tbl
```

```
##     symbol                                             company       weight
## 1     MSFT                               Microsoft Corporation 3.589659e-02
## 2     AAPL                                          Apple Inc. 3.299844e-02
## 3     AMZN                                     Amazon.com Inc. 2.834845e-02
## 4    BRK.B                     Berkshire Hathaway Inc. Class B 1.714493e-02
## 5       FB                               Facebook Inc. Class A 1.676060e-02
## 6      JNJ                                   Johnson & Johnson 1.570168e-02
## 7      JPM                                JPMorgan Chase & Co. 1.507235e-02
## 8     GOOG                               Alphabet Inc. Class C 1.470747e-02
## 9    GOOGL                               Alphabet Inc. Class A 1.436854e-02
## 10     XOM                             Exxon Mobil Corporation 1.412361e-02
## 11     BAC                                Bank of America Corp 1.141184e-02
## 12     UNH                     UnitedHealth Group Incorporated 1.119696e-02
## 13       V                                   Visa Inc. Class A 1.093462e-02
## 14      PG                            Procter & Gamble Company 1.053192e-02
## 15     PFE                                         Pfizer Inc. 1.052585e-02
## 16    INTC                                   Intel Corporation 1.012464e-02
## 17     CVX                                 Chevron Corporation 9.790428e-03
## 18      VZ                         Verizon Communications Inc. 9.784105e-03
## 19    CSCO                                  Cisco Systems Inc. 9.544976e-03
## 20       T                                           AT&T Inc. 9.518933e-03
## 21      BA                                      Boeing Company 9.479343e-03
## 22      HD                                     Home Depot Inc. 9.332370e-03
## 23     WFC                               Wells Fargo & Company 8.957703e-03
## 24     MRK                                    Merck & Co. Inc. 8.915412e-03
## 25      MA                     Mastercard Incorporated Class A 8.635942e-03
## 26      KO                                   Coca-Cola Company 7.439485e-03
## 27   CMCSA                         Comcast Corporation Class A 7.368779e-03
## 28     DIS                                 Walt Disney Company 7.194712e-03
## 29     PEP                                        PepsiCo Inc. 7.023937e-03
## 30       C                                      Citigroup Inc. 6.744127e-03
## 31    NFLX                                        Netflix Inc. 6.680205e-03
## 32     WMT                                        Walmart Inc. 6.127690e-03
## 33     MCD                              McDonald’s Corporation 5.961227e-03
## 34     ABT                                 Abbott Laboratories 5.673213e-03
## 35    ORCL                                  Oracle Corporation 5.649621e-03
## 36      PM                    Philip Morris International Inc. 5.569381e-03
## 37    ADBE                                          Adobe Inc. 5.423148e-03
## 38      IBM         International Business Machines Corporation 5.378546e-03
## 39      UNP                           Union Pacific Corporation 5.373873e-03
## 40     DWDP                                      DowDuPont Inc. 5.343558e-03
## 41      MDT                                       Medtronic plc 5.320276e-03
## 42     ABBV                                         AbbVie Inc. 5.227510e-03
## 43      MMM                                          3M Company 5.225519e-03
## 44      CRM                                 salesforce.com inc. 5.221497e-03
## 45     AMGN                                          Amgen Inc. 5.154364e-03
## 46     AVGO                                       Broadcom Inc. 5.010262e-03
## 47      LLY                               Eli Lilly and Company 4.959256e-03
## 48      HON                        Honeywell International Inc. 4.860377e-03
## 49     PYPL                                 PayPal Holdings Inc 4.796215e-03
## 50      NKE                                   NIKE Inc. Class B 4.662578e-03
## 51      UTX                     United Technologies Corporation 4.450672e-03
## 52      TXN                      Texas Instruments Incorporated 4.437206e-03
## 53      TMO                       Thermo Fisher Scientific Inc. 4.363659e-03
## 54      ACN                               Accenture Plc Class A 4.355615e-03
## 55     NVDA                                  NVIDIA Corporation 4.119677e-03
## 56     COST                        Costco Wholesale Corporation 4.072393e-03
## 57      LIN                                           Linde plc 3.986931e-03
## 58       MO                                    Altria Group Inc 3.917806e-03
## 59      CVS                              CVS Health Corporation 3.853464e-03
## 60     BKNG                               Booking Holdings Inc. 3.844550e-03
## 61      NEE                                 NextEra Energy Inc. 3.774455e-03
## 62       GE                            General Electric Company 3.767361e-03
## 63     SBUX                               Starbucks Corporation 3.765740e-03
## 64     GILD                                Gilead Sciences Inc. 3.740188e-03
## 65      BMY                        Bristol-Myers Squibb Company 3.620328e-03
## 66      LOW                               Lowe’s Companies Inc. 3.611353e-03
## 67      COP                                      ConocoPhillips 3.482849e-03
## 68     ANTM                                         Anthem Inc. 3.459557e-03
## 69      CAT                                    Caterpillar Inc. 3.452684e-03
## 70      AMT                          American Tower Corporation 3.362129e-03
## 71      USB                                        U.S. Bancorp 3.355776e-03
## 72      UPS                  United Parcel Service Inc. Class B 3.308592e-03
## 73      LMT                         Lockheed Martin Corporation 3.248902e-03
## 74      AXP                            American Express Company 3.238637e-03
## 75       CI                                   Cigna Corporation 3.172444e-03
## 76     MDLZ                 Mondelez International Inc. Class A 3.018507e-03
## 77       GS                            Goldman Sachs Group Inc. 2.949052e-03
## 78      DHR                                 Danaher Corporation 2.945331e-03
## 79     BIIB                                         Biogen Inc. 2.878567e-03
## 80      BDX                        Becton Dickinson and Company 2.859908e-03
## 81      ADP                      Automatic Data Processing Inc. 2.800078e-03
## 82     CELG                                 Celgene Corporation 2.724370e-03
## 83     QCOM                               QUALCOMM Incorporated 2.704791e-03
## 84      CME                              CME Group Inc. Class A 2.693005e-03
## 85      TJX                                   TJX Companies Inc 2.688162e-03
## 86     ISRG                             Intuitive Surgical Inc. 2.687962e-03
## 87      DUK                             Duke Energy Corporation 2.677987e-03
## 88     CHTR                 Charter Communications Inc. Class A 2.661359e-03
## 89      SLB                                     Schlumberger NV 2.656396e-03
## 90       CB                                       Chubb Limited 2.635526e-03
## 91     INTU                                         Intuit Inc. 2.599428e-03
## 92     WBA                       Walgreens Boots Alliance Inc 2.537987e-03
## 93     CSX                                    CSX Corporation 2.499398e-03
## 94     EOG                                 EOG Resources Inc. 2.479198e-03
## 95     SYK                                Stryker Corporation 2.475356e-03
## 96     PNC                  PNC Financial Services Group Inc. 2.461979e-03
## 97      CL                          Colgate-Palmolive Company 2.459598e-03
## 98     SPG                          Simon Property Group Inc. 2.420539e-03
## 99    SCHW                         Charles Schwab Corporation 2.380268e-03
## 100    BSX                      Boston Scientific Corporation 2.362500e-03
## 101      D                                Dominion Energy Inc 2.362490e-03
## 102     MS                                     Morgan Stanley 2.357517e-03
## 103   FOXA              Twenty-First Century Fox Inc. Class A 2.286632e-03
## 104    BLK                                     BlackRock Inc. 2.263240e-03
## 105    RTN                                   Raytheon Company 2.245281e-03
## 106    OXY                   Occidental Petroleum Corporation 2.194796e-03
## 107     GM                             General Motors Company 2.190574e-03
## 108     DE                                    Deere & Company 2.180539e-03
## 109     SO                                   Southern Company 2.143840e-03
## 110    NSC                       Norfolk Southern Corporation 2.139458e-03
## 111    NOC                       Northrop Grumman Corporation 2.133255e-03
## 112   SPGI                                    S&P Global Inc. 2.128033e-03
## 113    CCI                    Crown Castle International Corp 2.127052e-03
## 114     GD                       General Dynamics Corporation 2.084551e-03
## 115     BK                Bank of New York Mellon Corporation 2.081129e-03
## 116   VRTX                Vertex Pharmaceuticals Incorporated 2.052085e-03
## 117     MU                             Micron Technology Inc. 2.021239e-03
## 118    EXC                                 Exelon Corporation 1.989433e-03
## 119    MMC                    Marsh & McLennan Companies Inc. 1.961229e-03
## 120    ZTS                                Zoetis Inc. Class A 1.957868e-03
## 121    MPC                     Marathon Petroleum Corporation 1.930374e-03
## 122    PLD                                      Prologis Inc. 1.912765e-03
## 123    MET                                       MetLife Inc. 1.906152e-03
## 124    ITW                           Illinois Tool Works Inc. 1.901359e-03
## 125    AGN                                       Allergan plc 1.894716e-03
## 126   ILMN                                      Illumina Inc. 1.881459e-03
## 127    FDX                                  FedEx Corporation 1.858768e-03
## 128    ICE                     Intercontinental Exchange Inc. 1.849193e-03
## 129    EMR                               Emerson Electric Co. 1.828073e-03
## 130    HUM                                        Humana Inc. 1.825011e-03
## 131   CTSH Cognizant Technology Solutions Corporation Class A 1.818338e-03
## 132    AON                                            Aon plc 1.779839e-03
## 133    ECL                                        Ecolab Inc. 1.774246e-03
## 134    PGR                            Progressive Corporation 1.773456e-03
## 135    KMB                         Kimberly-Clark Corporation 1.754196e-03
## 136    PSX                                        Phillips 66 1.751575e-03
## 137    PRU                          Prudential Financial Inc. 1.680439e-03
## 138    ADI                                Analog Devices Inc. 1.677838e-03
## 139    BBT                                   BB&T Corporation 1.672945e-03
## 140    AEP               American Electric Power Company Inc. 1.667633e-03
## 141    COF                  Capital One Financial Corporation 1.667192e-03
## 142     WM                              Waste Management Inc. 1.664881e-03
## 143    HCA                                 HCA Healthcare Inc 1.662640e-03
## 144   AMAT                             Applied Materials Inc. 1.640689e-03
## 145    TGT                                 Target Corporation 1.633986e-03
## 146    APD                     Air Products and Chemicals Inc. 1.629554e-03
## 147    AFL                                  Aflac Incorporated 1.614086e-03
## 148    AIG                   American International Group Inc. 1.602040e-03
## 149     EW                    Edwards Lifesciences Corporation 1.591745e-03
## 150    HPQ                                             HP Inc. 1.572385e-03
## 151    BAX                           Baxter International Inc. 1.557538e-03
## 152    SHW                            Sherwin-Williams Company 1.553596e-03
## 153    VLO                           Valero Energy Corporation 1.538518e-03
## 154    FIS         Fidelity National Information Services Inc. 1.527503e-03
## 155    KMI                           Kinder Morgan Inc Class P 1.522860e-03
## 156   ROST                                    Ross Stores Inc. 1.512285e-03
## 157   ADSK                                       Autodesk Inc. 1.491685e-03
## 158    MAR                 Marriott International Inc. Class A 1.489754e-03
## 159     EL                 Estee Lauder Companies Inc. Class A 1.484361e-03
## 160   FISV                                         Fiserv Inc. 1.480919e-03
## 161    TRV                            Travelers Companies Inc. 1.469054e-03
## 162    ETN                                     Eaton Corp. Plc 1.454436e-03
## 163   EQIX                                        Equinix Inc. 1.453206e-03
## 164   ATVI                            Activision Blizzard Inc. 1.451855e-03
## 165      F                                  Ford Motor Company 1.427123e-03
## 166   EBAY                                           eBay Inc. 1.422420e-03
## 167    WMB                             Williams Companies Inc. 1.408363e-03
## 168   REGN                      Regeneron Pharmaceuticals Inc. 1.402270e-03
## 169     EA                                Electronic Arts Inc. 1.393026e-03
## 170    ALL                                Allstate Corporation 1.392405e-03
## 171    JCI                  Johnson Controls International plc 1.385652e-03
## 172    SYY                                   Sysco Corporation 1.378898e-03
## 173    ROP                             Roper Technologies Inc. 1.376557e-03
## 174    DAL                                Delta Air Lines Inc. 1.372395e-03
## 175    RHT                                        Red Hat Inc. 1.369004e-03
## 176     DG                          Dollar General Corporation 1.350724e-03
## 177    SRE                                       Sempra Energy 1.345972e-03
## 178   ORLY                            O’Reilly Automotive Inc. 1.332325e-03
## 179    PSA                                      Public Storage 1.328894e-03
## 180   XLNX                                         Xilinx Inc. 1.285252e-03
## 181    STI                                 SunTrust Banks Inc. 1.279929e-03
## 182    YUM                                    Yum! Brands Inc. 1.273546e-03
## 183    LUV                              Southwest Airlines Co. 1.271535e-03
## 184    KHC                                 Kraft Heinz Company 1.264782e-03
## 185   WELL                                      Welltower Inc. 1.251195e-03
## 186    STZ                   Constellation Brands Inc. Class A 1.248293e-03
## 187   ALXN                        Alexion Pharmaceuticals Inc. 1.231145e-03
## 188    TEL                                TE Connectivity Ltd. 1.220970e-03
## 189   LRCX                            Lam Research Corporation 1.219289e-03
## 190    PEG                 Public Service Enterprise Group Inc 1.214677e-03
## 191    VFC                                    V.F. Corporation 1.208463e-03
## 192    MCO                                 Moody’s Corporation 1.206382e-03
## 193    HAL                                 Halliburton Company 1.196988e-03
## 194    LYB                        LyondellBasell Industries NV 1.196237e-03
## 195    GLW                                         Corning Inc 1.194216e-03
## 196    OKE                                          ONEOK Inc. 1.188553e-03
## 197    APH                        Amphenol Corporation Class A 1.185542e-03
## 198    XEL                                    Xcel Energy Inc. 1.179399e-03
## 199    AVB                          AvalonBay Communities Inc. 1.156808e-03
## 200    MCK                               McKesson Corporation 1.156177e-03
## 201    EQR                                 Equity Residential 1.150735e-03
## 202    GIS                                 General Mills Inc. 1.145642e-03
## 203    STT                           State Street Corporation 1.145102e-03
## 204    CNC                                Centene Corporation 1.138238e-03
## 205    PPG                                PPG Industries Inc. 1.127853e-03
## 206     IR                                 Ingersoll-Rand Plc 1.096718e-03
## 207    ZBH                        Zimmer Biomet Holdings Inc. 1.073786e-03
## 208      A                          Agilent Technologies Inc. 1.061240e-03
## 209    MTB                               M&T Bank Corporation 1.058008e-03
## 210    PXD                  Pioneer Natural Resources Company 1.051955e-03
## 211    CXO                              Concho Resources Inc. 1.051925e-03
## 212    DFS                        Discover Financial Services 1.043961e-03
## 213     ED                           Consolidated Edison Inc. 1.042370e-03
## 214    HLT                      Hilton Worldwide Holdings Inc 1.041860e-03
## 215    FOX              Twenty-First Century Fox Inc. Class B 1.041340e-03
## 216   PAYX                                       Paychex Inc. 1.035437e-03
## 217    FTV                                      Fortive Corp. 1.033396e-03
## 218   PCAR                                         PACCAR Inc 1.017388e-03
## 219    DLR                          Digital Realty Trust Inc. 1.011595e-03
## 220   TROW                                T. Rowe Price Group 1.010384e-03
## 221    ADM                     Archer-Daniels-Midland Company 1.006973e-03
## 222     KR                                         Kroger Co. 1.001020e-03
## 223    CMI                                       Cummins Inc. 9.979983e-04
## 224   DLTR                                   Dollar Tree Inc. 9.979783e-04
## 225    AZO                                      AutoZone Inc. 9.977982e-04
## 226    WEC                               WEC Energy Group Inc 9.976581e-04
## 227   MNST                       Monster Beverage Corporation 9.970779e-04
## 228    APC                     Anadarko Petroleum Corporation 9.903545e-04
## 229  CCL.U                               Carnival Corporation 9.873830e-04
## 230    VTR                                        Ventas Inc. 9.864626e-04
## 231    HPE                     Hewlett Packard Enterprise Co. 9.839113e-04
## 232     PH                        Parker-Hannifin Corporation 9.801494e-04
## 233    IQV                                 IQVIA Holdings Inc 9.759873e-04
## 234    MSI                            Motorola Solutions Inc. 9.730559e-04
## 235   TWTR                                       Twitter Inc. 9.606297e-04
## 236   WLTW         Willis Towers Watson Public Limited Company 9.449018e-04
## 237     ES                                  Eversource Energy 9.445016e-04
## 238    PPL                                    PPL Corporation 9.408298e-04
## 239    ROK                           Rockwell Automation Inc. 9.317452e-04
## 240    DTE                                 DTE Energy Company 9.294641e-04
## 241    SYF                                Synchrony Financial 9.250619e-04
## 242   APTV                                          Aptiv PLC 9.162075e-04
## 243   MCHP                  Microchip Technology Incorporated 9.087137e-04
## 244    TDG                       TransDigm Group Incorporated 9.086637e-04
## 245   SBAC                   SBA Communications Corp. Class A 9.083636e-04
## 246    SWK                        Stanley Black & Decker Inc. 8.942865e-04
## 247    AMD                        Advanced Micro Devices Inc. 8.933361e-04
## 248   NTRS                         Northern Trust Corporation 8.885036e-04
## 249      O                          Realty Income Corporation 8.874931e-04
## 250   VRSK                               Verisk Analytics Inc 8.821104e-04
## 251    BXP                             Boston Properties Inc. 8.754071e-04
## 252    UAL                   United Continental Holdings Inc. 8.631610e-04
## 253    RCL                       Royal Caribbean Cruises Ltd. 8.626407e-04
## 254    CLX                                       Clorox Company 8.558573e-04
## 255    FLT                           FleetCor Technologies Inc. 8.436713e-04
## 256    EIX                                 Edison International 8.369679e-04
## 257    GPN                                 Global Payments Inc. 8.353671e-04
## 258    HRS                                   Harris Corporation 8.295442e-04
## 259     IP                          International Paper Company 8.223906e-04
## 260     FE                                    FirstEnergy Corp. 8.221105e-04
## 261     WY                                 Weyerhaeuser Company 8.213501e-04
## 262   INFO                                      IHS Markit Ltd. 8.174982e-04
## 263   CERN                                   Cerner Corporation 8.136563e-04
## 264   VRSN                                        VeriSign Inc. 8.048018e-04
## 265    NUE                                    Nucor Corporation 8.041515e-04
## 266    BLL                                     Ball Corporation 7.976183e-04
## 267   ALGN                                Align Technology Inc. 7.962776e-04
## 268    TSN                             Tyson Foods Inc. Class A 7.915152e-04
## 269    AMP                            Ameriprise Financial Inc. 7.904947e-04
## 270    KEY                                              KeyCorp 7.861025e-04
## 271    DXC                                   DXC Technology Co. 7.849519e-04
## 272    ESS                            Essex Property Trust Inc. 7.820805e-04
## 273   IDXX                              IDEXX Laboratories Inc. 7.770380e-04
## 274    AME                                          AMETEK Inc. 7.766478e-04
## 275   FITB                                  Fifth Third Bancorp 7.736063e-04
## 276    WAT                                   Waters Corporation 7.714552e-04
## 277   FAST                                     Fastenal Company 7.690040e-04
## 278    FCX                                Freeport-McMoRan Inc. 7.602396e-04
## 279    AWK                    American Water Works Company Inc. 7.555272e-04
## 280    NEM                           Newmont Mining Corporation 7.529760e-04
## 281   CTAS                                   Cintas Corporation 7.481436e-04
## 282    CFG                        Citizens Financial Group Inc. 7.464627e-04
## 283   ULTA                                      Ulta Beauty Inc 7.426108e-04
## 284    HIG               Hartford Financial Services Group Inc. 7.408799e-04
## 285    FRC                                  First Republic Bank 7.325258e-04
## 286    CBS                              CBS Corporation Class B 7.311351e-04
## 287    RSG                               Republic Services Inc. 7.226008e-04
## 288   KLAC                               KLA-Tencor Corporation 7.217504e-04
## 289    AEE                                   Ameren Corporation 7.206898e-04
## 290    MTD                    Mettler-Toledo International Inc. 7.184887e-04
## 291    OMC                                    Omnicom Group Inc 7.175283e-04
## 292    CAH                                 Cardinal Health Inc. 7.103347e-04
## 293     RF                        Regions Financial Corporation 7.101146e-04
## 294   NTAP                                          NetApp Inc. 7.097444e-04
## 295    LLL                                  L3 Technologies Inc 7.066829e-04
## 296    MYL                                           Mylan N.V. 7.006999e-04
## 297   ABMD                                         ABIOMED Inc. 6.935163e-04
## 298   FANG                              Diamondback Energy Inc. 6.920756e-04
## 299    ETR                                  Entergy Corporation 6.896343e-04
## 300   EVRG                                          Evergy Inc. 6.780386e-04
## 301   CBRE                              CBRE Group Inc. Class A 6.753972e-04
## 302   MXIM                       Maxim Integrated Products Inc. 6.719555e-04
## 303    CHD                             Church & Dwight Co. Inc. 6.718755e-04
## 304    GPC                                Genuine Parts Company 6.684037e-04
## 305    MKC                     McCormick & Company Incorporated 6.650521e-04
## 306    TSS                           Total System Services Inc. 6.647519e-04
## 307   MSCI                                    MSCI Inc. Class A 6.631811e-04
## 308     LH          Laboratory Corporation of America Holdings 6.526559e-04
## 309    HSY                                     Hershey Company 6.524658e-04
## 310    CNP                             CenterPoint Energy Inc. 6.480336e-04
## 311   EXPE                                  Expedia Group Inc. 6.438815e-04
## 312   KEYS                           Keysight Technologies Inc 6.404798e-04
## 313   HBAN                  Huntington Bancshares Incorporated 6.392192e-04
## 314   SNPS                                       Synopsys Inc. 6.389991e-04
## 315    CMS                              CMS Energy Corporation 6.380286e-04
## 316    CMG                         Chipotle Mexican Grill Inc. 6.367779e-04
## 317   SWKS                             Skyworks Solutions Inc. 6.361676e-04
## 318    VMC                            Vulcan Materials Company 6.352072e-04
## 319   SYMC                                Symantec Corporation 6.343768e-04
## 320    HCP                                            HCP Inc. 6.318055e-04
## 321   CDNS                         Cadence Design Systems Inc. 6.312652e-04
## 322   INCY                                  Incyte Corporation 6.284338e-04
## 323   ANSS                                          ANSYS Inc. 6.232512e-04
## 324    MRO                            Marathon Oil Corporation 6.196694e-04
## 325    HES                                    Hess Corporation 6.190591e-04
## 326    AJG                           Arthur J. Gallagher & Co. 6.175784e-04
## 327    MGM                           MGM Resorts International 6.163778e-04
## 328    GWW                                  W.W. Grainger Inc. 6.140466e-04
## 329      K                                     Kellogg Company 6.137565e-04
## 330    AAL                        American Airlines Group Inc. 6.124658e-04
## 331    LEN                          Lennar Corporation Class A 6.092742e-04
## 332    ARE                Alexandria Real Estate Equities Inc. 6.082837e-04
## 333    RMD                                         ResMed Inc. 6.071331e-04
## 334    BBY                                   Best Buy Co. Inc. 6.056024e-04
## 335    CMA                               Comerica Incorporated 5.996494e-04
## 336    WCG                          WellCare Health Plans Inc. 5.953673e-04
## 337    DRI                             Darden Restaurants Inc. 5.935464e-04
## 338    ABC                       AmerisourceBergen Corporation 5.918655e-04
## 339    WDC                         Western Digital Corporation 5.916054e-04
## 340    HST                          Host Hotels & Resorts Inc. 5.866429e-04
## 341    DHI                                    D.R. Horton Inc. 5.829311e-04
## 342   CTXS                                 Citrix Systems Inc. 5.824008e-04
## 343    TXT                                        Textron Inc. 5.822107e-04
## 344   ANET                                Arista Networks Inc. 5.821006e-04
## 345    COO                               Cooper Companies Inc. 5.809801e-04
## 346    DOV                                   Dover Corporation 5.751772e-04
## 347    PFG                      Principal Financial Group Inc. 5.747170e-04
## 348    TFX                               Teleflex Incorporated 5.732262e-04
## 349    DVN                            Devon Energy Corporation 5.712452e-04
## 350    IFF             International Flavors & Fragrances Inc. 5.703548e-04
## 351    LNC                        Lincoln National Corporation 5.692042e-04
## 352    XYL                                          Xylem Inc. 5.646419e-04
## 353   BHGE                   Baker Hughes a GE Company Class A 5.601297e-04
## 354    EFX                                        Equifax Inc. 5.579286e-04
## 355     CE                                Celanese Corporation 5.579186e-04
## 356    CTL                                    CenturyLink Inc. 5.574683e-04
## 357      L                                   Loews Corporation 5.549771e-04
## 358   SIVB                                 SVB Financial Group 5.546369e-04
## 359     IT                                        Gartner Inc. 5.531062e-04
## 360   CINF                    Cincinnati Financial Corporation 5.520556e-04
## 361   EXPD         Expeditors International of Washington Inc. 5.477835e-04
## 362   CHRW                        C.H. Robinson Worldwide Inc. 5.420206e-04
## 363    APA                                  Apache Corporation 5.405199e-04
## 364    EXR                            Extra Space Storage Inc. 5.384689e-04
## 365   HOLX                                        Hologic Inc. 5.374083e-04
## 366    AAP                             Advance Auto Parts Inc. 5.350071e-04
## 367    NRG                                     NRG Energy Inc. 5.292443e-04
## 368    UDR                                            UDR Inc. 5.268831e-04
## 369   ETFC                       E*TRADE Financial Corporation 5.260527e-04
## 370    VAR                         Varian Medical Systems Inc. 5.234614e-04
## 371   WYNN                                Wynn Resorts Limited 5.205199e-04
## 372    CAG                                 Conagra Brands Inc. 5.101947e-04
## 373   FTNT                                       Fortinet Inc. 5.097445e-04
## 374    STX                              Seagate Technology PLC 5.096245e-04
## 375    DGX                      Quest Diagnostics Incorporated 5.065029e-04
## 376    MLM                      Martin Marietta Materials Inc. 5.062028e-04
## 377   TSCO                              Tractor Supply Company 5.057225e-04
## 378    VNO                                Vornado Realty Trust 5.054024e-04
## 379    MAA              Mid-America Apartment Communities Inc. 5.031012e-04
## 380    HRL                            Hormel Foods Corporation 5.012603e-04
## 381     BR                 Broadridge Financial Solutions Inc. 4.989791e-04
## 382    SJM                                J.M. Smucker Company 4.983588e-04
## 383    EMN                            Eastman Chemical Company 4.979786e-04
## 384    UHS              Universal Health Services Inc. Class B 4.975784e-04
## 385   NCLH                 Norwegian Cruise Line Holdings Ltd. 4.973683e-04
## 386    MAS                                   Masco Corporation 4.912953e-04
## 387   AKAM                            Akamai Technologies Inc. 4.905549e-04
## 388    ATO                            Atmos Energy Corporation 4.900247e-04
## 389    TAP                Molson Coors Brewing Company Class B 4.867230e-04
## 390    MOS                                      Mosaic Company 4.859326e-04
## 391    FMC                                     FMC Corporation 4.848721e-04
## 392    NOV                         National Oilwell Varco Inc. 4.833113e-04
## 393    REG                         Regency Centers Corporation 4.802398e-04
## 394    URI                                 United Rentals Inc. 4.765079e-04
## 395    COG                         Cabot Oil & Gas Corporation 4.752273e-04
## 396    AES                                     AES Corporation 4.750672e-04
## 397    KSS                                  Kohl’s Corporation 4.714254e-04
## 398    KMX                                         CarMax Inc. 4.696045e-04
## 399    KSU                                Kansas City Southern 4.682138e-04
## 400   CPRT                                         Copart Inc. 4.660327e-04
## 401    NBL                                   Noble Energy Inc. 4.633514e-04
## 402    RJF                        Raymond James Financial Inc. 4.619907e-04
## 403   TTWO                  Take-Two Interactive Software Inc. 4.529462e-04
## 404    DRE                             Duke Realty Corporation 4.512753e-04
## 405    LNT                                 Alliant Energy Corp 4.485540e-04
## 406   CBOE                             Cboe Global Markets Inc 4.448721e-04
## 407   FFIV                                    F5 Networks Inc. 4.446620e-04
## 408   JKHY                        Jack Henry & Associates Inc. 4.428011e-04
## 409     LW                           Lamb Weston Holdings Inc. 4.403699e-04
## 410    PKI                                    PerkinElmer Inc. 4.390992e-04
## 411    TPR                                       Tapestry Inc. 4.385890e-04
## 412   VIAB                                 Viacom Inc. Class B 4.367881e-04
## 413    FTI                                      TechnipFMC Plc 4.341868e-04
## 414    HAS                                         Hasbro Inc. 4.310552e-04
## 415   NDAQ                                         Nasdaq Inc. 4.308651e-04
## 416    IRM                                  Iron Mountain Inc. 4.289042e-04
## 417    PNW                   Pinnacle West Capital Corporation 4.272633e-04
## 418    WRK                                    WestRock Company 4.253424e-04
## 419  DISCK                              Discovery Inc. Class C 4.248021e-04
## 420    BEN                             Franklin Resources Inc. 4.240517e-04
## 421    TIF                                       Tiffany & Co. 4.230212e-04
## 422    FRT                     Federal Realty Investment Trust 4.207801e-04
## 423     NI                                        NiSource Inc 4.200297e-04
## 424   JBHT                   J.B. Hunt Transport Services Inc. 4.181888e-04
## 425   ZION                           Zions Bancorporation N.A. 4.156776e-04
## 426     CF                         CF Industries Holdings Inc. 4.141368e-04
## 427   XRAY                                DENTSPLY SIRONA Inc. 4.130963e-04
## 428   HSIC                                   Henry Schein Inc. 4.068632e-04
## 429    HII                  Huntington Ingalls Industries Inc. 4.054825e-04
## 430   JNPR                               Juniper Networks Inc. 4.021908e-04
## 431    HFC                           HollyFrontier Corporation 4.006400e-04
## 432   NLSN                                Nielsen Holdings Plc 4.002899e-04
## 433    PKG                    Packaging Corporation of America 3.944870e-04
## 434    AVY                          Avery Dennison Corporation 3.883139e-04
## 435    IPG                 Interpublic Group of Companies Inc. 3.825310e-04
## 436    SNA                                Snap-on Incorporated 3.805400e-04
## 437    WHR                               Whirlpool Corporation 3.793094e-04
## 438     RE                               Everest Re Group Ltd. 3.785190e-04
## 439    ALB                               Albemarle Corporation 3.767281e-04
## 440    MHK                              Mohawk Industries Inc. 3.750773e-04
## 441    BWA                                     BorgWarner Inc. 3.740268e-04
## 442   ALLE                                        Allegion PLC 3.714054e-04
## 443   GRMN                                         Garmin Ltd. 3.696846e-04
## 444    PVH                                           PVH Corp. 3.696646e-04
## 445    TMK                               Torchmark Corporation 3.691343e-04
## 446    LKQ                                     LKQ Corporation 3.688242e-04
## 447    ADS                   Alliance Data Systems Corporation 3.505650e-04
## 448   BF.B                    Brown-Forman Corporation Class B 3.505650e-04
## 449    RHI                      Robert Half International Inc. 3.495245e-04
## 450    JEC                       Jacobs Engineering Group Inc. 3.482939e-04
## 451    ALK                               Alaska Air Group Inc. 3.471433e-04
## 452   QRVO                                          Qorvo Inc. 3.466931e-04
## 453     WU                               Western Union Company 3.396196e-04
## 454    UNM                                          Unum Group 3.383189e-04
## 455    SLG                               SL Green Realty Corp. 3.379187e-04
## 456    AIV Apartment Investment and Management Company Class A 3.317456e-04
## 457    IVZ                                        Invesco Ltd. 3.289042e-04
## 458      M                                          Macy’s Inc 3.234915e-04
## 459   ARNC                                        Arconic Inc. 3.221308e-04
## 460    KIM                            Kimco Realty Corporation 3.205200e-04
## 461    DVA                                         DaVita Inc. 3.198897e-04
## 462    NWL                                   Newell Brands Inc 3.183990e-04
## 463    AOS                             A. O. Smith Corporation 3.176186e-04
## 464    XEC                                  Cimarex Energy Co. 3.077136e-04
## 465   NKTR                                 Nektar Therapeutics 3.070933e-04
## 466   FLIR                                   FLIR Systems Inc. 3.052424e-04
## 467    PHM                                     PulteGroup Inc. 3.023210e-04
## 468     RL                    Ralph Lauren Corporation Class A 3.008902e-04
## 469   DISH                    DISH Network Corporation Class A 3.003400e-04
## 470    PNR                                         Pentair plc 2.993395e-04
## 471     FL                                    Foot Locker Inc. 2.956276e-04
## 472    HBI                                    Hanesbrands Inc. 2.951674e-04
## 473    XRX                                   Xerox Corporation 2.891744e-04
## 474   FBHS                 Fortune Brands Home & Security Inc. 2.876636e-04
## 475    SEE                              Sealed Air Corporation 2.856726e-04
## 476   CPRI                              Capri Holdings Limited 2.830813e-04
## 477    CPB                               Campbell Soup Company 2.824010e-04
## 478   PBCT                      People’s United Financial Inc. 2.756476e-04
## 479     LB                                       L Brands Inc. 2.663130e-04
## 480    FLS                               Flowserve Corporation 2.653125e-04
## 481     HP                              Helmerich & Payne Inc. 2.652424e-04
## 482    HOG                                Harley-Davidson Inc. 2.649123e-04
## 483   PRGO                                     Perrigo Co. Plc 2.626111e-04
## 484    JEF                      Jefferies Financial Group Inc. 2.601699e-04
## 485    ROL                                        Rollins Inc. 2.528763e-04
## 486    LEG                        Leggett & Platt Incorporated 2.523660e-04
## 487    AMG                      Affiliated Managers Group Inc. 2.485041e-04
## 488   TRIP                                    TripAdvisor Inc. 2.479238e-04
## 489   IPGP                           IPG Photonics Corporation 2.379788e-04
## 490    GPS                                            Gap Inc. 2.343470e-04
## 491    PWR                                Quanta Services Inc. 2.245821e-04
## 492    AIZ                                       Assurant Inc. 2.211204e-04
## 493    JWN                                      Nordstrom Inc. 2.172385e-04
## 494    FLR                                   Fluor Corporation 2.166282e-04
## 495    BHF                          Brighthouse Financial Inc. 2.135266e-04
## 496   COTY                                   Coty Inc. Class A 2.120159e-04
## 497    HRB                                      H&R Block Inc. 2.095646e-04
## 498   NWSA                            News Corporation Class A 2.074036e-04
## 499    MAT                                         Mattel Inc. 2.017908e-04
## 500    MAC                                    Macerich Company 1.996897e-04
## 501  DISCA                              Discovery Inc. Class A 1.940669e-04
## 502     GT                      Goodyear Tire & Rubber Company 1.899448e-04
## 503    UAA                           Under Armour Inc. Class A 1.670134e-04
## 504     UA                           Under Armour Inc. Class C 1.521260e-04
## 505    NWS                            News Corporation Class B 6.290141e-05
## 506 ECA-CA                                  Encana Corporation 7.893942e-06
##                      sector shares_held
## 1   Information Technology    84853600
## 2   Information Technology    49533308
## 3   Consumer Discretionary     4510051
## 4               Financials    21364490
## 5   Communication Services    26385216
## 6              Health Care    29452358
## 7               Financials    36529800
## 8   Communication Services     3378423
## 9   Communication Services     3282939
## 10                  Energy    46493644
## 11              Financials   100285460
## 12             Health Care    10564454
## 13  Information Technology    19303236
## 14        Consumer Staples    27357982
## 15             Health Care    63506110
## 16  Information Technology    50135996
## 17                 Energy    20984748
## 18  Communication Services    45375500
## 19  Information Technology    49397930
## 20  Communication Services    79917256
## 21             Industrials     5801735
## 22  Consumer Discretionary    12408924
## 23              Financials    46556430
## 24             Health Care    28576474
## 25  Information Technology     9946411
## 26        Consumer Staples    42067310
## 27  Communication Services    49908344
## 28  Communication Services    16347008
## 29        Consumer Staples    15501865
## 30              Financials    26843670
## 31  Communication Services     4788556
## 32        Consumer Staples    15677056
## 33  Consumer Discretionary     8473443
## 34             Health Care    19286212
## 35  Information Technology    27943780
## 36        Consumer Staples    17070768
## 37  Information Technology     5347148
## 38  Information Technology     9968187
## 39             Industrials     8075142
## 40               Materials    25202004
## 41             Health Care    14750220
## 42             Health Care    16540164
## 43             Industrials     6400274
## 44  Information Technology     8398198
## 45             Health Care     7000953
## 46  Information Technology     4546147
## 47             Health Care    10358008
## 48             Industrials     8109534
## 49  Information Technology    12927395
## 50  Consumer Discretionary    13969941
## 51             Industrials     8911586
## 52  Information Technology    10552200
## 53             Health Care     4421107
## 54  Information Technology     6997603
## 55  Information Technology     6698059
## 56        Consumer Staples     4812566
## 57               Materials     6051462
## 58        Consumer Staples    20562772
## 59             Health Care    14177615
## 60  Consumer Discretionary      508639
## 61               Utilities     5246468
## 62             Industrials    95514760
## 63  Consumer Discretionary    13623676
## 64             Health Care    14155833
## 65             Health Care    17923948
## 66  Consumer Discretionary     8862585
## 67                  Energy    12695394
## 68             Health Care     2840374
## 69             Industrials     6484917
## 70             Real Estate     4836797
## 71              Financials    16730737
## 72             Industrials     7634037
## 73             Industrials     2705191
## 74              Financials     7715496
## 75             Health Care     4101458
## 76        Consumer Staples    16033591
## 77              Financials     3800548
## 78             Health Care     6773251
## 79             Health Care     2212211
## 80             Health Care     2945983
## 81  Information Technology     4785852
## 82             Health Care     7684789
## 83  Information Technology    13311328
## 84              Financials     3927643
## 85  Consumer Discretionary    13690399
## 86             Health Care     1253634
## 87               Utilities     7828438
## 88  Communication Services     1950416
## 89                  Energy    15117770
## 90              Financials     5061222
## 91  Information Technology     2850040
## 92        Consumer Staples     8841804
## 93             Industrials     8814182
## 94                  Energy     6326332
## 95             Health Care     3389350
## 96              Financials     5072966
## 97        Consumer Staples     9464497
## 98             Real Estate     3377012
## 99              Financials    13134280
## 100            Health Care    15105250
## 101              Utilities     8249501
## 102             Financials    14362621
## 103 Communication Services    11606211
## 104             Financials     1340362
## 105            Industrials     3111283
## 106                 Energy     8356286
## 107 Consumer Discretionary    14335656
## 108            Industrials     3508474
## 109              Utilities    11293749
## 110            Industrials     2992855
## 111            Industrials     1901582
## 112             Financials     2744956
## 113            Real Estate     4529516
## 114            Industrials     3043009
## 115             Financials    10046857
## 116            Health Care     2791257
## 117 Information Technology    12313897
## 118              Utilities    10545466
## 119             Financials     5503610
## 120            Health Care     5251650
## 121                 Energy     7579710
## 122            Real Estate     6873344
## 123             Financials    10869825
## 124            Industrials     3372816
## 125            Health Care     3485269
## 126            Health Care     1605308
## 127            Industrials     2651972
## 128             Financials     6265545
## 129            Industrials     6845957
## 130            Health Care     1504560
## 131 Information Technology     6323489
## 132             Financials     2647597
## 133              Materials     2776346
## 134             Financials     6366478
## 135       Consumer Staples     3788826
## 136                 Energy     4667958
## 137             Financials     4565907
## 138 Information Technology     4059161
## 139             Financials     8441104
## 140              Utilities     5381653
## 141             Financials     5228546
## 142            Industrials     4299405
## 143            Health Care     2948341
## 144 Information Technology    10734333
## 145 Consumer Discretionary     5738562
## 146              Materials     2394666
## 147             Financials     8378780
## 148             Financials     9683932
## 149            Health Care     2290413
## 150 Information Technology    17278248
## 151            Health Care     5426107
## 152              Materials      904940
## 153                 Energy     4663221
## 154 Information Technology     3587225
## 155                 Energy    20721726
## 156 Consumer Discretionary     4115142
## 157 Information Technology     2379755
## 158 Consumer Discretionary     3148294
## 159       Consumer Staples     2449646
## 160 Information Technology     4416413
## 161             Financials     2919089
## 162            Industrials     4725856
## 163            Real Estate      882199
## 164 Communication Services     8327456
## 165 Consumer Discretionary    42749332
## 166 Consumer Discretionary     9947385
## 167                 Energy    13211548
## 168            Health Care      846096
## 169 Communication Services     3335426
## 170             Financials     3774086
## 171            Industrials    10098861
## 172       Consumer Staples     5222715
## 173            Industrials     1128806
## 174            Industrials     6873085
## 175 Information Technology     1935077
## 176 Consumer Discretionary     2903658
## 177              Utilities     2987326
## 178 Consumer Discretionary      878425
## 179            Real Estate     1636418
## 180 Information Technology     2755723
## 181             Financials     5028027
## 182 Consumer Discretionary     3461448
## 183            Industrials     5637370
## 184       Consumer Staples     6794417
## 185            Real Estate     4124124
## 186       Consumer Staples     1825683
## 187            Health Care     2433510
## 188 Information Technology     3802557
## 189 Information Technology     1722416
## 190              Utilities     5517268
## 191 Consumer Discretionary     3557434
## 192             Financials     1823290
## 193                 Energy     9613979
## 194              Materials     3491712
## 195 Information Technology     8852467
## 196                 Energy     4490440
## 197 Information Technology     3271969
## 198              Utilities     5643593
## 199            Real Estate     1509296
## 200            Health Care     2181810
## 201            Real Estate     4020945
## 202       Consumer Staples     6506921
## 203             Financials     4145673
## 204            Health Care     4481716
## 205              Materials     2644321
## 206            Industrials     2678846
## 207            Health Care     2221510
## 208            Health Care     3467173
## 209             Financials     1571095
## 210                 Energy     1851432
## 211                 Energy     2188314
## 212             Financials     3746094
## 213              Utilities     3396411
## 214 Consumer Discretionary     3260214
## 215 Communication Services     5325635
## 216 Information Technology     3495366
## 217            Industrials     3231765
## 218            Industrials     3821761
## 219            Real Estate     2249676
## 220             Financials     2648802
## 221       Consumer Staples     6136183
## 222       Consumer Staples     8680506
## 223            Industrials     1642124
## 224 Consumer Discretionary     2582660
## 225 Consumer Discretionary      277521
## 226              Utilities     3427101
## 227       Consumer Staples     4343785
## 228                 Energy     5601322
## 229 Consumer Discretionary     4412013
## 230            Real Estate     3869811
## 231 Information Technology    15643081
## 232            Industrials     1443835
## 233            Health Care     1760100
## 234 Information Technology     1795575
## 235 Communication Services     7868838
## 236             Financials     1425562
## 237              Utilities     3441836
## 238              Utilities     7901413
## 239            Industrials     1343665
## 240              Utilities     1984554
## 241             Financials     7453370
## 242 Consumer Discretionary     2895350
## 243 Information Technology     2551726
## 244            Industrials      528184
## 245            Real Estate     1252681
## 246            Industrials     1677327
## 247 Information Technology     9650679
## 248             Financials     2441622
## 249            Real Estate     3239184
## 250            Industrials     1799774
## 251            Real Estate     1675955
## 252            Industrials     2500381
## 253 Consumer Discretionary     1870616
## 254       Consumer Staples     1400955
## 255 Information Technology      963283
## 256              Utilities     3538982
## 257 Information Technology     1733167
## 258            Industrials     1287679
## 259              Materials     4461923
## 260              Utilities     5312109
## 261            Real Estate     8226775
## 262            Industrials     3914760
## 263            Health Care     3594290
## 264 Information Technology     1173766
## 265              Materials     3457348
## 266              Materials     3769475
## 267            Health Care      798947
## 268       Consumer Staples     3234016
## 269             Financials     1547442
## 270             Financials    11484608
## 271 Information Technology     3067559
## 272            Real Estate      717552
## 273            Health Care      945392
## 274            Industrials     2514572
## 275             Financials     7283773
## 276            Health Care      840888
## 277            Industrials     3124053
## 278              Materials    15837152
## 279              Utilities     1971184
## 280              Materials     5794860
## 281            Industrials      939128
## 282             Financials     5203126
## 283 Consumer Discretionary      620090
## 284             Financials     3889356
## 285             Financials     1843857
## 286 Communication Services     3693436
## 287            Industrials     2381179
## 288 Information Technology     1706564
## 289              Utilities     2645846
## 290            Health Care      274795
## 291 Communication Services     2447402
## 292            Health Care     3275280
## 293             Financials    11353641
## 294 Information Technology     2835577
## 295            Industrials      851775
## 296            Health Care     5629673
## 297            Health Care      490005
## 298                 Energy     1678142
## 299              Utilities     1963267
## 300              Utilities     2951350
## 301            Real Estate     3452740
## 302 Information Technology     3077792
## 303       Consumer Staples     2656922
## 304 Consumer Discretionary     1589238
## 305       Consumer Staples     1324279
## 306 Information Technology     1832858
## 307             Financials      968497
## 308            Health Care     1111794
## 309       Consumer Staples     1526384
## 310              Utilities     5366678
## 311 Consumer Discretionary     1296049
## 312 Information Technology     2038376
## 313             Financials    11671771
## 314 Information Technology     1608117
## 315              Utilities     3092984
## 316 Consumer Discretionary      268854
## 317 Information Technology     1951800
## 318              Materials     1436228
## 319 Information Technology     7010013
## 320            Real Estate     5240775
## 321 Information Technology     3071238
## 322            Health Care     1910436
## 323 Information Technology      913731
## 324                 Energy     9281057
## 325                 Energy     2750316
## 326             Financials     1978764
## 327 Consumer Discretionary     5589458
## 328            Industrials      496123
## 329       Consumer Staples     2764699
## 330            Industrials     4470119
## 331 Consumer Discretionary     3187318
## 332            Real Estate     1153852
## 333            Health Care     1546184
## 334 Consumer Discretionary     2574321
## 335             Financials     1776056
## 336            Health Care      545599
## 337 Consumer Discretionary     1354233
## 338            Health Care     1747146
## 339 Information Technology     3176075
## 340            Real Estate     8051085
## 341 Consumer Discretionary     3730843
## 342 Information Technology     1399057
## 343            Industrials     2716830
## 344 Information Technology      564156
## 345            Health Care      532562
## 346            Industrials     1613347
## 347             Financials     2894667
## 348            Health Care      512924
## 349                 Energy     5141867
## 350              Materials     1105247
## 351             Financials     2363409
## 352            Industrials     1953788
## 353                 Energy     5547419
## 354            Industrials     1305700
## 355              Materials     1423524
## 356 Communication Services    10379065
## 357             Financials     3040086
## 358             Financials      574548
## 359 Information Technology      987044
## 360             Financials     1652133
## 361            Industrials     1902907
## 362            Industrials     1516193
## 363                 Energy     4152349
## 364            Real Estate     1381347
## 365            Health Care     2969890
## 366 Consumer Discretionary      805121
## 367              Utilities     3188619
## 368            Real Estate     3022753
## 369             Financials     2835503
## 370            Health Care     1008799
## 371 Consumer Discretionary     1069451
## 372       Consumer Staples     5327094
## 373 Information Technology     1569001
## 374 Information Technology     2852071
## 375            Health Care     1475566
## 376              Materials      681336
## 377 Consumer Discretionary     1325791
## 378            Real Estate     1879215
## 379            Real Estate     1235370
## 380       Consumer Staples     2968258
## 381 Information Technology     1272004
## 382       Consumer Staples     1233183
## 383              Materials     1540210
## 384            Health Care      939188
## 385 Consumer Discretionary     2399286
## 386            Industrials     3355027
## 387 Information Technology     1790425
## 388              Utilities     1291661
## 389       Consumer Staples     2044159
## 390              Materials     3871360
## 391              Materials     1453268
## 392                 Energy     4147562
## 393            Real Estate     1852404
## 394            Industrials      903877
## 395                 Energy     4818499
## 396              Utilities     7182509
## 397 Consumer Discretionary     1829183
## 398 Consumer Discretionary     1935735
## 399            Industrials     1113767
## 400            Industrials     2206502
## 401                 Energy     5235531
## 402             Financials     1435488
## 403 Communication Services     1241900
## 404            Real Estate     3876499
## 405              Utilities     2551075
## 406             Financials     1216629
## 407 Information Technology      664116
## 408 Information Technology      846668
## 409       Consumer Staples     1620658
## 410            Health Care     1195097
## 411 Consumer Discretionary     3124383
## 412 Communication Services     3833174
## 413                 Energy     4718422
## 414 Consumer Discretionary     1276288
## 415             Financials     1255942
## 416            Real Estate     3124109
## 417              Utilities     1214980
## 418              Materials     2786398
## 419 Communication Services     3930185
## 420             Financials     3342977
## 421 Consumer Discretionary     1191398
## 422            Real Estate      794526
## 423              Utilities     3967883
## 424            Industrials      941785
## 425             Financials     2122059
## 426              Materials     2536327
## 427            Health Care     2424846
## 428            Health Care     1668249
## 429            Industrials      472130
## 430 Information Technology     3793694
## 431                 Energy     1770424
## 432            Industrials     3893577
## 433              Materials     1024844
## 434              Materials      946952
## 435 Communication Services     4185522
## 436            Industrials      616986
## 437 Consumer Discretionary      696269
## 438             Financials      446368
## 439              Materials     1184371
## 440 Consumer Discretionary      689241
## 441 Consumer Discretionary     2282471
## 442            Industrials     1037700
## 443 Consumer Discretionary     1320464
## 444 Consumer Discretionary      837593
## 445             Financials     1132802
## 446 Consumer Discretionary     3475186
## 447 Information Technology      517747
## 448       Consumer Staples     1832793
## 449            Industrials     1334917
## 450            Industrials     1296545
## 451            Industrials     1339031
## 452 Information Technology     1361089
## 453 Information Technology     4880875
## 454             Financials     2382921
## 455            Real Estate      943705
## 456            Real Estate     1710661
## 457             Financials     4461157
## 458 Consumer Discretionary     3326163
## 459            Industrials     4695504
## 460            Real Estate     4616746
## 461            Health Care     1384655
## 462 Consumer Discretionary     4746547
## 463            Industrials     1573427
## 464                 Energy     1035895
## 465            Health Care     1884332
## 466 Information Technology     1489880
## 467 Consumer Discretionary     2851670
## 468 Consumer Discretionary      615328
## 469 Communication Services     2486454
## 470            Industrials     1792505
## 471 Consumer Discretionary     1275513
## 472 Consumer Discretionary     4022810
## 473 Information Technology     2428599
## 474            Industrials     1552478
## 475              Materials     1733776
## 476 Consumer Discretionary     1627708
## 477       Consumer Staples     2076504
## 478             Financials     4066548
## 479 Consumer Discretionary     2491820
## 480            Industrials     1420509
## 481                 Energy     1182082
## 482 Consumer Discretionary     1816851
## 483            Health Care     1372418
## 484             Financials     3166258
## 485            Industrials     1612804
## 486 Consumer Discretionary     1436217
## 487             Financials      583435
## 488 Communication Services     1116383
## 489 Information Technology      393061
## 490 Consumer Discretionary     2391279
## 491            Industrials     1606564
## 492             Financials      575956
## 493 Consumer Discretionary     1250523
## 494            Industrials     1526223
## 495             Financials     1302087
## 496       Consumer Staples     4912631
## 497 Consumer Discretionary     2224465
## 498 Communication Services     4161396
## 499 Consumer Discretionary     3735261
## 500            Real Estate     1169252
## 501 Communication Services     1694339
## 502 Consumer Discretionary     2585962
## 503 Consumer Discretionary     2019164
## 504 Consumer Discretionary     2043966
## 505 Communication Services     1244468
## 506                 Energy      292529
```

Question

Which stock prices behave similarly?

Answering this question helps us **understand which companies are related**, and we can use clustering to help us answer it!

Even if you're not interested in finance, this is still a great analysis because it will tell you which companies are competitors and which are likely in the same space (often called sectors) and can be categorized together. Bottom line - This analysis can help you better understand the dynamics of the market and competition, which is useful for all types of analyses from finance to sales to marketing.

Let's get started.

Step 1 - Convert stock prices to a standardized format (daily returns)

What you first need to do is get the data in a format that can be converted to a "user-item" style matrix. The challenge here is to connect the dots between what we have and what we need to do to format it properly.

We know that in order to compare the data, it needs to be standardized or normalized. Why? Because we cannot compare values (stock prices) that are of completely different magnitudes. In order to standardize, we will convert from adjusted stock price (dollar value) to daily returns (percent change from previous day). Here is the formula.

$$return_{daily} = \frac{price_i - price_{i-1}}{price_{i-1}}$$

First, what do we have? We have stock prices for every stock in the SP 500 Index, which is the daily stock prices for over 500 stocks. The data set is over 1.2M observations.

```
sp_500_prices_tbl %>% glimpse()
```

```
## Rows: 1,225,765
## Columns: 8
## $ symbol   <chr> "MSFT", "MSFT", "MSFT", "MSFT", "MSFT", "MSFT", "MSFT", "M...
## $ date     <date> 2009-01-02, 2009-01-05, 2009-01-06, 2009-01-07, 2009-01-0...
## $ open     <dbl> 19.53, 20.20, 20.75, 20.19, 19.63, 20.17, 19.71, 19.52, 19...
## $ high     <dbl> 20.40, 20.67, 21.00, 20.29, 20.19, 20.30, 19.79, 19.99, 19...
## $ low      <dbl> 19.37, 20.06, 20.61, 19.48, 19.55, 19.41, 19.30, 19.52, 19...
## $ close    <dbl> 20.33, 20.52, 20.76, 19.51, 20.12, 19.52, 19.47, 19.82, 19...
## $ volume   <dbl> 50084000, 61475200, 58083400, 72709900, 70255400, 49815300...
## $ adjusted <dbl> 15.86624, 16.01451, 16.20183, 15.22628, 15.70234, 15.23408...
```

Your first task is to convert to a tibble named `sp_500_daily_returns_tbl` by performing the following operations:

- Select the `symbol`, `date` and `adjusted` columns

- Filter to dates beginning in the year 2018 and beyond.
- Compute a Lag of 1 day on the adjusted stock price. Be sure to group by symbol first, otherwise we will have lags computed using values from the previous stock in the data frame.
- Remove a NA values from the lagging operation
- Compute the difference between adjusted and the lag
- Compute the percentage difference by dividing the difference by that lag. Name this column pct_return.
- Return only the symbol, date, and pct_return columns
- Save as a variable named sp_500_daily_returns_tbl

```
# Apply your data transformation skills!
sp_500_daily_returns_tbl <- sp_500_index_tbl %>%
  left_join(sp_500_prices_tbl) %>%
  select(symbol,date, adjusted)%>%
  separate(col    = date,
           into   = c("year","month", "day"),
           sep    = "-",
           remove = FALSE)%>%
  filter(year >= 2018) %>%
  filter(!is.na(adjusted)) %>%
  group_by(symbol) %>%
  mutate(pct_return = (‘adjusted‘ - lag(‘adjusted‘)) / lag(‘adjusted‘)) %>%
  filter(!is.na(pct_return))  %>%
  select(symbol, date, pct_return )

sp_500_daily_returns_tbl
```

```
## # A tibble: 141,340 x 3
## # Groups:   symbol [502]
##    symbol date       pct_return
##    <chr>  <date>          <dbl>
##  1 MSFT   2018-01-03   0.00465
##  2 MSFT   2018-01-04   0.00880
##  3 MSFT   2018-01-05   0.0124
##  4 MSFT   2018-01-08   0.00102
##  5 MSFT   2018-01-09  -0.000680
##  6 MSFT   2018-01-10  -0.00453
##  7 MSFT   2018-01-11   0.00296
##  8 MSFT   2018-01-12   0.0173
##  9 MSFT   2018-01-16  -0.0140
## 10 MSFT   2018-01-17   0.0203
## # ... with 141,330 more rows
```

```
# Output: sp_500_daily_returns_tbl
```

Step 2 - Convert to User-Item Format

The next step is to convert to a user-item format with the symbol in the first column and every other column the value of the *daily returns* (pct_return) for every stock at each date.

We're going to import the correct results first (just in case you were not able to complete the last step).

```r
sp_500_daily_returns_tbl <- read_rds("sp_500_daily_returns_tbl.rds")
sp_500_daily_returns_tbl
```

```
## # A tibble: 141,340 x 3
##    symbol date       pct_return
##    <chr>  <date>          <dbl>
##  1 MSFT   2018-01-03   0.00465
##  2 MSFT   2018-01-04   0.00880
##  3 MSFT   2018-01-05   0.0124
##  4 MSFT   2018-01-08   0.00102
##  5 MSFT   2018-01-09  -0.000680
##  6 MSFT   2018-01-10  -0.00453
##  7 MSFT   2018-01-11   0.00296
##  8 MSFT   2018-01-12   0.0173
##  9 MSFT   2018-01-16  -0.0140
## 10 MSFT   2018-01-17   0.0203
## # ... with 141,330 more rows
```

Now that we have the daily returns (percentage change from one day to the next), we can convert to a user-item format. The user in this case is the `symbol` (company), and the item in this case is the `pct_return` at each `date`.

- Spread the `date` column to get the values as percentage returns. Make sure to fill an `NA` values with zeros.
- Save the result as `stock_date_matrix_tbl`

```r
# Convert to User-Item Format
stock_date_matrix_tbl <- sp_500_daily_returns_tbl %>%
  pivot_wider(names_from = date, values_from = pct_return, values_fill = 0) %>%
  ungroup()
stock_date_matrix_tbl
```

```
## # A tibble: 502 x 283
##    symbol `2018-01-03` `2018-01-04` `2018-01-05` `2018-01-08` `2018-01-09`
##    <chr>         <dbl>        <dbl>        <dbl>        <dbl>        <dbl>
##  1 MSFT       0.00465      0.00880       0.0124        0.00102    -0.000680
##  2 AAPL      -0.000174     0.00465       0.0114       -0.00371    -0.000115
##  3 AMZN       0.0128       0.00448       0.0162        0.0144      0.00468
##  4 FB         0.0179      -0.00184       0.0137        0.00765    -0.00218
##  5 JNJ        0.00955     -0.0000712     0.00825       0.00127     0.0159
##  6 JPM        0.00102      0.0143       -0.00642       0.00148     0.00507
##  7 GOOG       0.0164       0.00362       0.0146        0.00427    -0.000614
##  8 GOOGL      0.0171       0.00388       0.0133        0.00353    -0.00127
##  9 XOM        0.0196       0.00138      -0.000806      0.00450    -0.00425
## 10 BAC       -0.00334      0.0131        0.00464      -0.00692     0.00498
## # ... with 492 more rows, and 277 more variables: `2018-01-10` <dbl>,
## #   `2018-01-11` <dbl>, `2018-01-12` <dbl>, `2018-01-16` <dbl>,
## #   `2018-01-17` <dbl>, `2018-01-18` <dbl>, `2018-01-19` <dbl>,
## #   `2018-01-22` <dbl>, `2018-01-23` <dbl>, `2018-01-24` <dbl>,
## #   `2018-01-25` <dbl>, `2018-01-26` <dbl>, `2018-01-29` <dbl>,
## #   `2018-01-30` <dbl>, `2018-01-31` <dbl>, `2018-02-01` <dbl>,
## #   `2018-02-02` <dbl>, `2018-02-05` <dbl>, `2018-02-06` <dbl>,
## #   ‘2018-02-07‘ <dbl>, ‘2018-02-08‘ <dbl>, ‘2018-02-09‘ <dbl>,
## #   ‘2018-02-12‘ <dbl>, ‘2018-02-13‘ <dbl>, ‘2018-02-14‘ <dbl>,
## #   ‘2018-02-15‘ <dbl>, ‘2018-02-16‘ <dbl>, ‘2018-02-20‘ <dbl>,
## #   ‘2018-02-21‘ <dbl>, ‘2018-02-22‘ <dbl>, ‘2018-02-23‘ <dbl>,
## #   ‘2018-02-26‘ <dbl>, ‘2018-02-27‘ <dbl>, ‘2018-02-28‘ <dbl>,
## #   ‘2018-03-01‘ <dbl>, ‘2018-03-02‘ <dbl>, ‘2018-03-05‘ <dbl>,
## #   ‘2018-03-06‘ <dbl>, ‘2018-03-07‘ <dbl>, ‘2018-03-08‘ <dbl>,
## #   ‘2018-03-09‘ <dbl>, ‘2018-03-12‘ <dbl>, ‘2018-03-13‘ <dbl>,
## #   ‘2018-03-14‘ <dbl>, ‘2018-03-15‘ <dbl>, ‘2018-03-16‘ <dbl>,
## #   ‘2018-03-19‘ <dbl>, ‘2018-03-20‘ <dbl>, ‘2018-03-21‘ <dbl>,
## #   ‘2018-03-22‘ <dbl>, ‘2018-03-23‘ <dbl>, ‘2018-03-26‘ <dbl>,
## #   ‘2018-03-27‘ <dbl>, ‘2018-03-28‘ <dbl>, ‘2018-03-29‘ <dbl>,
## #   ‘2018-04-02‘ <dbl>, ‘2018-04-03‘ <dbl>, ‘2018-04-04‘ <dbl>,
## #   ‘2018-04-05‘ <dbl>, ‘2018-04-06‘ <dbl>, ‘2018-04-09‘ <dbl>,
## #   ‘2018-04-10‘ <dbl>, ‘2018-04-11‘ <dbl>, ‘2018-04-12‘ <dbl>,
## #   ‘2018-04-13‘ <dbl>, ‘2018-04-16‘ <dbl>, ‘2018-04-17‘ <dbl>,
## #   ‘2018-04-18‘ <dbl>, ‘2018-04-19‘ <dbl>, ‘2018-04-20‘ <dbl>,
## #   ‘2018-04-23‘ <dbl>, ‘2018-04-24‘ <dbl>, ‘2018-04-25‘ <dbl>,
## #   ‘2018-04-26‘ <dbl>, ‘2018-04-27‘ <dbl>, ‘2018-04-30‘ <dbl>,
## #   ‘2018-05-01‘ <dbl>, ‘2018-05-02‘ <dbl>, ‘2018-05-03‘ <dbl>,
## #   ‘2018-05-04‘ <dbl>, ‘2018-05-07‘ <dbl>, ‘2018-05-08‘ <dbl>,
## #   ‘2018-05-09‘ <dbl>, ‘2018-05-10‘ <dbl>, ‘2018-05-11‘ <dbl>,
## #   ‘2018-05-14‘ <dbl>, ‘2018-05-15‘ <dbl>, ‘2018-05-16‘ <dbl>,
## #   ‘2018-05-17‘ <dbl>, ‘2018-05-18‘ <dbl>, ‘2018-05-21‘ <dbl>,
## #   ‘2018-05-22‘ <dbl>, ‘2018-05-23‘ <dbl>, ‘2018-05-24‘ <dbl>,
## #   ‘2018-05-25‘ <dbl>, ‘2018-05-29‘ <dbl>, ‘2018-05-30‘ <dbl>,
## #   ‘2018-05-31‘ <dbl>, ‘2018-06-01‘ <dbl>, ‘2018-06-04‘ <dbl>, ...
```

```
# Output: stock_date_matrix_tbl
```

Step 3 - Perform K-Means Clustering

Next, we'll perform **K-Means clustering**.

We're going to import the correct results first (just in case you were not able to complete the last step).

```
stock_date_matrix_tbl <- read_rds("stock_date_matrix_tbl.rds")
stock_date_matrix_tbl
```

```
## # A tibble: 502 x 283
##    symbol ‘2018-01-03‘ ‘2018-01-04‘ ‘2018-01-05‘ ‘2018-01-08‘ ‘2018-01-09‘
##    <chr>         <dbl>        <dbl>        <dbl>        <dbl>        <dbl>
##  1 A          0.0254      -0.00750     0.0160       0.00215     0.0246
##  2 AAL       -0.0123       0.00630    -0.000380    -0.00988    -0.000959
##  3 AAP        0.00905      0.0369      0.0106      -0.00704    -0.00808
##  4 AAPL      -0.000174     0.00465     0.0114      -0.00371    -0.000115
##  5 ABBV       0.0156      -0.00570     0.0174      -0.0160      0.00754
##  6 ABC        0.00372     -0.00222     0.0121       0.0166      0.00640
##  7 ABMD       0.0173       0.0175      0.0154       0.0271      0.00943
##  8 ABT        0.00221     -0.00170     0.00289     -0.00288     0.00170
##  9 ACN        0.00462      0.0118      0.00825      0.00799     0.00333
## 10 ADBE       0.0188       0.0120      0.0116      -0.00162     0.00897
## # ... with 492 more rows, and 277 more variables: ‘2018-01-10‘ <dbl>,
## #   ‘2018-01-11‘ <dbl>, ‘2018-01-12‘ <dbl>, ‘2018-01-16‘ <dbl>,
## #   ‘2018-01-17‘ <dbl>, ‘2018-01-18‘ <dbl>, ‘2018-01-19‘ <dbl>,
## #   ‘2018-01-22‘ <dbl>, ‘2018-01-23‘ <dbl>, ‘2018-01-24‘ <dbl>,
## #   ‘2018-01-25‘ <dbl>, ‘2018-01-26‘ <dbl>, ‘2018-01-29‘ <dbl>,
## #   ‘2018-01-30‘ <dbl>, ‘2018-01-31‘ <dbl>, ‘2018-02-01‘ <dbl>,
## #   ‘2018-02-02‘ <dbl>, ‘2018-02-05‘ <dbl>, ‘2018-02-06‘ <dbl>,
## #   ‘2018-02-07‘ <dbl>, ‘2018-02-08‘ <dbl>, ‘2018-02-09‘ <dbl>,
## #   ‘2018-02-12‘ <dbl>, ‘2018-02-13‘ <dbl>, ‘2018-02-14‘ <dbl>,
## #   ‘2018-02-15‘ <dbl>, ‘2018-02-16‘ <dbl>, ‘2018-02-20‘ <dbl>,
## #   ‘2018-02-21‘ <dbl>, ‘2018-02-22‘ <dbl>, ‘2018-02-23‘ <dbl>,
## #   ‘2018-02-26‘ <dbl>, ‘2018-02-27‘ <dbl>, ‘2018-02-28‘ <dbl>,
## #   ‘2018-03-01‘ <dbl>, ‘2018-03-02‘ <dbl>, ‘2018-03-05‘ <dbl>,
## #   ‘2018-03-06‘ <dbl>, ‘2018-03-07‘ <dbl>, ‘2018-03-08‘ <dbl>,
## #   ‘2018-03-09‘ <dbl>, ‘2018-03-12‘ <dbl>, ‘2018-03-13‘ <dbl>,
## #   ‘2018-03-14‘ <dbl>, ‘2018-03-15‘ <dbl>, ‘2018-03-16‘ <dbl>,
## #   ‘2018-03-19‘ <dbl>, ‘2018-03-20‘ <dbl>, ‘2018-03-21‘ <dbl>,
## #   ‘2018-03-22‘ <dbl>, ‘2018-03-23‘ <dbl>, ‘2018-03-26‘ <dbl>,
## #   ‘2018-03-27‘ <dbl>, ‘2018-03-28‘ <dbl>, ‘2018-03-29‘ <dbl>,
## #   ‘2018-04-02‘ <dbl>, ‘2018-04-03‘ <dbl>, ‘2018-04-04‘ <dbl>,
## #   ‘2018-04-05‘ <dbl>, ‘2018-04-06‘ <dbl>, ‘2018-04-09‘ <dbl>,
## #   ‘2018-04-10‘ <dbl>, ‘2018-04-11‘ <dbl>, ‘2018-04-12‘ <dbl>,
## #   ‘2018-04-13‘ <dbl>, ‘2018-04-16‘ <dbl>, ‘2018-04-17‘ <dbl>,
## #   ‘2018-04-18‘ <dbl>, ‘2018-04-19‘ <dbl>, ‘2018-04-20‘ <dbl>,
## #   ‘2018-04-23‘ <dbl>, ‘2018-04-24‘ <dbl>, ‘2018-04-25‘ <dbl>,
## #   ‘2018-04-26‘ <dbl>, ‘2018-04-27‘ <dbl>, ‘2018-04-30‘ <dbl>,
## #   ‘2018-05-01‘ <dbl>, ‘2018-05-02‘ <dbl>, ‘2018-05-03‘ <dbl>,
## #   ‘2018-05-04‘ <dbl>, ‘2018-05-07‘ <dbl>, ‘2018-05-08‘ <dbl>,
## #   ‘2018-05-09‘ <dbl>, ‘2018-05-10‘ <dbl>, ‘2018-05-11‘ <dbl>,
## #   ‘2018-05-14‘ <dbl>, ‘2018-05-15‘ <dbl>, ‘2018-05-16‘ <dbl>,
## #   ‘2018-05-17‘ <dbl>, ‘2018-05-18‘ <dbl>, ‘2018-05-21‘ <dbl>,
## #   ‘2018-05-22‘ <dbl>, ‘2018-05-23‘ <dbl>, ‘2018-05-24‘ <dbl>,
## #   ‘2018-05-25‘ <dbl>, ‘2018-05-29‘ <dbl>, ‘2018-05-30‘ <dbl>,
## #   ‘2018-05-31‘ <dbl>, ‘2018-06-01‘ <dbl>, ‘2018-06-04‘ <dbl>, ...
```

Beginning with the `stock_date_matrix_tbl`, perform the following operations:

- Drop the non-numeric column, `symbol`
- Perform `kmeans()` with `centers = 4` and `nstart = 20`
- Save the result as `kmeans_obj`

```r
# Create kmeans_obj for 4 centers
kmeans_obj <- stock_date_matrix_tbl %>%
              select(-symbol) %>%
              kmeans(centers = 4, nstart = 20)
```

Use `glance()` to get the `tot.withinss`.

```r
# Apply glance() to get the tot.withinss
broom::glance(kmeans_obj)
```

```
## # A tibble: 1 x 4
##   totss tot.withinss betweenss  iter
##   <dbl>        <dbl>     <dbl> <int>
## 1  33.6         29.2      4.40     3
```

Step 4 - Find the optimal value of K

Now that we are familiar with the process for calculating `kmeans()`, let's use `purrr` to iterate over many values of "k" using the `centers` argument.

We'll use this **custom function** called `kmeans_mapper()`:

```
kmeans_mapper <- function(center = 3) {
    stock_date_matrix_tbl %>%
        select(-symbol) %>%
        kmeans(centers = center, nstart = 20)
}
```

Apply the `kmeans_mapper()` and `glance()` functions iteratively using `purrr`.

- Create a tibble containing column called `centers` that go from 1 to 30
- Add a column named `k_means` with the `kmeans_mapper()` output. Use `mutate()` to add the column and `map()` to map centers to the `kmeans_mapper()` function.
- Add a column named `glance` with the `glance()` output. Use `mutate()` and `map()` again to iterate over the column of `k_means`.
- Save the output as `k_means_mapped_tbl`

```
# Use purrr to map
k_means_mapped_tbl  <- tibble(centers = 1:30) %>%
  mutate(k_means = centers %>% map(kmeans_mapper)) %>%
  mutate(glance  = k_means %>% map(glance))

k_means_mapped_tbl
```

```
## # A tibble: 30 x 3
##    centers k_means  glance
##      <int> <list>   <list>
##  1       1 <kmeans> <tibble [1 x 4]>
##  2       2 <kmeans> <tibble [1 x 4]>
##  3       3 <kmeans> <tibble [1 x 4]>
##  4       4 <kmeans> <tibble [1 x 4]>
##  5       5 <kmeans> <tibble [1 x 4]>
##  6       6 <kmeans> <tibble [1 x 4]>
##  7       7 <kmeans> <tibble [1 x 4]>
##  8       8 <kmeans> <tibble [1 x 4]>
##  9       9 <kmeans> <tibble [1 x 4]>
## 10      10 <kmeans> <tibble [1 x 4]>
## # ... with 20 more rows
```

```
# Output: k_means_mapped_tbl
```

Next, let's visualize the "tot.withinss" from the glance output as a ***Scree Plot***.

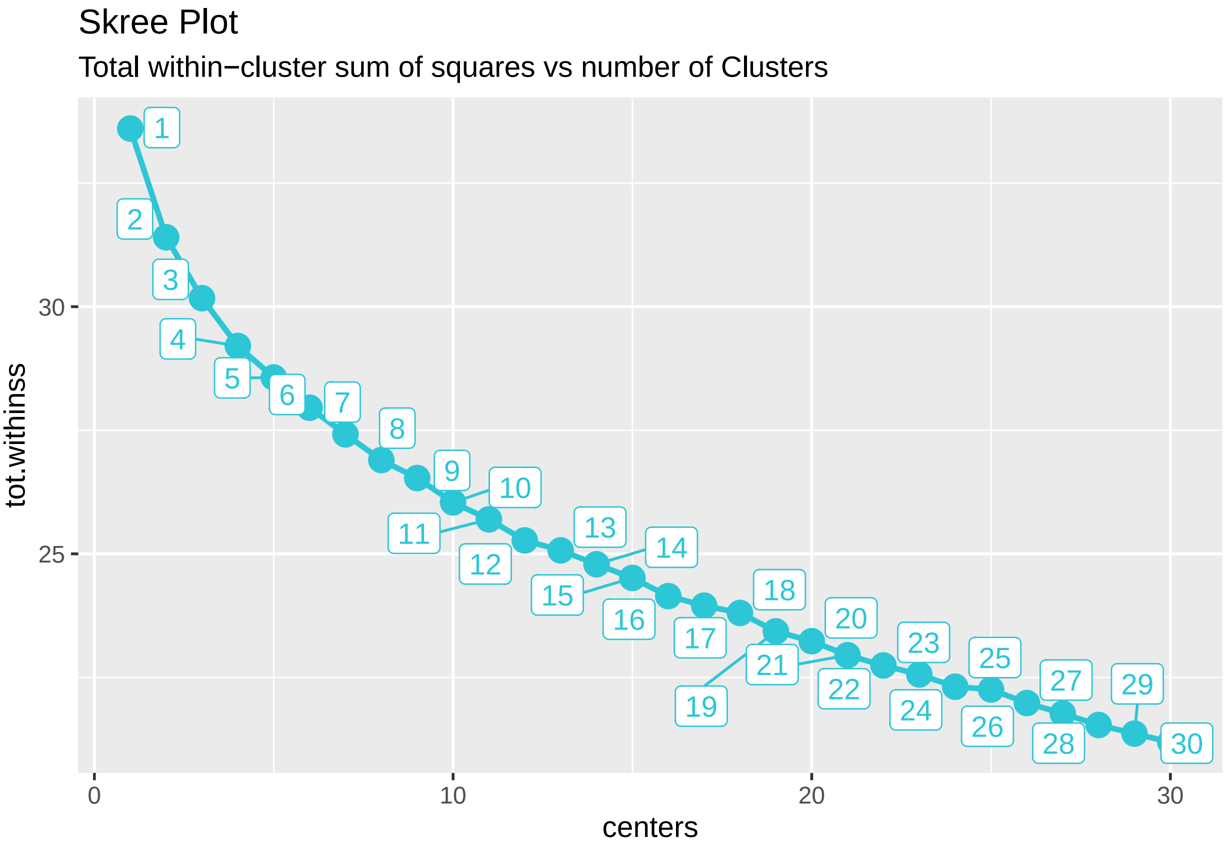
- Begin with the `k_means_mapped_tbl`
- Unnest the `glance` column
- Plot the `centers` column (x-axis) versus the `tot.withinss` column (y-axis) using `geom_point()` and `geom_line()`

- Add a title “Scree Plot” and feel free to style it with your favorite theme

```
# Visualize Scree Plot
k_means_mapped_tbl %>%
  unnest(glance) %>%
  select(centers, tot.withinss) %>%

  # Visualization
  ggplot(aes(centers, tot.withinss)) +
  geom_point(color = "#2DC6D6", size = 4) +
  geom_line(color = "#2DC6D6", size = 1) +
  # Add labels (which are repelled a little)
  ggrepel::geom_label_repel(aes(label = centers), color = "#2DC6D6") +

  # Formatting
  labs(title = "Skree Plot",
       subtitle = "Total within-cluster sum of squares vs number of Clusters")
```



We can see that the Scree Plot becomes linear (constant rate of change) between 5 and 10 centers for K.

Step 5 - Apply UMAP

Next, let’s plot the `UMAP` 2D visualization to help us investigate cluster assignments.

We’re going to import the correct results first (just in case you were not able to complete the last step).

```
k_means_mapped_tbl <- read_rds("k_means_mapped_tbl.rds")
```

First, let's apply the `umap()` function to the `stock_date_matrix_tbl`, which contains our user-item matrix in tibble format.

- Start with `stock_date_matrix_tbl`
- De-select the `symbol` column
- Use the `umap()` function storing the output as `umap_results`

```
# Apply UMAP
umap_results <- stock_date_matrix_tbl %>% select(-symbol) %>% umap()

umap_results
# Store results as: umap_results
```

Next, we want to combine the `layout` from the `umap_results` with the `symbol` column from the `stock_date_matrix_tbl`.

- Start with `umap_results$layout`
- Convert from a `matrix` data type to a `tibble` with `as_tibble()`
- Bind the columns of the umap tibble with the `symbol` column from the `stock_date_matrix_tbl`.
- Save the results as `umap_results_tbl`.

```
# Convert umap results to tibble with symbols
umap_results_tbl <- umap_results$layout %>%
  as_tibble(.name_repair = "unique") %>% # argument is required to set names in the next step
  set_names(c("x", "y")) %>%
  bind_cols(
    stock_date_matrix_tbl %>% select(symbol)
  )

umap_results_tbl
```

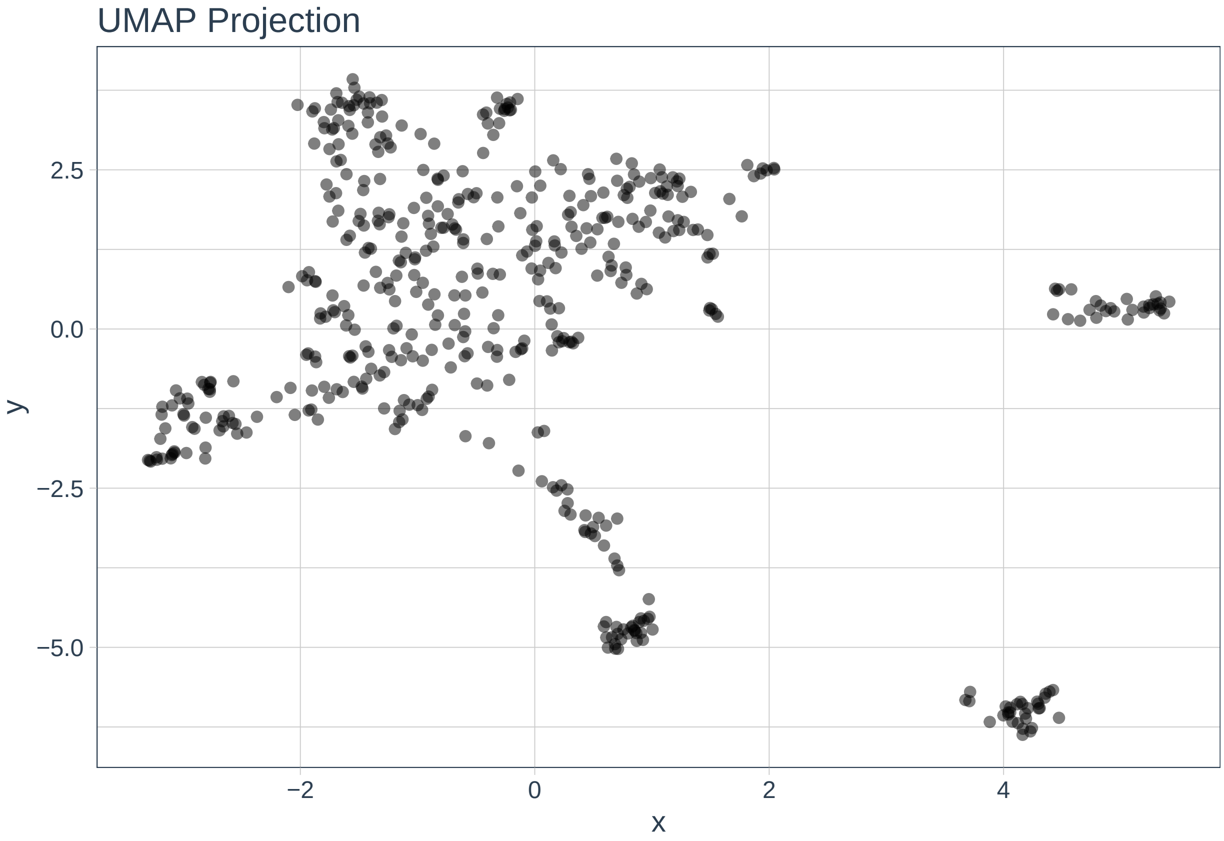
```
## # A tibble: 502 x 3
##         x      y symbol
##     <dbl>  <dbl> <chr>
##  1 -0.648  2.04  A
##  2  1.50   0.329 AAL
##  3 -0.118 -0.319 AAP
##  4 -1.14   3.20  AAPL
##  5 -1.71   0.264 ABBV
##  6 -1.22  -0.437 ABC
##  7 -1.80   3.25  ABMD
##  8 -0.910  1.78  ABT
##  9 -1.33   1.83  ACN
## 10 -1.46   3.54  ADBE
## # ... with 492 more rows
```

```
# Output: umap_results_tbl
```

Finally, let's make a quick visualization of the `umap_results_tbl`.

- Pipe the `umap_results_tbl` into `ggplot()` mapping the columns to x-axis and y-axis
- Add a `geom_point()` geometry with an `alpha = 0.5`
- Apply `theme_tq()` and add a title "UMAP Projection"

```
# Visualize UMAP results
umap_results_tbl %>%
  ggplot(aes(x, y)) +
  geom_point(alpha= 0.5) +
# Formatting
  labs(title = "UMAP Projection ") +
  theme_tq()
```



We can now see that we have some clusters. However, we still need to combine the K-Means clusters and the UMAP 2D representation.

Step 6 - Combine K-Means and UMAP

Next, we combine the K-Means clusters and the UMAP 2D representation

We're going to import the correct results first (just in case you were not able to complete the last step).

```
k_means_mapped_tbl <- read_rds("k_means_mapped_tbl.rds")
umap_results_tbl   <- read_rds("umap_results_tbl.rds")
```

First, pull out the K-Means for 10 Centers. Use this since beyond this value the Scree Plot flattens. Have a look at the business case to recall how that works.

```
# Get the k_means_obj from the 10th center
k_means_obj <- k_means_mapped_tbl %>%
               pull(k_means) %>%
               pluck(10)

# Store as k_means_obj
```

Next, we'll combine the clusters from the `k_means_obj` with the `umap_results_tbl`.

- Begin with the `k_means_obj`
- Augment the `k_means_obj` with the `stock_date_matrix_tbl` to get the clusters added to the end of the tibble
- Select just the `symbol` and `.cluster` columns
- Left join the result with the `umap_results_tbl` by the `symbol` column
- Left join the result with the result of `sp_500_index_tbl %>% select(symbol, company, sector)` by the `symbol` column.
- Store the output as `umap_kmeans_results_tbl`

```
# Use your dplyr & broom skills to combine the k_means_obj with the umap_results_tbl
umap_kmeans_results_tbl <- k_means_obj%>%
                           augment(stock_date_matrix_tbl) %>%
                           # Select the data we need
                          select(symbol, .cluster)

umap_kmeans_results_tbl <- umap_kmeans_results_tbl %>%
                             left_join(umap_results_tbl)%>%
                             left_join(sp_500_index_tbl %>% select(symbol, company, sector))
umap_kmeans_results_tbl
```

```
## # A tibble: 502 x 6
##    symbol .cluster      V1      V2 company                   sector
##    <chr>  <fct>      <dbl>   <dbl> <chr>                     <chr>
##  1 A      7         -0.764   1.65  Agilent Technologies Inc. Health Care
##  2 AAL    2         -2.70    0.455 American Airlines Group ~ Industrials
##  3 AAP    10         0.739  -0.0320 Advance Auto Parts Inc.   Consumer Discretio~
##  4 AAPL   9          0.0130  3.09  Apple Inc.                Information Techno~
##  5 ABBV   7         -0.965  -0.0193 AbbVie Inc.               Health Care
##  6 ABC    5         -0.506  -0.659  AmerisourceBergen Corpor~ Health Care
##  7 ABMD   9          0.436   3.10  ABIOMED Inc.              Health Care
##  8 ABT    7         -0.262   1.35  Abbott Laboratories       Health Care
##  9 ACN    7          0.0598  1.63  Accenture Plc Class A     Information Techno~
## 10 ADBE   9          0.570   3.43  Adobe Inc.                Information Techno~
## # ... with 492 more rows
```

```
# Output: umap_kmeans_results_tbl
```

Plot the K-Means and UMAP results.

- Begin with the `umap_kmeans_results_tbl`
- Use `ggplot()` mapping `V1`, `V2` and `color = .cluster`
- Add the `geom_point()` geometry with `alpha = 0.5`

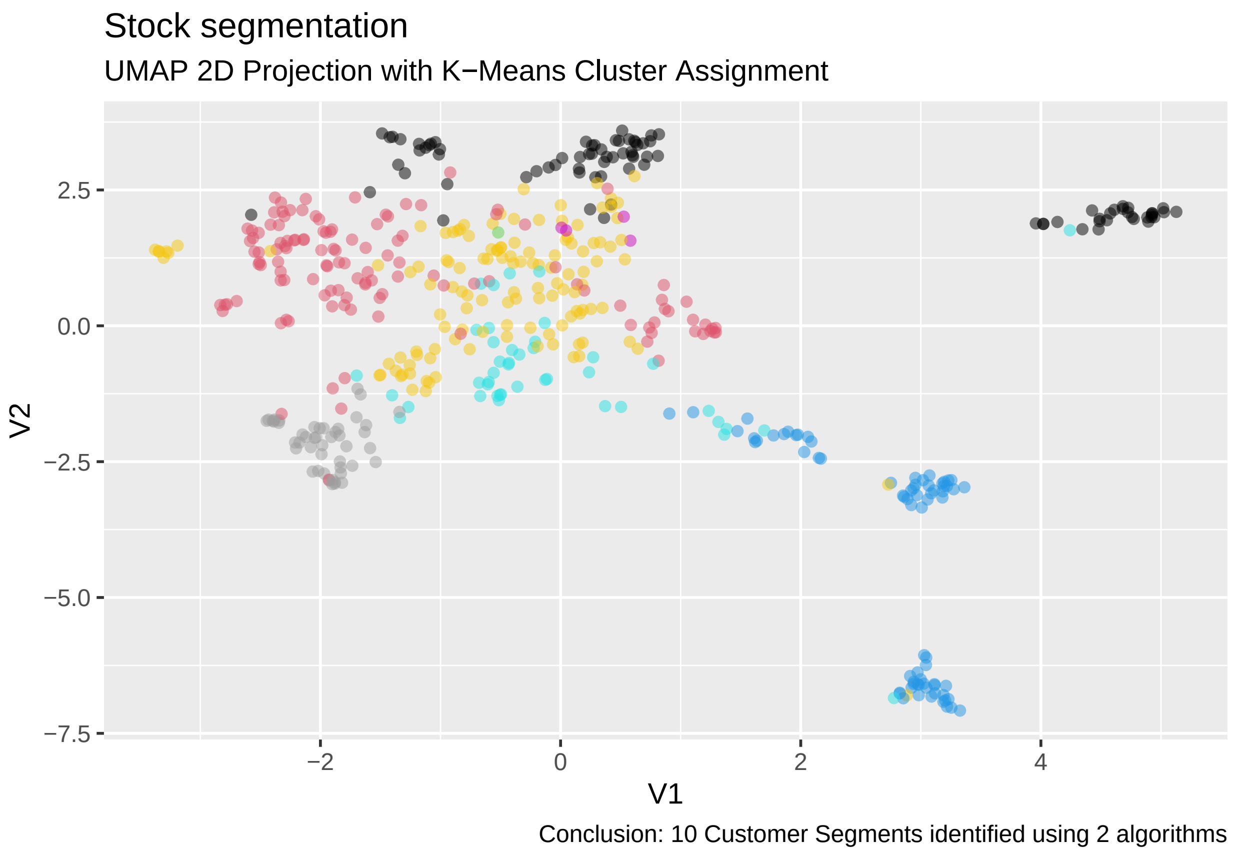
- Apply colors as you desire (e.g. `scale_color_manual(values = palette_light() %>% rep(3))`)

```
# Visualize the combined K-Means and UMAP results
  umap_kmeans_results_tbl %>%
  mutate(label_text = str_glue("Symbol: {symbol}
                                 Cluster: {.cluster}")) %>%

  ggplot(aes(V1, V2, color = .cluster)) +

  # Geometries
  geom_point(alpha = 0.5) +
  geom_label_repel(aes(label = label_text), size = 2, fill = "#282A36") +

  # Formatting
  scale_color_manual(values=c("1", "2", "3", "4", "5", "6", "7", "8", "9", "10")) +
  labs(title = "Stock segmentation",
       subtitle = "UMAP 2D Projection with K-Means Cluster Assignment",
       caption = "Conclusion: 10 Customer Segments identified using 2 algorithms") +
  theme(legend.position = "none")
```



Congratulations! You are done with the 1st challenge!