Project Description

STAT 489: SYE Independent Project (Dr. Higham)

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**Introduction:**

For my Senior Year Experience, I have decided to create a web application to teach beginning investors how being invested in five publicly traded companies would have performed over a given time period. The reason for this is to teach investors how their money would have grown if they allocated their initial investment, assuming they only invested their money one time, into a portfolio of five different equities. By doing this, it will show investors that the earlier that they invest the better off they will be, especially in recent years given the run of bull markets that we have had. There are many components that went into building this web application, all of which will be discussed below. In the rest of this write, the following will be discussed in order to give some color around the purpose of the app and what each element of the app entails: key features and R packages used for the app, the purpose of each element in the app, why what’s happening in the app is important to an individual, analysis of the code used to write the app, and a conclusion to sum up the benefits and pitfalls of the app.

**Key Features:**

* R Packages Utilized
  + Shiny (R Package)
    - This package allowed for the creation of the web application by creating the following elements:
      * User Interface
        + Allows the user to interact with content or software running on a remote server through a Web browser
        + The content or Web page is downloaded from the Web server and the user can interact with this content in a Web browser, which acts as a client
      * Server
        + Delivers static web content—e.g., HTML pages, files, images, video—primarily in response to hypertext transfer protocol (HTTP) requests from a web browser
    - R Packages Utilizied For Technical Analysis
      * Tidyquant and PerformanceAnalytics
        + Get Quantitative Data from the internet (Yahoo Finance)
        + Perform and scale financial calculations completely within the tidyverse. These functions integrate the xts, zoo, quantmod, TTR, and PerformanceAnalytics packages
        + The PerformanceAnalytics integration enables analyzing performance of assets and portfolios
        + Performance is based on the statistical properties of returns, and as a result both functions use returns as opposed to stock prices
      * Quantmod
        + Designed to assist quantitative traders in the development, testing, and deployment of statistically based trading models
        + The goal of the package is to aid practitioners and researchers in solving portfolio optimization problems with complex constraints and objectives
  + Tidyverse (R Package)
    - Provides access to multiple different, and highly useful, R packages utilized in this project such as:
      * ggplot2 (package within tidyverse)
        + ggplot2 is a system for declaratively creating graphics, based on The Grammar of Graphics. You provide the data, tell ggplot2 how to map variables to aesthetics, what graphical primitives to use, and it takes care of the details
        + Used to create the graphics displayed in the web application
      * dplyr (package within tidyverse)
        + dplyr provides a grammar of data manipulation, providing a consistent set of verbs that solve the most common data manipulation challenges
        + Used to manipulate the variables into specific statistical and quantitative financial analytics variables used in the math to create the desired graphics
      * forcats (package within tidyverse)
        + forcats provides a suite of useful tools that solve common problems with factors. R uses factors to handle categorical variables, variables that have a fixed and known set of possible values
        + Allowed me to change certain variables to be numeric in order to change the portfolio investment
* Other elements integrated into the app
  + Real Stock Market Data
    - Data was scraped, using the tidyquant package in R, from Yahoo Finance
      * By doing this, it allows for the data to be up to date and accurate
  + Weighting of Equities
    - Allows you to change how much of your investment is allocated into five different equities on any exchange in the world, data must be from Yahoo Finance
    - The weighting of every equity must sum to 1
      * e.g. five investments: each equity will be weighted by 0.2
  + Different Functions
    - Simple Linear Regression
    - Smoother
    - Double Exponential Moving Average
    - Benchmark Ticker
  + Investment Size
    - Adjustable to the value of your initial investment into the five equities in your portfolio
  + Portfolio Growth Plot
    - Shows the change in the value of your portfolio based upon the initial investment date to the current date, or any date of your choosing
    - Descriptive Statistics
      * Max Portfolio Value: The maximum value of your portfolio over the course your portfolios life
      * Min Portfolio Value: The minimum value of your portfolio over the course your portfolios life
      * Standard Deviation of the Portfolio
        + Standard deviation of returns, based on a dollar value, in the portfolio
        + A high portfolio standard deviation highlights that the portfolio risk is high, and return is more volatile in nature and, as such unstable as well
        + A Portfolio with low Standard Deviation implies less volatility and more stability in the returns of a portfolio and is a very useful financial metric when comparing different portfolios
      * Average Value of the Portfolio: the mean of the portfolio, based on weekly returns, over the last year of the portfolio’s life
  + Aggregated Portfolio Returns
    - The aggregated portfolio returns (as a percentage) calculate the change in the value of the portfolio and expresses it as apercentage of the original amount invested by an individual.

**Purpose of Each Element:**

* Portfolio Growth Plot
  + The image [**APPENDIX REFERENCE**] shows how much the investor would have made from the first time they invested in the following five equities and their weightings in the portfolio.
  + Descriptive statistics on the investor’s earnings with four different investing metrics described in the image [**APPENDIX REFERENCE**]
* Descriptive Statistics
  + The image [**APPEDNIX REFERENCE**] depicts the highest return with the lowest risk investment for the five securities held in the app when you first open it
  + Max Portfolio Value
    - Shows how much your portfolio would have made, at it’s peak, at any given point in time (not connected at all – remove or change to make sense)
      * Allows investors to know how much money they would have made
      * Gives the investor a good idea of how they should allocate their investment into each equity or what equities they should have in their portfolio
  + Min Portfolio Value
    - Shows how little your portfolio would have been worth, at its lowest point, at any given point in time
      * Gives the investor a good idea of how not to allocate their investment into each equity or what equities they should have in their portfolio
  + Standard Deviation of the Portfolio
    - A high portfolio standard deviation highlights that the portfolio risk is high, and return is more volatile in nature and, as such unstable as well
    - A Portfolio with low Standard Deviation implies less volatility and more stability in the returns of a portfolio and is a very useful financial metric when comparing different portfolios
      * This shows the investor how volatile their portfolio is, which either indicates that their portfolio is extremely risky or if there is not enough risk in the portfolio
      * This means the portfolio will either make a lot or a little if the portfolio is extremely volatile, or the portfolio will not make desirable returns if there is not enough risk factored into the portfolio
      * Although there is no standard rule of thumb for how much risk is too much risk, shown in a dollar amount of the standard deviation, this can be based off the value of your portfolio.
        + So if your portfolio is worth $100,000 and you have a standard deviation of $20,000, that would be a lot of volatility for a portfolio
        + Whereas a portfolio with a standard deviation of around $5,000 would be optimal depending on the year.
  + Average Value of the Portfolio (change to be the average for the last 1-2 years)
    - This shows the investor how their portfolio would perform, on average based on a dollar value, over the desired investment period for the portfolio
    - Gives the investor a better idea of how their portfolio stacks up to other portfolio’s with either similar weighting, similar equities, or completely different equities and weightings in the portfolio
* Aggregated Portfolio Returns
  + Weekly Portfolio Returns, depicted in [**APPENDIX REFERENCE**], on a percentage basis, and their impact on the portfolio
    - Allows for beginning investors to see how much a portfolio lost or gained on a percentage basis at a weekly rate over the course of time using historical data
      * This shows how much each portfolio investment gained or lost based on a percentage any given week since you first invested
        + Any stock you have invested in, and the weight they hold in the portfolio, since whenever you first held the equities
        + Can give the investor better confidence so long as he’s able to mitigate his downside risk in exchange for the most favorable return as demonstrated in the app
* Weighting & Investment Size
  + By allocating your investment differently according to the equity, this will allow investors to optimize their portfolio to achieve the best returns which can be seen in [**APPENDIX REFERENCE**]
    - Although an individual might need to have some background knowledge on this, it still allows the investor to educate themselves on how to optimize the returns on any given portfolio
  + By allowing the investment size to be adjustable, this shows how much money the individual would have made based upon different initial investments which can be depicted in [**APPENDIX REFERENCE**]
    - Allows the investor to see how holding long on securities where the companies have good innovation and outstanding IP for their industry
      * Tickers depicted in the image above as well as the securities weighting in the portfolio
* Forecast Plot
  + The graph below shows the performance of the portfolio that the investor has created 5-years into the future which can be seen in [**APPENDIX REFERENCE**]
  + By showing this, it will give the investor confidence that their portfolio will bring favorable returns into the future.
    - The forecast plot utilizes a Holt-Winter Smoothing Model in order to determine the future performance of the portfolio.
      * The Holt-Winters method therefore is often referred to as triple exponential smoothing, as it is literally the combination of 3 smoothing methods built on top of each-other.
      * Holt-Winters method looks at these three elements: a typical value (average), a slope (trend) over time, and a cyclical repeating pattern (seasonality).
  + A 90% prediction interval is used to show how well the portfolio will perform at it’s worst, shown by the bottom red line, and the best your portfolio will perform, the top red line.
    - The blue line is the predicted performance of the portfolio given the historical data for the time series model.
      * The given model predicts very reasonable returns given the five equities because the 5 equities given are the highest return with the lowest risk given their asset class and weighting.
        + The 5 equities, only large cap growth and large cap value, chosen to determine this return and risk profile were from a wealth manager out of Burlington, Vermont.

**Why All of this Important:**

All of this is significantly important to beginning investors because by using this application they would see how of an impact investing is if you either get in at the right time or buy securities with huge upside potential. This gives beginning investors a way of educating themselves on what they’re buying rather than buying whatever they see if hot in the news. Much like the AMC and Gamestop buying craze in mid-2021, although these companies have performed well in the near term, these are not profitable companies who will have favorable returns in your portfolio. Rather than investing in these equities because of word of mouth and them being currently hot, an individual can do research on companies and see how by adding that particular security to their portfolio will directly impact their returns as well as their risk and maximum gain on the portfolio if they’re long holding the equities. By utilizing the different packages and tools above, I believe this will give individuals a huge leg up since they can educate themselves and become more financially literate in the process. Wealth managers can come at a huge expense and with high barriers to entry due to many having a minimum required investment amount of $100,000~ USD, so by using this you might not receive the best returns but you will certainly learn and it will help develop the base key tools to investing wisely.

**Code:**

* UI

|  |  |
| --- | --- |
| ui <- fluidPage(  titlePanel("Analysis of Equities: Portfolio Growth") | Creates web app title |
| sidebarPanel(    tabsetPanel(    tabPanel("Portfolio",    textInput("Ticker1", # Enter ticker symbol to get data  label = h3("Enter Ticker Symbol"),  value = "JPM"),  textInput("Ticker2", # Enter ticker symbol to get data  label = h3("Enter Ticker Symbol"),  value = "TSLA"),  textInput("Ticker3", # Enter ticker symbol to get data  label = h3("Enter Ticker Symbol"),  value = "MA"),  textInput("Ticker4", # Enter ticker symbol to get data  label = h3("Enter Ticker Symbol"),  value = "MSFT"),  textInput("Ticker5", # Enter ticker symbol to get data  label = h3("Enter Ticker Symbol"),  value = "BRK-A"),  textInput("Benchmark1", # Enter benchmark ticker symbol to get data  label = h3("Enter Benchmark Symbol"),  value = "^GSPC"), | Creates side bar panel which allows you to input your desired ticker symbol corresponding to a given equity on Yahoo Finance, as well as a benchmark ticker like the S&P 500 to see how well your portfolio performs to that given index. H3 function formats the size of the html text. |
| dateRangeInput("Date", label = h3("Date range"), start = "2015-01-01" ) | Allows you to adjust the time from when you first invested until now or until you pulled out your money of that particular portfolio. |
| checkboxInput("SMR", label = "Simple Linear Regression", value = FALSE),  checkboxInput("Smoother", label = "Smoother", value = FALSE),  checkboxInput("DoubleExponentialMovingAverage", label = "Double Exponential Moving Average", value = FALSE),  checkboxInput("benchmark", label = "Benchmark Ticker", value = FALSE) | The checkboxInput allows you to apply specific statistical functions, i.e. a simple linear regression model fitted to the data. |
| numericInput("DBLMovAvgN", label = h3("Weeks for Double Exponential Moving Average"), value = 27)    )  , | Used to calculate the average price of the equities in the portfolio over the past 27 weeks (half of a year), and fits a curve to the data. 27 most recent observations used to calculate the average price of the portfolio respectively. |
| tabPanel("Weighting & Investment Size",  h5("Weights Must Sum to 1"),  textInput("Weight1", # Enter ticker symbol to get data  label = h3("Enter Weighting on 1st Stock"),  value = "0.3"),  textInput("Weight2", # Enter ticker symbol to get data  label = h3("Enter Weighting on 2nd Stock"),  value = "0.133"),  textInput("Weight3", # Enter ticker symbol to get data  label = h3("Enter Weighting on 3rd Stock"),  value = "0.133"),  textInput("Weight4", # Enter ticker symbol to get data  label = h3("Enter Weighting on 4th Stock"),  value = "0.134"),  textInput("Weight5", # Enter ticker symbol to get data  label = h3("Enter Weighting on 5th Stock"),  value = "0.3"),  textInput("Investment",  label = h3("Enter Investment Size"),  value = "10000") | Creates a tab in the sidebar panel to input the weighting of each investment in the portfolio, i.e. allocating a percentage of your invested amount into specific equities. This corresponds to the ticker symbol in the first panel of the side bar. |
| mainPanel(tabsetPanel(id = "tabs",  tabPanel("Historical Portfolio Performance", plotOutput("plot", height= 800),  textOutput("SumStats")    ),    tabPanel("Aggregated Weekly Portfolio Returns", plotOutput("bar", height= 800)    ),    tabPanel("Forecasted Portfolio Performance", plotOutput("plot2", height= 800),  textOutput("model")    ) | Creates the main panels showing the plots of your portfolio’s historical performance, i.e. how much money you would have made if you invested in 5 specific equities of your choice over the given time interval. Also, the aggreagted weekly portfolio returns displays are faceted, organized by equity, to show the return as a percentage of each equity over the given time interval. Also, the forecasted performance of your portfolio is displayed to show how you portfolio will perform 5 years into the future from now. |

* Server

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| --- | --- |
| server <- function(input, output) {    portfolio <- reactive({    weekly\_portfolio\_returns <- c(input$Ticker1, input$Ticker2, input$Ticker3, input$Ticker4, input$Ticker5)  weekly\_portfolio\_returns <- tq\_get(weekly\_portfolio\_returns,  get = "stock.prices",  from = "1850-01-01",  to = input$Date[2]) %>%  group\_by(symbol) %>%  tq\_transmute(select = adjusted,  mutate\_fun = periodReturn,  period = "weekly",  col\_rename = "Portfolio")  weekly\_portfolio\_returns <- weekly\_portfolio\_returns %>%  filter(date >= input$Date[1]) %>%  filter(date <= input$Date[2])  weights <- c(input$Weight1,input$Weight2,input$Weight3,input$Weight4,input$Weight5)    portfolio <- weekly\_portfolio\_returns %>%  tq\_portfolio(assets\_col = symbol,  returns\_col = Portfolio,  weights = weights,  col\_rename = "investment.growth",  wealth.index = TRUE) %>%  mutate(investment.growth = investment.growth \* as.numeric(input$Investment))  portfolio$MA6 <- TTR::DEMA(portfolio$investment.growth, n = input$DBLMovAvgN)      return(portfolio) | Highlights correspond to what’s going on in the code:  Allows you to decide which 5 equities you’re investing in.  Creates the initial data set which collects weekly data from each of the 5 equities from 1850, the earliest data can be retrieved from the stock market, and mutates the data so it’s organized by ticker symbol and the return that the equity will receive in that period.  Allows the data of the given portfolio into the date range that investor has invested in, i.e. the duration of the investments in the portfolio.    Allows you to create the weightings of each investment.  Creates the final data set used to create the historical plot and forecast plot, which will be transformed into a time series so a Holt-Winter Smoothing model can be created. This also creates the return for the portfolio with the given initial investment. This also allows for the investment size to be factored into calculating the DEMA for the historical model. |
| weekly\_returns <- reactive({    weekly\_returns <- c(input$Ticker1, input$Ticker2, input$Ticker3, input$Ticker4, input$Ticker5)  weekly\_returns <- tq\_get(weekly\_returns,  get = "stock.prices",  from = "1850-01-01",  to = input$Date[2]) %>%  group\_by(symbol) %>%  tq\_transmute(select = adjusted,  mutate\_fun = periodReturn,  period = "weekly",  col\_rename = "Weekly\_Returns")    weekly\_returns <- weekly\_returns %>%  filter(date >= input$Date[1]) %>%  filter(date <= input$Date[2])    return(weekly\_returns) | Creates the weekly returns data set, as a percentage, for the faceted bar plot in the second tab of the main panel for the given period that the investor is invested in those 5 equities. |
| benchmark <- reactive({  benchmark <- c(input$Benchmark1)  benchmark <- tq\_get(benchmark,  get = "stock.prices",  from = "1850-01-01",  to = input$Date[2]) %>%  group\_by(symbol) %>%  tq\_transmute(select = adjusted,  mutate\_fun = periodReturn,  period = "weekly",  col\_rename = "Benchmark")    benchmark <- benchmark %>%  filter(date >= input$Date[1]) %>%  filter(date <= input$Date[2])    benchmark <- benchmark %>%  tq\_portfolio(assets\_col = symbol,  returns\_col = Benchmark,  col\_rename = "benchmark.growth",  wealth.index = TRUE) %>%  mutate(benchmark.growth = benchmark.growth \* as.numeric(input$Investment))      return(benchmark) | This function creates the final data set for the benchmark index to compare your historical portfolio returns against. Wealth managers use this to see if their portfolio is beating that bench mark, which in the case of the S&P 500 you return 10% per year. This data set is showing the performance of your initial investment that you made into the portfolio, i.e. $10,000. |
| portfolio\_forecast <- reactive({    portfolio\_forecast <- ts(portfolio()$investment.growth, frequency = 52, start = 2015)    portfolio\_forecast <- hw(portfolio\_forecast, initial="simple", h = 260, level=0.90)    return(portfolio\_forecast) | Creates the time series Holt-Winter Smoothing model to forecast the performance of your portfolio 5 years, i.e. 260 weeks, into the future. Frequency is tethered to the weekly data (S=52, this means the frequency of the data is weekly over the course of a year). |
| output$plot <- renderPlot({    g = ggplot(data = portfolio(), aes(x = date, y = investment.growth)) +  geom\_line(size = 1) +  labs(x = "Time", y = "Portfolio Value") +  scale\_y\_continuous(labels = scales::dollar)    if(input$SMR == TRUE){  g <- g + geom\_smooth(method=lm, se=FALSE, color = "red")  }    if(input$Smoother == TRUE){  g <- g + geom\_smooth(color = "blue", se = FALSE)  }    if(input$DoubleExponentialMovingAverage == TRUE){  g <- g + geom\_line(aes(x = date, y = MA6), color = "purple", size = 0.75)  }    if(input$benchmark == TRUE){  g <- g + geom\_line(data = benchmark(), aes(x = date, y = benchmark.growth), color = "mediumseagreen", size = 0.75)  }    return(g) }) | Creates the historical plot of your portfolio’s performance using the ggplot2 package. Furthermore, this allows you to attach the functions corresponding to the checkboxInput buttons in the UI. |
| output$SumStats <- renderText({  textStats = ""  a = mean(portfolio()$investment.growth)  b = sd(portfolio()$investment.growth)  c = max(portfolio()$investment.growth)  d = min(portfolio()$investment.growth)  textStats = paste("Average Value of the Portfolio = ", round (a,2),"|" ,  "Standard Deviation of the Portfolio = ", round(b,2), "|",  "Max Portfolio Value = ", round(c,2), "|",  "Min Portfolio Value = ", round(d,2))    return(textStats) | Creates the following 4 summary statistics in the historical performance plot, displayed below the plot: standard deviation of the portfolio (used to determine risk), the maximum value the portfolio receives during the time period, the minimum value of the portfolio during the time period, and the average value of the portfolio during the time period. |
| output$bar <- renderPlot({    ggplot(data = weekly\_returns(), aes(x = date, y = Weekly\_Returns)) +  geom\_area(data = weekly\_returns(), stat = "identity", aes(fill = symbol)) +  labs(title = "Portfolio Returns by Stock (Weekly)",  x = "Date", y = "Weekly Returns (%)") +  scale\_y\_continuous(labels = scales::percent) +  facet\_wrap(~symbol) | Creates the faceted bar plot of the 5 equities during the time period that the investor is invested in using the ggplot2 package. |
| output$plot2 <- renderPlot({""      sesplotmod = function (mod, include = NULL, attach = "fits", main = "", ylab = "", xlab = "",  lwd = 2)  {  x = mod$x  n = length(x)  past = mod$fitted  upper = mod$upper  lower = mod$lower  nextfit = mod$mean  if (!is.null(include)) {  x = subset(x, start = n - include + 1)  past = subset(past, start = n - include + 1)  }  if (attach == "series") {  nextfit = ts(c(tail(x, 1), nextfit), start = end(x),  freq = frequency(x))  lower = ts(c(tail(x, 1), lower), start = end(x), freq = frequency(x))  upper = ts(c(tail(x, 1), upper), start = end(x), freq = frequency(x))  }  if (attach == "fits") {    nextfit = ts(c(tail(past, 1), nextfit), start = end(past),  freq = frequency(past))  lower = ts(c(tail(past, 1), lower), start = end(past),  freq = frequency(past))  upper = ts(c(tail(past, 1), upper), start = end(past),  freq = frequency(past))  }    ts.plot(x, past, nextfit, lower, upper, col = c("black",  "blue", "blue", "red", "red"),  lwd = lwd, main = main, ylab = ylab, xlab = xlab)  }    sesplotmod(mod = portfolio\_forecast(), ylab = "Portfolio Value (USD)", xlab = "Date (Years)", main = "Forecasted Portfolio Performance")      }) | Modified Dr. Lock’s sesplot() function from ts343 to display the forecast model. Modified Dr. Lock’s sesplot() to allow for an X-Axis label and Y-Axis label to be added to the plot (new function being sesplotmod()). |
| output$model <- renderText({  textModel = ("Holt-Winter Smoothing Used to Forecast Portfolio Performance")    return(textModel) | Displays text below the forecast plot to tell the person using the app what kind of time series model is being used to forecast the data. |

* Running the app

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| --- | --- |
| shinyApp(ui = ui, server = server) | Runs the app |

**Conclusion:**

In conclusion, by creating this app it will show beginning investors how important it is to invest early. The reason for this is due to your portfolio earning compounded interest over time, and the longer you hold the investment, the more time your investment has to grow and earn higher returns. Granted, this is determined by the performance of the equities in your portfolio, but by using this app it will allow you to make a more informed decision on how you invest your money and give you different ways of determining how your investment will be effected by a number of different factors. Those factors include the risk of your portfolio, i.e. the standard deviation, the maximum value of your portfolio, and the average value of your portfolio. Furthermore, now that an investor can see how their portfolio will perform in the future, by using the forecast plot, it will further drive home the point of how much your portfolio will return in the future and show that holding onto your investments is a good thing. All and all, I think this app will help a lot of novice investors and give them a better grasp on how to put their money into the stock market and do it effectively with the lowest risk and highest return portfolio that the investor can create for themselves.

Appendix

Graphical user interface, chart, application

Description automatically generatedA1.

Graphical user interface, application

Description automatically generatedA2.

A3.

A4. Chart, line chart

Description automatically generated

Chart

Description automatically generatedB1.

B2.

Chart, line chart

Description automatically generated