COMPUTATIONAL FINANCE & RISK MANAGEMENT

UNIVERSITY of WASHINGTON

Department of Applied Mathematics

WELCOME TO THE COURSE (OVERVIEW)

CFRM 522 (001)

Introduction to Trading Systems

Welcome to the Course

- Also known as

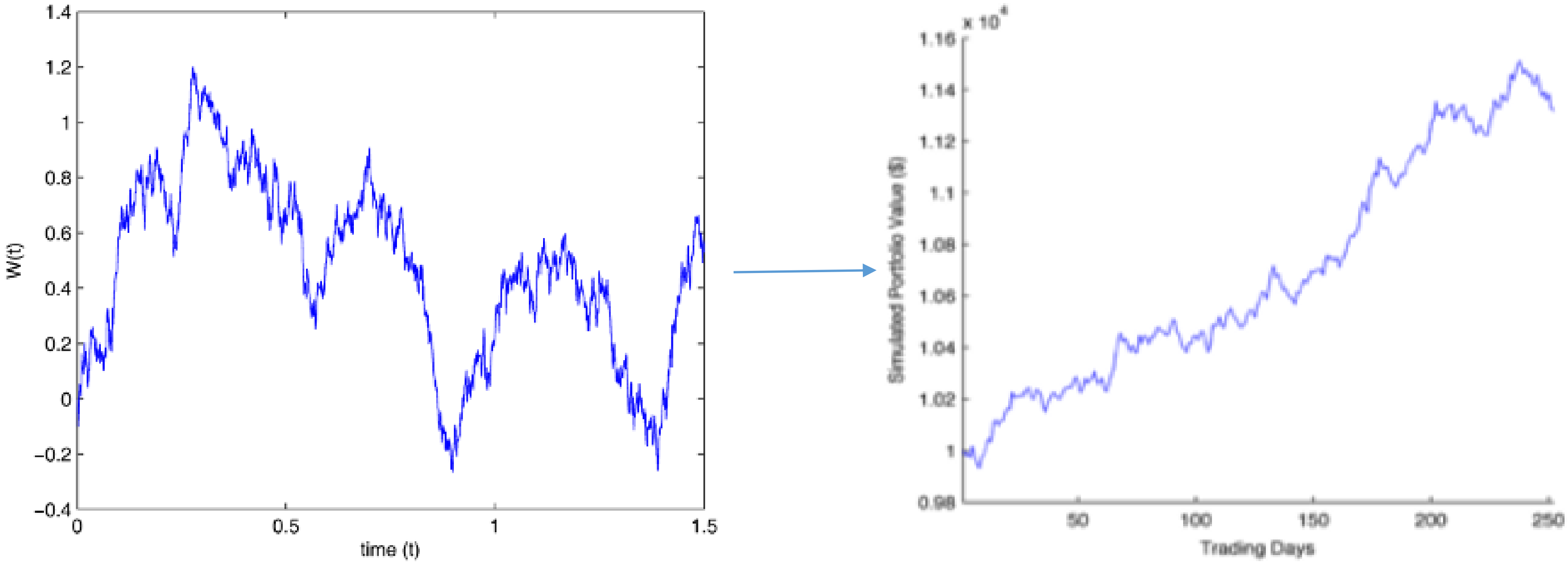
  *“How to Outperform the Market without Going to Prison”**

- Reading assignment: Aronson, Ch 1 (good overview of what this course is all about – books to be introduced shortly)

*Just kidding, of course (see slide 14)

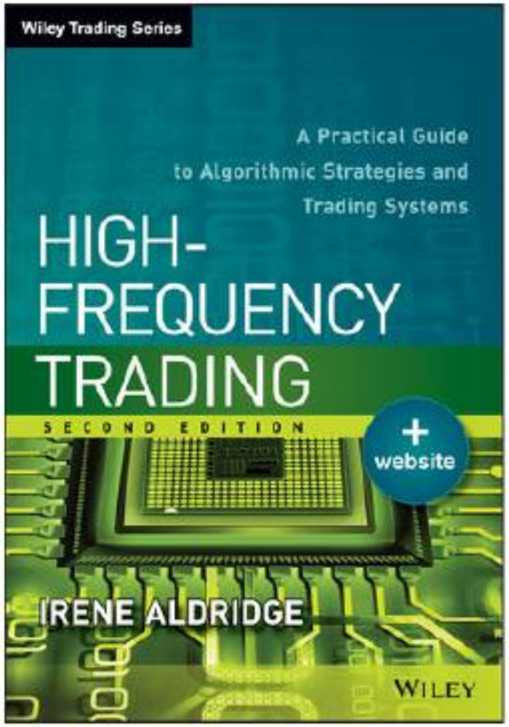
Primary Focus

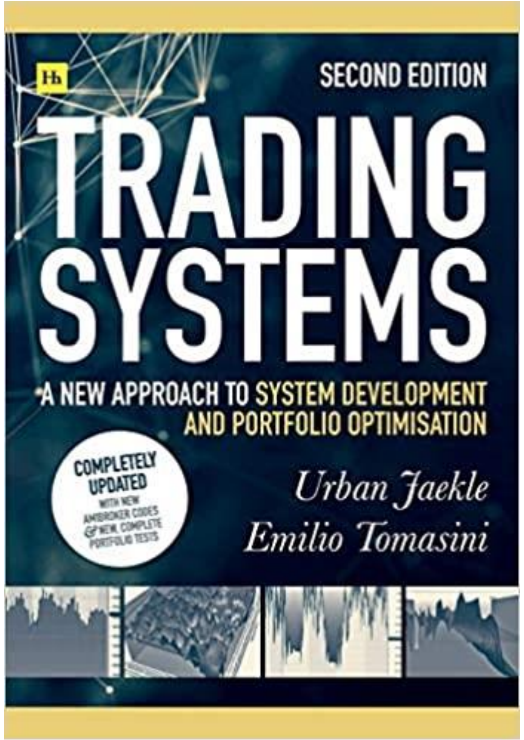
- Research, design, implement, test, and deploy automated quantitative trading strategies
  - A successful trading strategy transforms an undesirable equity line into a more desirable equity line

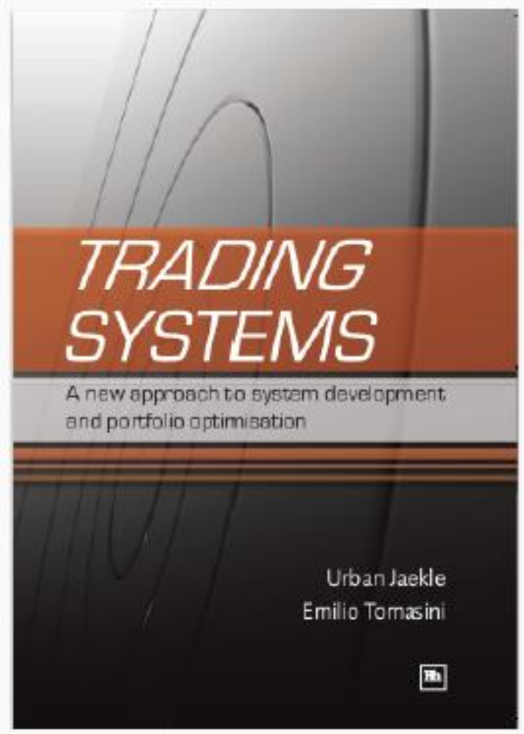


Primary Texts

- Irene Aldridge, *High-Frequency Trading: A Practical Guide to Algorithmic Strategies and Trading Systems 2nd Edition*, (Wiley 2013)
- Jaekle and Tomasini, *Trading Systems: A new approach to system development and portfolio optimisation*, (Harriman House, 2019 (2E), 2009 (1E))



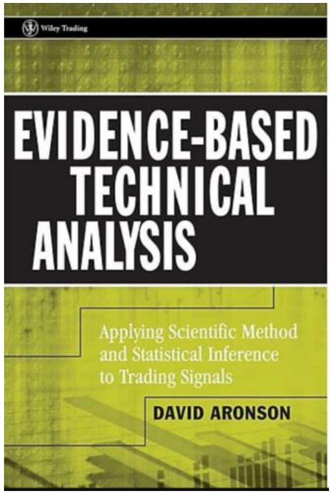

Hh
SECOND EDITION
TRADING SYSTEMS
A NEW APPROACH TO SYSTEM DEVELOPMENT AND PORTFOLIO OPTIMISATION
COMPLETELY UPDATED
WITH NEW AMIBROKER CODES & NEW COMPLETE PORTFOLIO TESTS
Urban Jaekle
Emilio Tomasini

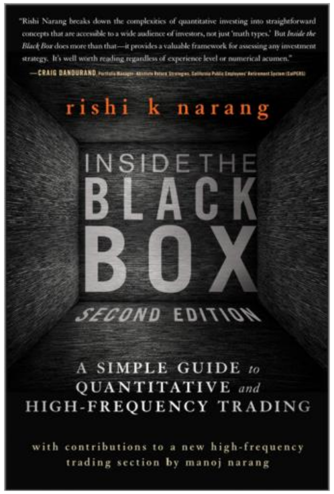

TRADING SYSTEMS
A new approach to system development and portfolio optimisation
Urban Jaekle
Emilio Tomasini
Hh

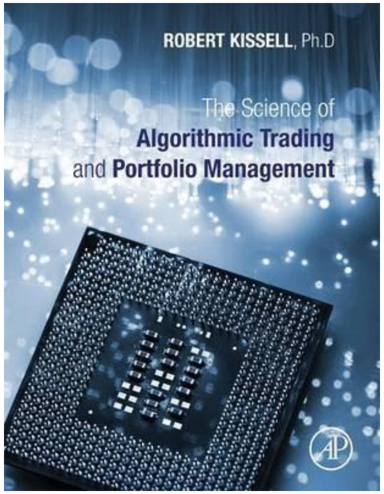
- The Aldridge text is available for free on the UW library website
- You will need to obtain your own copy of Jaekle and Tomasini

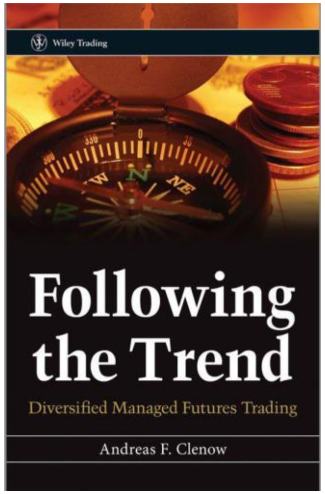
More Texts

- David Aronson, *Evidence Based Technical Analysis*, (Wiley 2007)
- Rishi Narang, *Inside the Black Box*, (Wiley 2013)
- Robert Kissell, *The Science of Algorithmic Trading and Portfolio Management*, (Academic Press 2014)
- Andreas Clenow, *Following the Trend*, (Wiley Trading 2013)


Wiley Trading
EVIDENCE-BASED TECHNICAL ANALYSIS
Applying Scientific Method and Statistical Inference to Trading Signals
DAVID ARONSON


"Rishi Narang breaks down the complexities of quantitative investing into straightforward concepts that are accessible to a wide audience of investors, not just 'math types.' But Inside the Black Box does more than that—it provides a valuable framework for assessing any investment strategy. It's well worth reading regardless of experience level or numerical acumen."
—CRAIG DANDURAND, Portfolio Manager–Absolute Return Strategies, California Public Employees' Retirement System (CalPERS)
rishi k narang
INSIDE THE BLACK BOX
SECOND EDITION
A SIMPLE GUIDE to QUANTITATIVE and HIGH-FREQUENCY TRADING
with contributions to a new high-frequency trading section by manoj narang





- All of these are available on the UW library website
- Readings are not limited to these texts

Additional Reading

- In addition to chapters from these texts, there may be additional reading assigned
  - from other books
  - research articles
- A bibliography will posted on Canvas and updated during the course
- UW library online:

  http://www.lib.washington.edu/

- Others may include implementation of models in the reading, and analysis
- Topics of personal interest may also be in the mix for such assignments or larger projects

Grade will be determined by

- Assignments: Coding and strategies
- Final/Comprehensive project for graduate students
- Midterm exam
  - Will be posted on Canvas
  - Open book/open note/Computer OK
  - ~Two hours to complete, 24 hour window
- Participation on Canvas Discussions
- Late assignments not accepted unless reasonable justification is given ***in advance*** (eg a job interview, medical issue, etc)

Assignments

- Homework will typically involve
  - Analyzing or developing trading strategies using R and various R packages (see programming/modeling assignments, below)
  - Working through a topic or research paper, and presenting a model and individual analysis
- Programming/modeling assignments (in R)
  - Should include your own written up analysis, plus R code, and plots generated in R
  - Your completed work should be publishable to pdf using either RMarkdown (.Rmd) or Sweave (.Rnw)
- More details on submission requirements will also follow soon

Final/Comprehensive Project

- Details to follow

- For graduate students

- May be one of the following
  - Comprehensive high-value assignment for all
  - Several options provided by instructor
  - Topic of interest to individual

Academic Integrity

- In this class, a substantial portion of your grade will be determined by your work on homework assignments
- You are welcome to discuss topics covered in class, or literature in the public domain, with others
- However, submitting work that is not your own, including plagiarism, will not be tolerated, and you will be subject to the highest sanctions provided by the University of Washington policies on academic integrity and academic misconduct
- Please familiarize yourselves with the information provided on the following websites:
- http://depts.washington.edu/grading/pdf/AcademicResponsibility.pdf
- http://depts.washington.edu/grading/conduct/reporting.html
- https://www.cs.washington.edu/academics/misconduct

More specifically about collaborative work and academic integrity

- In soliciting technical help for programming exercises, do not post any part of your actual software source code on the forum. It is usually appropriate to ask others - the TA, the instructor, or other students - for hints and debugging help or to talk generally about problem solving strategies and program structure, as well as lecture and textbook content. However, you must not share actual program code with other students. In addition, if you use external sources for reference, you must cite them in your work; failure to do so is considered plagiarism and may ultimately result in penalties ranging from reduced credit for an assignment through expulsion from the university.
- This information, along with supplemental information, is also available on the main page of our Canvas site for the class.
- **WARNINGS**:
  - ***Plagiarism checking will be enforced***
  - ***Academic dishonesty can result in very serious consequences, including grounds for canceling student visas***
  - ***You may also forfeit assistance from CFRM Placement Services, letters of recommendation, and/or references***

Required Knowledge and Skills/What You Will Learn

- Financial markets, financial instruments, contract specifications, order types
- Professional trading tools to perform analytical tasks and place, modify, and cancel orders
- Gather and clean historical market data
- Quantitative strategy research, design, and implementation
- Quantitative software system architecture, design, and implementation
- Quantitative trading strategy back testing
- Languages and software APIs used in quantitative trading
- Knowledge of existing quantitative trading strategies
- Prepare for CFRM 523 (Advanced Trading Strategies)

Advanced Trading Strategies CFRM 523

- Taught by Brian Peterson (Chicago)
- (A lot of) reading: research papers
- No exams, but there is a final project
- 11-12 hours of lectures, plus three class hours per week
- Expect to read about 2-3 research papers per week (more reading is actually assigned, but will need to concentrate on areas of interest)
- 10 hours/week on project
- In 522, coding experience in R will help you in 523
  - Gain familiarity with R packages in Performance Analytics
  - Testing strategies in quantstrat
- Will need to code in some of the strategies in research papers covered in 523
- Topics we cover from the textbooks and R programming (quantstrat) in 522 will be assumed to be known in 523
- ***522 is an introductory class***. 523 will involve more rigor.
- If you have interest in quantitative trading, this course is highly recommended; it is being taught this summer (offered alternate years)

Introductions

Daniel Hanson

- 20+ years experience in finance:
  - C++ financial models software development
  - Derivatives Pricing and Risk Management
  - Empirical Finance (portfolio optimization)
- Three years in data science
  - Revolution Analytics (commercial R package: RevoScaleR)
  - Acquired by Microsoft May 2015
- UW CFRM – Full-time since September 2016
- Other courses taught:
  - CFRM 520/524 Intro C++/Advanced C++ for quant finance
  - CFRM 506 SQL and VBA
  - CFRM 425 R Programming for Finance
  - CFRM 415 Introduction to Financial Markets
  - Independent study projects/Google Summer of Code mentor (C++/R quant development)
- Also assist with placement for internships and employment of CFRM students
- Education:
  - MA, Mathematics, Indiana University
  - MA, Economics, ***The*** Ohio State University

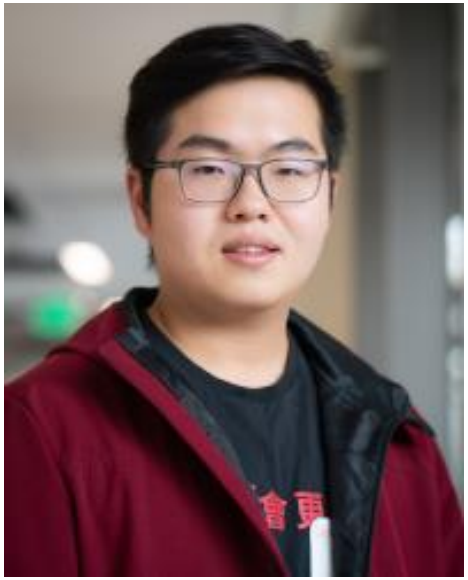
Introductions

- More importantly:

  - **Part owner, Green Bay Packers**
  - **Music aficionado, LP collector**
  - **Love bad jokes and classic comedians**

Introductions

Dayou (David) Luo - Teaching Assistant



- PhD student, UW Applied Mathematics
- MSc, Statistics
- Research interests
  - optimization
  - convex analysis
  - optimal transport

- Otherwise, enjoys cooking and baking

More about the course...Desired Results

- Deploy automated quantitative trading strategies with demonstrated positive expected returns

- By demonstrated positive expected returns we mean
  - Deductive - make assumptions about the market (axioms) and deductively prove under those assumptions expected returns are positive
    - ➢ Ito calculus and stochastic differential equations (SDEs)
    - ➢ Option pricing (Black-Scholes theory)
  - Inductive - use back testing with market data to calculate the expected returns
    - ➢ Inferential statistics, bootstrap (resample) market data [Efron, 1979]
    - ➢ Walk Forward Analysis

- However, in real world practice, ~90% of strategies get thrown out

Some Basic Strategies You May Have Already Used

- Particularly for retirement plans such as 401k plans and Individual Retirement Accounts (IRA’s)
    - Dollar Cost Averaging
    - Periodic Rebalancing of Funds

Dollar Cost Averaging

- Invest a fixed dollar amount at regular periods
  - Each pay check, eg every two weeks (eg 401k)
  - When markets drop, buy more shares with same monetary amount, and reap gain when prices recover
  - When markets rise, buy fewer shares, reducing purchase “at the top”
  - Risk is spread out over time vs one lump sum investment
  - Research has shown better expected long-term performance

Periodic Rebalancing

- Example in this case, again, say, a 401k plan (may or may not be receiving contributions)
- However, over time, gains in one fund become more vulnerable as underlying prices become overvalued
- In another fund, however, underlying prices have declined, offering the opportunity to buy lower with the expectation they will recover
- Using concept similar to dollar cost averaging, we reallocate funds to fixed percentages; ie, the funds are rebalanced to these weightings.
- For example:
    - 21% S&P 500 Index → 25%
    - 27% Midcap Index → 25%
    - 29% International Index → 25%
    - 23% Bond Index → 25%

Going a Step Further

- Dollar Cost Averaging, and Periodic Reallocation, are basically passive strategies that can improve returns by lowering risk

- In this course, and in the realm of strategy research, we go further by using filters and signals to construct an automated strategy.

- Simple example:
  - Filter: closing price in a 30-minute time bar
  - Signal 1: a short-term moving average closing price curve (eg 10-day MA) crosses above a long-term moving average curve (eg 60-day MA)
    - ➢ Indicates upward momentum => place order to buy
  - Signal 2: the same short-term moving average closing price curve crosses below the long-term moving average curve
    - ➢ Indicates sell momentum => sell all shares and get out of the market

Discretionary vs Systematic Trading

Trading styles prior to automated electronic trading

- *Discretionary Trading*
  - Trader uses judgment and intuition to decide what instruments to trade, how to size positions, and when to enter and exit positions
    - ➢ Relies on skill of trader for success
    - ➢ Every discretionary trader unique

- *Systematic Trading (this is what we are going for)*
  - Trader follows a specified trading plan determined prior to trading which has documented rules as when to enter or exit market and how to size positions
    - ➢ Possible to improve system by modifying rules and comparing results
    - ➢ Multiple traders can use system in a repeatable manner
    - ➢ Remove emotion and intuition from decision making

Process

Quantitative strategy trading is a highly disciplined scientific process

[Peterson, 2015]

- Form a quantitatively measurable/testable hypothesis about market phenomena
- Develop filters that select financial instruments where the phenomenon is most visible
- Develop indicators derived from market and economic data
- Develop signals based on the indicators that may be actionable trading opportunities
- Develop rules that specify which states and combination of signals, indicators, and market data lead to market entry or exit and determine position size

Process

- Use either deductive or inferential logic (or both) to demonstrate the strategy has a significant positive expected return *in excess of trading costs and slippage* to justify deployment

- Select instruments to trade and select parameter values with back testing

- Deploy the strategy fully automated so results are measurable and repeatable

Discretionary Aspects

- Market dynamics can change abruptly on a single instrument or the entire market temporarily or permanently
  - Earnings reports
  - Extreme negative or positive news
- Automated trader must be prepared to intervene
  - Temporary - turn off strategy and restart when conditions revert
  - Permanent - re-optimize parameters or retire strategy

Interactive Brokers Applications

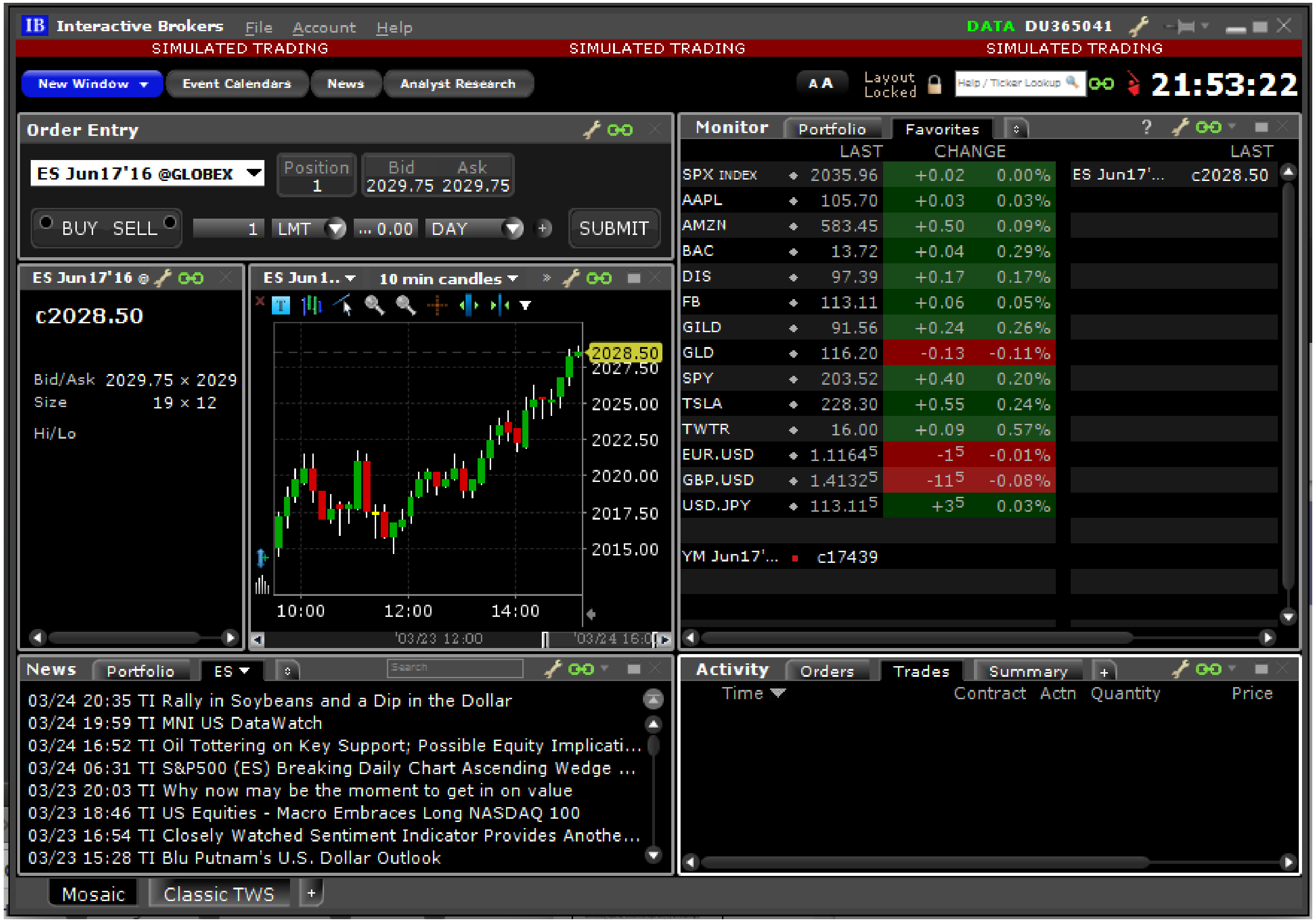
1. Trader Workstation (IB TWS)

2. Gateway

3. Broker Dealer and Proprietary Trading Businesses

Interactive Brokers Trader Workstation

- Each student will be given a "paper trading account" for simulated trading in actual market environments
- Download TWS here: https://www.interactivebrokers.com/en/index.php?f=16040



ES Jun17'16 @GLOBEX

Position	Bid	Ask
1	2029.75	2029.75

○ BUY SELL ○ 1 LMT ... 0.00 DAY SUBMIT

ES Jun17'16 @

c2028.50

Bid/Ask 2029.75 × 2029

Size 19 × 12

Hi/Lo

ES Jun1..

	LAST	CHANGE	
SPX INDEX	2035.96	+0.02	0.00%
AAPL	105.70	+0.03	0.03%
AMZN	583.45	+0.50	0.09%
BAC	13.72	+0.04	0.29%
DIS	97.39	+0.17	0.17%
FB	113.11	+0.06	0.05%
GILD	91.56	+0.24	0.26%
GLD	116.20	-0.13	-0.11%
SPY	203.52	+0.40	0.20%
TSLA	228.30	+0.55	0.24%
TWTR	16.00	+0.09	0.57%
EUR.USD	1.1164^5	-1^5	-0.01%
GBP.USD	1.4132^5	-11^5	-0.08%
USD.JPY	113.11^5	+3^5	0.03%
YM Jun17'...	c17439		

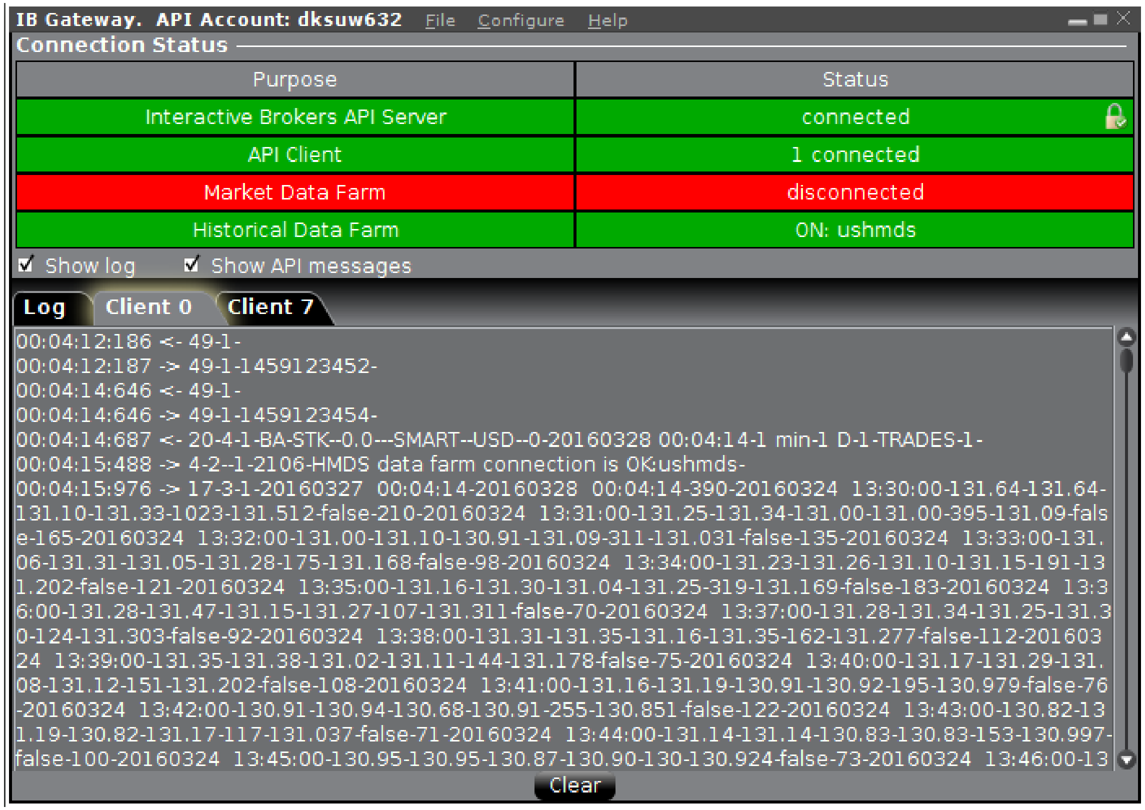
	LAST
ES Jun17'...	c2028.50

03/24 20:35 TI Rally in Soybeans and a Dip in the Dollar
03/24 19:59 TI MNI US DataWatch
03/24 16:52 TI Oil Tottering on Key Support; Possible Equity Implicati...
03/24 06:31 TI S&P500 (ES) Breaking Daily Chart Ascending Wedge ...
03/23 20:03 TI Why now may be the moment to get in on value
03/23 18:46 TI US Equities - Macro Embraces Long NASDAQ 100
03/23 16:54 TI Closely Watched Sentiment Indicator Provides Anothe...
03/23 15:28 TI Blu Putnam's U.S. Dollar Outlook

Time	Contract	Actn	Quantity	Price

Interactive Brokers Gateway

- Automated trading interface through IB API
- Provides a low-resource alternative to TWS for connecting to the IB trading system via the API.
- Uses approximately 40% fewer system resources than TWS.
- However, the gateway is GUI-less, which means that you cannot view the API activity as you can when running TWS.
- Available for download here: https://www.interactivebrokers.com/en/index.php?f=16457



Connection Status

Purpose	Status
Interactive Brokers API Server	connected
API Client	1 connected
Market Data Farm	disconnected
Historical Data Farm	ON: ushmds

☑ Show log ☑ Show API messages

```
00:04:12:186 <- 49-1-
00:04:12:187 -> 49-1-1459123452-
00:04:14:646 <- 49-1-
00:04:14:646 -> 49-1-1459123454-
00:04:14:687 <- 20-4-1-BA-STK--0.0---SMART--USD--0-20160328 00:04:14-1 min-1 D-1-TRADES-1-
00:04:15:488 -> 4-2--1-2106-HMDS data farm connection is OK:ushmds-
00:04:15:976 -> 17-3-1-20160327  00:04:14-20160328  00:04:14-390-20160324  13:30:00-131.64-131.64-
131.10-131.33-1023-131.512-false-210-20160324  13:31:00-131.25-131.34-131.00-131.00-395-131.09-fals
e-165-20160324  13:32:00-131.00-131.10-130.91-131.09-311-131.031-false-135-20160324  13:33:00-131.
06-131.31-131.05-131.28-175-131.168-false-98-20160324  13:34:00-131.23-131.26-131.10-131.15-191-13
1.202-false-121-20160324  13:35:00-131.16-131.30-131.04-131.25-319-131.169-false-183-20160324  13:3
6:00-131.28-131.47-131.15-131.27-107-131.311-false-70-20160324  13:37:00-131.28-131.34-131.25-131.3
0-124-131.303-false-92-20160324  13:38:00-131.31-131.35-131.16-131.35-162-131.277-false-112-201603
24  13:39:00-131.35-131.38-131.02-131.11-144-131.178-false-75-20160324  13:40:00-131.17-131.29-131.
08-131.12-151-131.202-false-108-20160324  13:41:00-131.16-131.19-130.91-130.92-195-130.979-false-76
-20160324  13:42:00-130.91-130.94-130.68-130.91-255-130.851-false-122-20160324  13:43:00-130.82-13
1.19-130.82-131.17-117-131.037-false-71-20160324  13:44:00-131.14-131.14-130.83-130.83-153-130.997-
false-100-20160324  13:45:00-130.95-130.95-130.87-130.90-130-130.924-false-73-20160324  13:46:00-13
```

Broker-Dealer and Proprietary Trading Businesses

- Access to over 100 exchanges in 24 countries

- Wide range of products
  - Stocks, equity options, bonds, forex
  - Futures contracts: equity index, volatility, commodities, energy, metals, single stock, interest rate

- Automated trading through IB API

- Trade execution and clearing services to institutional and professional traders

- Over $5 billion in equity accounts

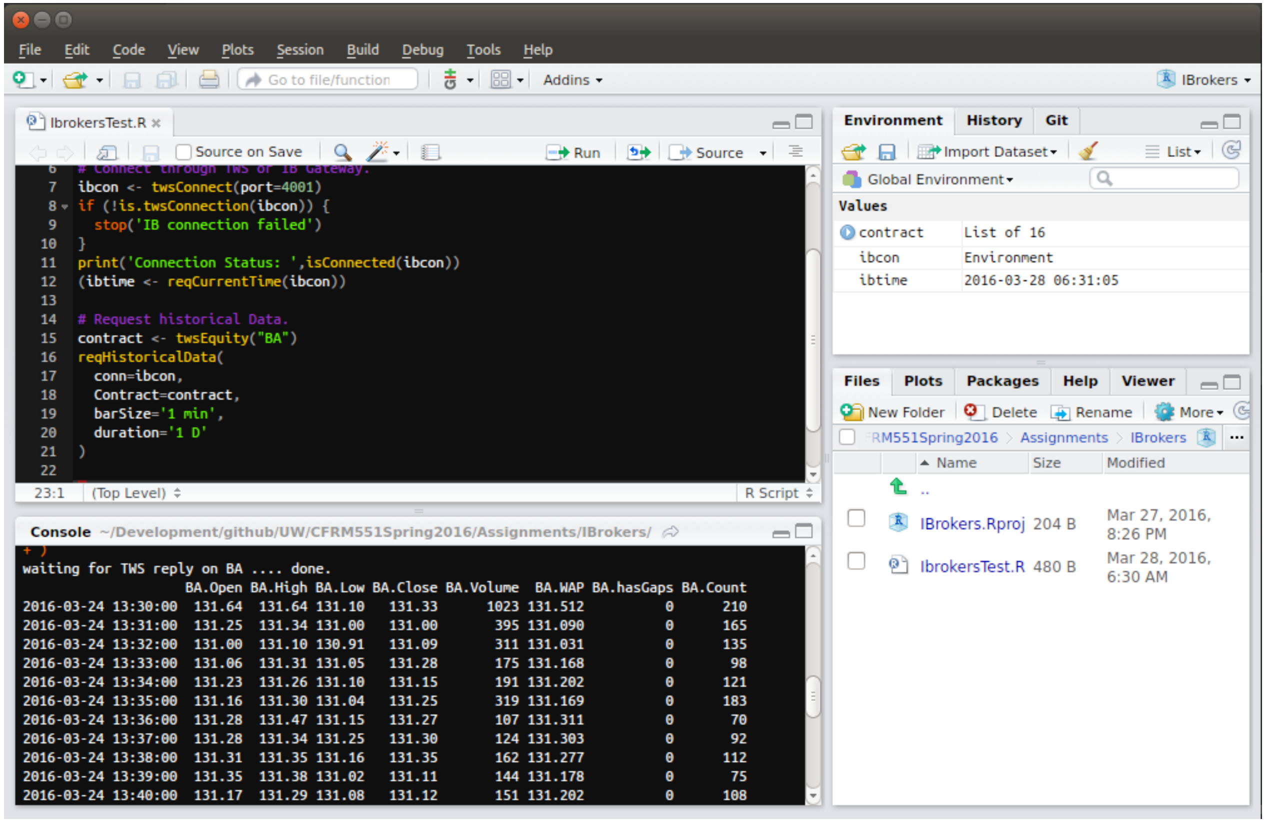
- Standard data access provided with student accounts

- Additional data sources require extra cost

R Development

- R Programming Language: Available from the Comprehensive R Archive Network (CRAN): https://www.r-project.org/
  - **Version 4.0.3** is the most recent stable version (4.0.4 to follow soon)

- RStudio Desktop Open Source Edition: Available on https://www.rstudio.com/products/rstudio/#Desktop



```r
# Connect through TWS or IB Gateway.
ibcon <- twsConnect(port=4001)
if (!is.twsConnection(ibcon)) {
  stop('IB connection failed')
}
print('Connection Status: ',isConnected(ibcon))
(ibtime <- reqCurrentTime(ibcon))

# Request historical Data.
contract <- twsEquity("BA")
reqHistoricalData(
  conn=ibcon,
  Contract=contract,
  barSize='1 min',
  duration='1 D'
)
```

Console ~/Development/github/UW/CFRM551Spring2016/Assignments/IBrokers/

```
+ )
waiting for TWS reply on BA .... done.
                    BA.Open BA.High BA.Low BA.Close BA.Volume  BA.WAP BA.hasGaps BA.Count
2016-03-24 13:30:00  131.64  131.64 131.10   131.33      1023 131.512          0      210
2016-03-24 13:31:00  131.25  131.34 131.00   131.00       395 131.090          0      165
2016-03-24 13:32:00  131.00  131.10 130.91   131.09       311 131.031          0      135
2016-03-24 13:33:00  131.06  131.31 131.05   131.28       175 131.168          0       98
2016-03-24 13:34:00  131.23  131.26 131.10   131.15       191 131.202          0      121
2016-03-24 13:35:00  131.16  131.30 131.04   131.25       319 131.169          0      183
2016-03-24 13:36:00  131.28  131.47 131.15   131.27       107 131.311          0       70
2016-03-24 13:37:00  131.28  131.34 131.25   131.30       124 131.303          0       92
2016-03-24 13:38:00  131.31  131.35 131.16   131.35       162 131.277          0      112
2016-03-24 13:39:00  131.35  131.38 131.02   131.11       144 131.178          0       75
2016-03-24 13:40:00  131.17  131.29 131.08   131.12       151 131.202          0      108
```

Values

contract	List of 16
ibcon	Environment
ibtime	2016-03-28 06:31:05

Name	Size	Modified
..		
IBrokers.Rproj	204 B	Mar 27, 2016, 8:26 PM
IbrokersTest.R	480 B	Mar 28, 2016, 6:30 AM

quantstrat and its Family of R Packages

- Developed and maintained by Brian Peterson and associates
- Open source, used by a wide range of professionals in quantitative trading
- We will use for backtesting, walk-forward analysis, risk management, and other analysis

Primary Sources of Data

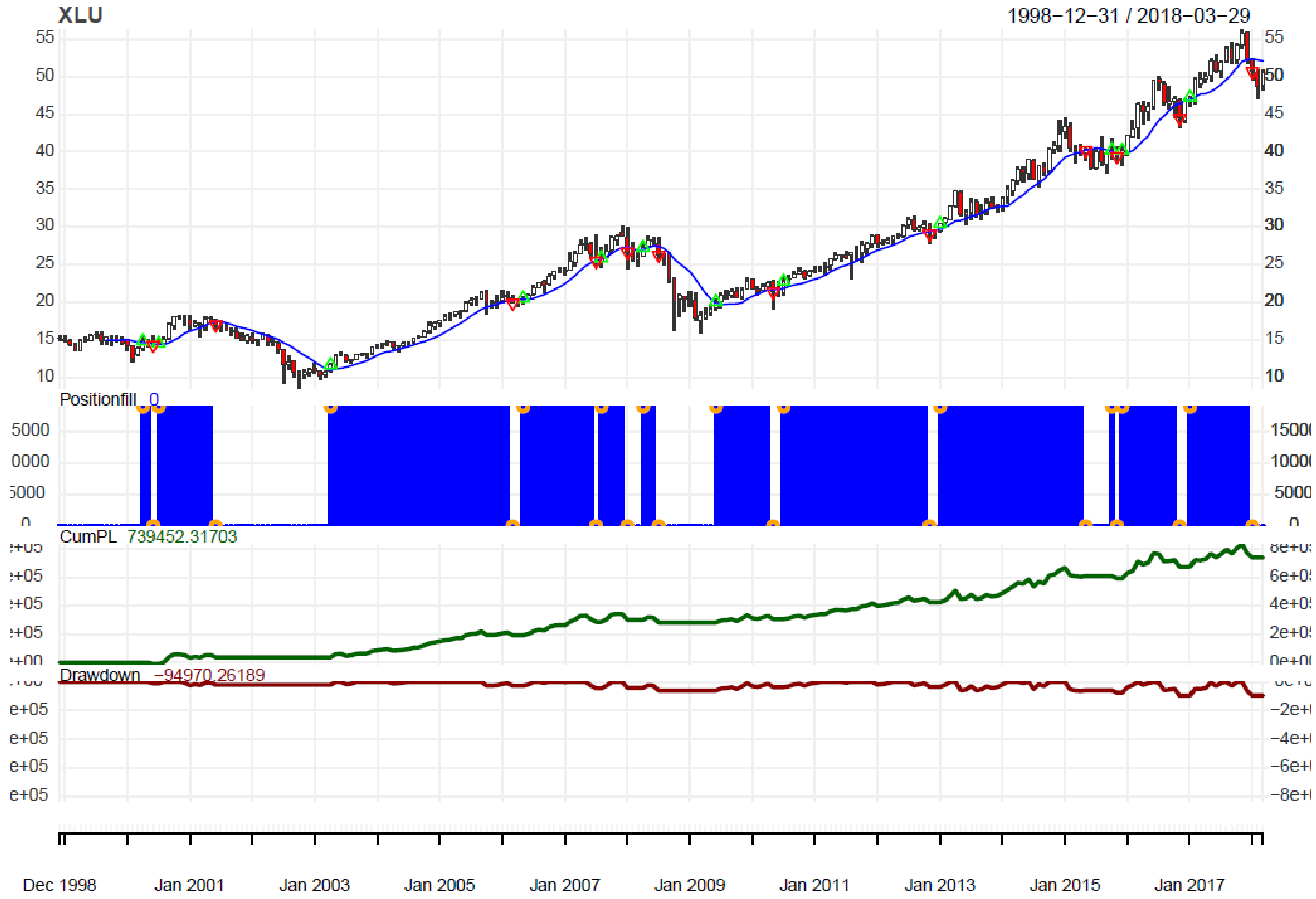
- Yahoo (via quantmod R package): Mostly daily and quarterly prices
- Interactive Brokers (via IBrokers R package): Can get data down to one-minute intervals
- Investing.com for rolled/continuous futures data (limited, but reasonably sufficient for our purposes)
- Others
  - Quandl (and quandl R package)
  - Hedge Fund Research

Quantitative analysis package hierarchy

Application Area	R Package
Performance metrics and graphs	**PerformanceAnalytics** - Tools for performance and risk analysis
Portfolio optimization and quantitative trading strategies	**PortfolioAnalytics** - Portfolio analysis and optimization
	quantstrat – Rules-based trading system development
	blotter – Trading system accounting infrastructure
Data access and financial charting	**quantmod** - Quantitative financial modeling framework
	TTR - Technical trading rules
Time series objects	**xts** - Extensible time series
	zoo - Ordered observation

quantstrat and its Family of R Packages

```
chart.Posn(Portfolio = portfName, Symbol = symbol,
           TA = "add_SMA(n = 10, col = 'blue')")
```

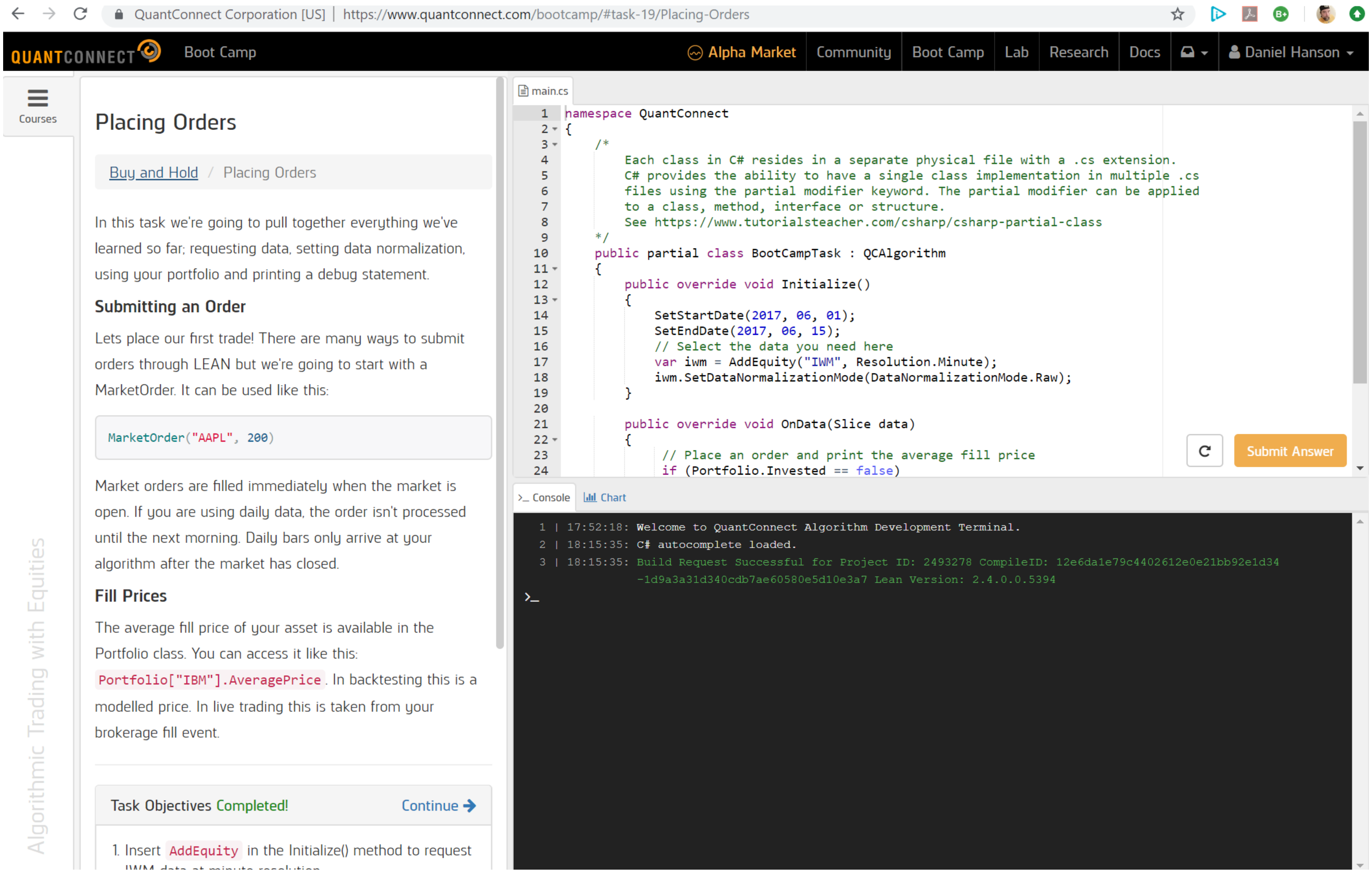


QuantConnect (Optional)

- QuantConnect (QC) is an online strategy development service
  - Develop and backtest strategies
  - Simulate strategies in real-time
  - Marketplace for successful strategies
  - Interface to Interactive Brokers and others allow real-time trading
  - Wide variety of market data available (mainly online)
- Experimental feature for CFRM 522 this year
- QC relocated headquarters to Seattle several years ago
- CEO: Jared Broad
- Core open source C# library called LEAN
  - Extend from C# base classes
  - Python interface
  - Both require basic understanding of object-oriented programming and class inheritance
- Complete set of features available for free for .edu email addresses
- Sign up on www.quantconnect.com
- *BootCamp* online training

QuantConnect

- BootCamp:



Placing Orders

Buy and Hold / Placing Orders

In this task we're going to pull together everything we've learned so far; requesting data, setting data normalization, using your portfolio and printing a debug statement.

Submitting an Order

Lets place our first trade! There are many ways to submit orders through LEAN but we're going to start with a MarketOrder. It can be used like this:

```
MarketOrder("AAPL", 200)
```

Market orders are filled immediately when the market is open. If you are using daily data, the order isn't processed until the next morning. Daily bars only arrive at your algorithm after the market has closed.

Fill Prices

The average fill price of your asset is available in the Portfolio class. You can access it like this: `Portfolio["IBM"].AveragePrice`. In backtesting this is a modelled price. In live trading this is taken from your brokerage fill event.

Task Objectives Completed! Continue →

1. Insert `AddEquity` in the Initialize() method to request IWM data at minute resolution

```
namespace QuantConnect
{
    /*
        Each class in C# resides in a separate physical file with a .cs extension.
        C# provides the ability to have a single class implementation in multiple .cs
        files using the partial modifier keyword. The partial modifier can be applied
        to a class, method, interface or structure.
        See https://www.tutorialsteacher.com/csharp/csharp-partial-class
    */
    public partial class BootCampTask : QCAlgorithm
    {
        public override void Initialize()
        {
            SetStartDate(2017, 06, 01);
            SetEndDate(2017, 06, 15);
            // Select the data you need here
            var iwm = AddEquity("IWM", Resolution.Minute);
            iwm.SetDataNormalizationMode(DataNormalizationMode.Raw);
        }

        public override void OnData(Slice data)
        {
            // Place an order and print the average fill price
            if (Portfolio.Invested == false)
```

```
   1 | 17:52:18: Welcome to QuantConnect Algorithm Development Terminal.
   2 | 18:15:35: C# autocomplete loaded.
   3 | 18:15:35: Build Request Successful for Project ID: 2493278 CompileID: 12e6da1e79c4402612e0e21bb92e1d34
               -1d9a3a31d340cdb7ae60580e5d10e3a7 Lean Version: 2.4.0.0.5394

>_
```

Reading Assignment

- Some useful introductory reading:
  - Aronson, Ch’s 1-3
  - Narang, Ch’s 1-2

- Aronson compares subjective technical analysis (mostly voodoo, but sometimes self-fulfilling prophecy) with objective technical analysis (the roots of modern quantitative trading practice)

- Narang: What is a quant, what does a quant do (within the context of quantitative trading), and other interesting background information

[END]