IE523: Financial Computing
Fall, 2018
Instructor: Prof. R.S. Sreenivas
201E Transportation Building (Primary Office)
155 Coordinated Science Laboratory (Secondary Office)
e-mail: rsree@illinois.edu
MW, 2:00-3:20PM, 112 Transportation Building
Teaching Assistant: Arun Raman (raman12@illinois.edu)
Office hours: TBA

Course Description: This course will introduce you to programming and computational concepts in C++ using examples that are relevant to Financial Engineering.

Primary Text: Lessons with Code Samples written by me.

1 Tentative Syllabus

“You must fill your heads with wisdom before you can break boards with it.”
— Karate instructor on “The Simpsons”.

Lectures

1. Overview of C++.

(a) Review of C++: You have to review the material from the Preparatory Course in Computing on the Compass Website on your own. You were sent a Sample Quiz (to help you figure out if you needed to attend the Preparatory Course in Computing) – you need to be familiar with the topics covered in these problems as a pre-requisite to this course. I will not cover any of this material.

(b) Lesson 1: Recursion in C++; Tower of Hanoi Problem; The Master Theorem; Karatsuba’s $O(n^{1.585})$ algorithm for multiplying two $n$ bit numbers; Strassen’s $O(n^{2.81})$ algorithm for multiplying two $n \times n$ matrices.


(a) Lesson 2: Review of Linear Algebra: Linear Independence, Bases and Subspaces; Orthogonality, Orthogonal Projection, Pseudo-Inverses; General Solution to $Ax = b$; The NEWMAT C++ library for linear algebra problems; Installing the Lpsolve API; Solving Mixed Integer Linear Programs (MILPs) within C++ code using the Lpsolve API.

(b) Lesson 3: Root-finding by Method of Bisection; Newton’s Method; Secant Method; Descartes’ Rule of Signs; Application to IRR-computation in C++. 
(c) **Lesson 4**: Taylor’s Expansion and its uses; Bond Duration, Convexity, etc.; Bond Immunization in C++; Maximizing Convexity subject to Duration-matching constraints: An illustration “by-hand” and lp-solve.

(d) **Lesson 5: Statistics and Simulation**: (C++ code for) Pseudo Random number generation and Uniform Distributions; (C++ code for) Inverse Transform Technique for other distributions; Efficient Discrete Random Variate generation; (C++ code for) Geometric Distributions; (C++ code for) Binomial Random Variates; The Box-Muller Transform and (C++ code for) Unit-Normal Variate generation; (C++ code for) Multivariate Gaussian; Generating constrained Random Variates; Generating Random Variates from Empirical Data; Basics of Discrete-time Markov Chains and some related computational problems (in C++); Infinitesimal Perturbation Analysis via Examples; Where do the probabilities come from? Baxter & Rennie’s Parable of the Bookmaker, The Expected Martingale Measure or No-Arbitrage-Measure.

3. Computational Finance: Case Studies (Tentative)

(a) **Lesson 6: Computational Aspects of Option Pricing**: Models for the dynamics of Asset Price; Ito calculus and Delta Hedging; Short introduction to the Black-Scholes PDE for the value of a derivative instrument; (C++ code for) Black-Scholes formula for the price of an European Option; Put-Call parity; Binomial Trees and Binomial Lattices; The Martingale Property; Option Pricing using the Binomial Lattice via Recursion (in C++); Pricing a path-dependent (American-Asian) Option using Recursion (in C++); Computational limitations of the Binomial Model; Discretization of asset-price in to b-many values; (C++ code for an) \(O(b^2T)\)-algorithm for pricing American Option of duration \(T\) discrete-steps using Dynamic Programming; (C++ code for an) \(O(b^3\log T)\)-algorithm for pricing an European Option using Dynamic Programming and the method of repeated-squaring; Replication Portfolios; (C++ code for) Edirisingleh et al’s approach to pricing European Options with transaction costs using Linear Programming. (C++ code for) Carr and Madan’s approach to price an European Option with the Fast Fourier Transform (FFT).

(b) **Lesson 7: Pricing Exotic Options – Barrier Options**: (C++ code for) Pricing using Truncated Binomial Lattices; “Overestimation of price” phenomenon; (C++ code for) Adjusted Binomial Lattices using the Baron-Adesi, Fusari and Theal correction-term; Compendium of Closed-Form Expressions for European Barrier Options; Pricing an European Discrete Barrier Option – role of Random Walks, Weiner Processes, Brownian-bridges in asset pricing; (C++ code for)
Computing the price of an European Discrete Barrier Option using Brownian-bridge correction-terms.

c) Lesson 8: Pricing an American-Asian Option using the Hull-White Interpolation Method: The intractability of path-dependent option pricing; (C++ code for) Hull and White’s interpolation method; Experimental observations of accuracy vs. grid-size trade-off.

d) Lesson 9: Simulation: Simulating Random-walks in C++; Pricing an European Option by Simulation; Computing the greeks from a single-run simulation using Infinitesimal Perturbation Analysis; Can we run a simulation “backwards” and price an American Option?; Pricing American Options and the “Monte-Carlo within Monte-Carlo” problem; Longstaff and Schwartz’s solution to the “Monte-Carlo within Monte-Carlo” problem; (C++ code for) Least Squares Monte Carlo.

e) Lesson 10: Recursion for Statistical Computing: Median (and k-th order statistic) selection using sorting; The Blum-Floyd-Pratt-Tarjan $O(n)$ Median-of-Median algorithm for efficient picking of the k-th order statistic in a list; Experimental Determination of the relevant constants in implementation of algorithms; Moving-Median filtering vs. Moving-Average Filtering for outlier elimination in noisy real-time data.

f) Lesson 11: Epilogue: The “do not drink the kool-aid” spiel; Videos of Nicholas Taleb, Robert Merton and Benoit Mandelbrot (on Bachelier, Brownian Motion, Markets and Risk-Management);

2 Grade Composition

- $\approx 10$ Programming Assignments (50%).
- ($\approx 10$) Quizzes (10%)
- (Take-Home + In-Class) Mid-Term (20%).
- (Take-Home + In-Class) Final (20%).
3 General Instructions

I plan to have \( \approx 10 \) programming assignments for this course. Since the pace of the course will be dictated by the class needs/skills, the exact number of these assignments might vary. The contribution to your final grade will be 50% independent of the number.

I am planning to have \( \approx 10 \) weekly quizzes/assessments, that will be held in the end of the Wednesday-class (with one exception – the quiz for the week of September 10th-12th, 2017 will be held on Monday, September 10, 2017 (cf. Section 4)). Their contribution to your final grade will be 10% independent of the number. These will be short, mostly multiple-choice, questions.

Since this is a 500-level course on programming, your proficiency in the course material will be tested primarily in your programming assignments. You must turn-in an electronic version of your code on or before the date they are due. Please do not ask for extensions in the 11-th hour. The TA and I have a very demanding schedule this semester and delays intrude into the other tasks that we need to get done. You will get full-credit if your submitted code works when compiled and run on a data-set of my choice. We will revert back to you if there is an error/problem with your submission. You then have three days to turn-in a corrected version, at the loss of 20 points. This process is repeated at most two times (i.e. inclusive of your first attempt, you have three chances at getting the programming assignment right). You will submit your *.cpp and *.h files, along with any PDF-documents that explain your code on Compass. Please do not e-mail the TA or me. The graded quiz can be picked from the TA during his office hours –

Fridays, 2:30PM-4:00PM, (Tentative Location: Van Valkenberg Library, CSL 156).

Make sure you e-mail him with your questions before you show up at his desk. This way, he will be able to answer your questions better.

The mid-term and final examinations consist of two parts (1) a take-home component, that is a programming project, and (2) an in-class written component with short-answers. You have a week to design, compile and test your C++ code. You turn-in your code on the due date (no extensions, please!). Just as with the programming assignments, we will get back to you if your code does not do what it is supposed to. You have three days to turn-in a corrected version for a loss of 20 points. This process is repeated at most two times (i.e. inclusive of your first attempt, you have three chances at getting the programming component of the mid-term and final exams right).

The mid-term exam will be held during class-hours on October 17, 2018. The details regarding the final exam schedule can be found at this link. Since we have a full class (\( \approx 70 \) students), I will arrange for an alternate venue for our exams. I will let you know about the venue afterwards.

I intend to use the \( \pm \)-grading system. My lecture notes for the course can be found on the University of Illinois’ Compass Website. I suggest you print
the appropriate lesson before class and follow-along. This will free you from
the tedium of copying material off the board during class, you can use that
time to follow the material presented in class instead. It is your responsibility
to check the above URL regularly for updates/due-date-announcements as the
course progresses.

The TA can help you with any programming related questions you might
have. If you have coding-related questions, you can address it to him via e-mail.
If you cannot resolve the issue over e-mail, you can meet with him at a time
that is to-be-announced.

I will be happy to speak to you if you are having trouble with the algorithmic-
aspects of the course material. I prefer to work on an “interrupt-driven” mode
– as opposed to having a fixed-meeting time each week. If you need to speak
to me for any reason, just send me an e-mail, and I will let you know the times
when I can meet with you. I will let you know where, among my two offices, we
will meet.

Good luck and I am looking forward to seeing you do well in this course!

4 Travel Dates & Administrivia

1. On September 11 & 12, 2017, the Engineering Career Services hosts a
Career Fair. Since some of you may have an on-site interview with a
company that might offer you an summer internship, I am going to move
the regularly scheduled weekly Quiz from Wednesday to Monday for this
week alone.

2. The tentative due dates for your programming assignments are shown in
table 1. If there are any changes to this schedule I will let you know in
class at the appropriate time.

3. If you have a MAC, you can download XCode for free from the App Store.
If you have a Windows machine, you can get Visual Studio for free from
UIUC Webstore. If you install Visual Studio 2017 – keep in mind
that the look-and-feel of this release is very different from the
previous releases. That said, any version of Visual Studio 2015 or
higher will work fine for this course. Do not use any bootlegged-
copies of Visual Studio! You can get the legitimate-version for
free!
<table>
<thead>
<tr>
<th>Assignment</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming Assignment 1</td>
<td>7 September 2018</td>
</tr>
<tr>
<td>Programming Assignment 2</td>
<td>14 September 2018</td>
</tr>
<tr>
<td>Programming Assignment 3</td>
<td>21 September 2018</td>
</tr>
<tr>
<td>Programming Assignment 4</td>
<td>28 September 2018</td>
</tr>
<tr>
<td>Programming Assignment 5</td>
<td>5 October 2018</td>
</tr>
<tr>
<td>In-Class Mid-Term Exam</td>
<td>Regular Class Hours, 17 October 2018</td>
</tr>
<tr>
<td>Take-Home Mid-Term Programming Assignment</td>
<td>19 October 2018</td>
</tr>
<tr>
<td>Programming Assignment 6</td>
<td>26 October 2017</td>
</tr>
<tr>
<td>Programming Assignment 7</td>
<td>2 November 2018</td>
</tr>
<tr>
<td>Programming Assignment 8</td>
<td>9 November 2018</td>
</tr>
<tr>
<td>Programming Assignment 9</td>
<td>16 November 2018</td>
</tr>
<tr>
<td>Thanksgiving Break</td>
<td>17-25 November 2018</td>
</tr>
<tr>
<td>Programming Assignment 10</td>
<td>3 December 2017 (Monday!)</td>
</tr>
<tr>
<td>Take-Home End-Term Programming Assignment</td>
<td>14 December 2018</td>
</tr>
<tr>
<td>In-Class End-Term Exam</td>
<td>7:00PM - 10:00PM, 14 December 2018</td>
</tr>
</tbody>
</table>

Table 1: Tentative Due Dates for Programming Assignments & Exams.