Brandeis University
Division of Graduate Professional Studies
Rabb School of Continuing Studies

Course Syllabus

I. Course Information

Course Name: **Modern C++ and Robotics Frameworks**
Course Number : RBOT 210
Course Start & End Dates: Jan 2018 - March 2018
Instructor's Name and Contact Information

Geoff Wright
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Document Overview

This syllabus contains all relevant information about the course: its objectives and outcomes, the grading criteria, the texts and other materials of instruction, and of weekly topics, outcomes, assignments, and due dates.
Consider this your roadmap for the course. Please read through the syllabus carefully and feel free to share any questions that you may have. Please print a copy of this syllabus for reference.

Course Description

This course will provide an introduction to Modern C++ with emphasis on template metaprogramming, C++11 idioms, shared pointers, etc. This course will also introduce the ROS framework and all of its core components. It will provide a tour of common libraries such as Boost, and Eigen and their use in ROS-based software development.

Course Outcomes

At the end of the course, students will be able to:

1. Use Modern C++ Idioms and language features
2. Successfully employ template metaprogramming techniques
3. Describe the features of ROS
4. Design and implement a Robotic application using ROS

Relevant Programs: Master of Science in Robotic Software Engineering
Prerequisites:
Undergraduate-level programming experience or equivalent
Working knowledge of C++
Working knowledge of git version control system
Familiarity with a Linux-based Operating System

Materials of Instruction

a. Textbooks: NA

b. Required/Recommended Software :

Students will need a PC or laptop running Ubuntu Linux 16.04

Students will need a github account to receive starter code and submit assignments (which are distributed via Github Classroom).

c. Recommended Text(s) / Journals: NA

d. Online Course Content

This section of the course will be conducted completely online using Brandeis' LATTE site, available at http://moodle2.brandeis.edu. The site contains the course syllabus, assignments, discussion forums, links/resources to course-related professional organizations and sites, and weekly checklists, objectives, outcomes, topic notes, self-tests, and discussion questions. Access information is emailed to enrolled students before the start of the course. To begin participating in the course, review Week 1 and read the first Course Announcement.

• Students will be provided with PDF copies of additional course material and links to relevant material, if required.

Course Grading Criteria

Percent	Component	Outcomes Met	Week Due
30%	Discussions/On-line participation)	NA	Every week
5%	Assignment 1: Install & Setup, Hello World	#	Week 1
5%	Assignment 2: Topics, Messages, Parameters, Launch files	#	Week 2
5%	Assignment 3:: Dynamic Objects, RQT, Logging	#	Week 3
5%	Assignment 4: Dynamic Reconfigure, Services, Actions, Recordings	#	Week 4
5%	Assignment 5: Building a Visual Robot Model, Introducing Gazebo	#	Week 5
5%	Assignment 6: Managing Coordinate Systems	#	Week 6
9%	Assignment 7: Gazebo World	#	Week 7
9%	Assignment 8:Motion Planning using MoveIt!	#	Week 8
9%	Assignment 9: Motion Planning, Programmatic	#	Week 9

13%	Final Assignment: Manipulation Using Perception	#	Week 10

Online Collaboration and Rubric

Online collaboration should be completed during the course week in which they are assigned. Early or late discussion posts do not earn credit. Your first post should be made by Saturday midnight of each course week; following posts should be made by Tuesday midnight. You are expected to post on at least three different days of the course week. Unless stated otherwise, you should expect to post substantive answers to each discussion question and at least one response to a post from another student (3 to 4 substantive posts per week). A substantive post is one that is about 150-250 words, and which makes a insightful point or asks a useful question. Posts which are poorly written, which merely quote from external sources, or which merely echo agreement or disagreement with another post will not earn credit. Participation beyond these minimum requirements will earn additional credit.

Question Responses	60% of weekly participation grade	Max. Points per criteria
	Includes your own insights into the topics, sharing your professional experiences as appropriate and your own conclusions	16
	Includes references to weekly required readings and/or other external sources, cited appropriately. All original responses must draw on external references	16
	Answers the question posed completely; poses questions or points of consideration to elicit responses from classmates	16
	Consists of at least **250-300 words**	6
	Well written, with no spelling or grammatical errors, and with the care normally exercised for the student's professional communications	6

One day late: *-15 out of 30 possible raw points; more than one day late: no credit*

Discussion Replies	30% of Weekly Participation Grade	Max. Points per criteria
	Substantive (beyond an "I agree" or complimentary post) with: ○ Follow-on points from your related experiences and/or from the readings ○ Consists of at least 200 words ○ Follow-up questions of others to extend the conversation (encouraged, but not required)	24
	Grammar/spelling/format/sources noted as appropriate	6

Posting Activity	10% of Participation Grade	Max. Points
	Post the minimum number of required posts on three or more days of the course week	10
	Post the minimum number of required posts on two days of the course week	5
	Post any number of posts on one day of the course week	1

Assignment Descriptions and Rubrics

Unless otherwise specified all assignments will be graded according to the following rubric. The grade will be calculated by summing the products of the row and the column.

Component	Sophisticated | 100%	Competent | 75%	Not Yet Competent | 50%
Technical Objectives: 50%	All objectives are complete, software is functioning correctly	Most objectives are complete, some are incomplete or software exhibits minor bugs	Many objectives are incomplete or software exhibits major bugs
Software Design: 10 %	Classes were designed to encapsulate functionality with well defined and clearly named methods. Standard design patterns such as pImpl, adaptor are used, where applicable.	An attempt has been made to design classes and method names that make sense but the purpose of some classes is unclear or overlapping and/or the method names are confusing	Class structure is confusing or missing, code may have been written in script style. Method names are confusing, not enough thought was given to software design.
Code Style: 10%	Classes and public methods are documented in doxygen format. Numeric values are well documented and use constants. All code is compliant with Google style guide [1]	Most classes and public methods are documented. Majority of code is compliant with Google style guide [1]	Majority of classes and public methods lacking documentation and/or majority of code not compliant with Google style guide.
Written Assignments: 30%	Assignment is clearly written. The arguments are logical and supported by examples or sufficient explanation.	Assignment contains meaningful analysis but is insufficient in length or is confusing or hard to follow.	Assignment is brief or missing and/or analysis is confused, missing the point or otherwise doesn't make sense

[1] https://google.github.io/styleguide/cppguide.html

Assignment 1: Install & Setup, Hello World

Assignment 2: Topics, Messages, Parameters, Launch files

Assignment 3: Dynamic Objects, RQT, Logging

Assignment 4: Dynamic Reconfigure, Services, Actions, Recordings

Assignment 5: Building a Visual Robot Model, Introducing Gazebo

Assignment 6: Managing Coordinate Systems

Assignment 7: Navigation

Assignment 8: Motion Planning using MoveIt!

Assignment 9: Motion Planning with Constraints

Final Assignment: Manipulation Using Perception

II. Weekly Information

Week 1	Install & Setup, Hello World
Objectives	● Apply docker container technology to manage a robotics development environment ● Employ a version control system to track code changes ● Write and compile custom software using infrastructure of Robot Operating System ● Employ template programming techniques to complete programming tasks
Readings	● Week 1 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 1 due
Week 2	Topics, Messages, Parameters, Launch files
Objectives	● Describe the publish/subscribe design pattern, explaining the advantages and disadvantages of architecting software in this way. ● Describe the role of topics and messages within the ROS communications subsystem, and the benefits of this approach. ● Incorporate modern C++ features in your software ● Write dynamic software that can be controlled with variable input parameters ● Employ command line tools available in the Robot Operating System for testing and verification purposes
Readings	● Week 2 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 2 due
Week 3	Dynamic Objects, RQT, Logging
Objectives	● Describe several design patterns and idioms. ● Explain the advantages and disadvantages of each. ● Employ standard template library shared pointers to manage ownership of dynamically created objects. ● Generalize your previous solution to to previous week employing design patterns and shared pointers where appropriate. ● Employ plotting tools provided by the Robot Operating System to test and validate your solution
Readings	● Week 3 Topic Notes ●

Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 3 due
Week 4	Dynamic Reconfigure, Services, Actions, Recordings
Objectives	● Extend the software you developed during Week 3 to support changing parameters on the fly. ● Discuss the difference between messages, services and actions. ● Identify the use cases for each of the above ● Create an asynchronous service that controls the state of your software ● Validate that your solution is working properly by using a combination of rqt dynamic reconfigure, rqt_plot, and command line service calls. ● Employ built-in recording tools of the Robot Operating System to save and replay the data streams. ● Employ a popular C++ library to serialize and deserialize the data streams.
Readings	● Week 4 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 4 due
Week 5	Building a Visual Robot Model, Introducing Gazebo
Objectives	● Describe the geometry and kinematics of an industrial robot using the URDF format ● Reduce code duplication and improve maintainability by utilizing XACRO macros in your URDF files ● Visualize the robot you have created, by rendering it in RViz ● Visualize the same robot in Gazebo and load it into a world scene ● Move a robot around in a world scene that is modeled in Gazebo ● Understand some of the limitations of ROS with respect to high performance real world systems
Readings	● Week 5 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● None, assignment # available, and/or assignment # due
Week 6	Managing Coordinate Systems
Objectives	● Generate a diagram of the entire TF tree of the UR5 robot, using the built-in tools ● Employ the built in TF tools to define a coordinate system ● Use built in tools to play pre-recorded point cloud data in a loop

	● Modify a perception node using TF transforms to manage the coordinate systems of an incoming data stream. ● Employ visualization tools to validate that your solution is working correctly.
Readings	● Week 6 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 6 due
Week 7	Navigation
Objectives	● Employ the Gazebo simulator to create a simulated test environment around a robot ● Employ the ROS navigation stack to build a 2D costmap of the simulated environment ● Create control software that navigates a robot across around a series of pre-defined waypoints, avoiding obstacles. ● Reflect on the challenges of implementing autonomous navigation in 2D for a robot that has a mobile base.
Readings	● Week 7 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 7 due
Week 8	Motion Planning using MoveIt!
Objectives	● Build a MoveIt! configuration package, for motion planning ● Create configuration files for the Robot Operating System that start the system with a specific industrial robot and the relevant motion control software running. ● Employ visualization tools to move the robot to a goal state ● Introduce an obstacle into the scene and use the visualization tools to plan a path around the obstacle. ● Write a control node in C++ that repeatedly moves an industrial robot from one pose to another, and back. ● Employ visualization tools to validate that your solution is working correctly ● Create a software requirement specification for a robot
Readings	● Week 8 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday

Assignments / Assessments	● Assignment 8 due
Week 9	Motion Planning with Constraints
Objectives	● Define various 3D geometric tool paths using functionality from the C++ Eigen library ● Control a simulated industrial robot such that the end effector follows constrained paths and orientations. ● Reflect on the trade-offs in the physical and mechanical design of an industrial robot
Readings	● Week 9 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Assignment 9 due
Week 10	Manipulation Using Perception
Objectives	● Conduct a pick & place maneuver to move a box between two positions based on simulated sensor input, using a common industrial robot. ● Reflect on and describe what challenges you anticipate would arise when deploying this system in the real world.
Readings	● Week 10 Topic Notes ●
Discussions	● Initial Response is due Saturday, a minimum of 2 replies are due Tuesday
Assignments / Assessments	● Final Assignment due

III. Course Policies and Procedures

Late Policies

Assignments are due by the end of the relevant course week. For example, Homework 1 is due at the end of week 2. In fall 2016, this will be just after 11:59pm on Tuesday, Feb. 4. To avoid any problems caused by confusion over dates and times, I set assignment deadlines to be 6am on the following Wednesday. This gives you an automatic six-hour grace period for each assignment. If an assignment is late, it will lose 5 points for every day it is late. Continuing with this example, if the first assignments is submitted after 6am but before midnight on Feb. 5, it will lose 5 points. Submission by midnight on Feb. 6 loses 10 points. If an assignment is more than a week late, I will not accept it for credit. I do this so that I will have an opportunity to discuss the assignments and possibly post reference solutions to help the class.

Brandeis and its servers run on Eastern Time. If you are in another timezone, the times you see in Latte are not converted to your local time unless you change your preferences. Due dates and times always reflect Standard Time or Daylight Saving Time when these are observed in Massachusetts. Note that Brandeis will change from Eastern Daylight Time to Eastern Standard Time during this semester.

Grading Standards

- Work expectations – Students are responsible to explore each week's materials and submit required work by their due dates. On average, a student can expect to spend approximately 3-5 hours per week reading and approximately 5-8 hours per week completing assignments and posting to discussions.
- How points and percentages equate to grades

100-94	A	76-73	C
93-90	A-	72-70	C-
89-87	B+	69-67	D+
86-83	B	66-63	D
82-80	B-	62-60	D-
79-77	C+	59 or <	F

Feedback

My goal is to grade homework within a week of the due date. I will post an announcement if I am delayed in grading for some reason. If you submit an assignment late, I usually grade it after the following assignment is due, so that my feedback is timely for the greatest number of students.

If you have questions about assignments, the most reliable private way to reach me is via the One on One Discussion forum. If your question will help the entire class, I may take the liberty of answering it via the Questions and Answers forum.

If you send me a message at my Brandeis email address, I normally respond within 24 hours of receiving it. However, email may be delayed several days.

Confidentiality

- We can draw on the wealth of examples from our organizations in class discussions and in our written work. However, it is imperative that we not share information that is confidential, privileged, or proprietary in nature. We must be mindful of any contracts we have agreed to with our companies. In addition, we should respect our fellow classmates and work under the assumption that what is discussed here (as it pertains to the workings of particular organizations) stays within the confines of the classroom.
- Finally, for your awareness, members of the University's technical staff have access to all course sites to aid in course setup and technical troubleshooting. Program Chairs and a small number of Graduate Professional Studies (GPS) staff have access to all GPS courses for oversight purposes. Students enrolled in GPS courses can expect that individuals other than their fellow classmates and the course instructor(s) may visit their course for various purposes. Their intentions are to aid in technical troubleshooting and to ensure that quality course delivery standards are met. Strict confidentiality of student information is maintained.

Class Schedule

Week	Dates
1	Jan 17 - Jan 23
2	Jan 24 - Jan 30
3	Jan 31 - Feb 6
4	Feb 7 - Feb 13
5	Feb 14 - Feb 20
6	Feb 21 - Feb 27
7	Feb 28 - Mar 6
8	Mar 7 - Mar 13
9	Mar 14 - Mar 20
10	Mar 21 - Mar 27

Time Management

Students sometimes run into problems related to managing their time, especially in distance learning courses. I hope these ideas will help you to succeed in the class:

- If you are employed full-time, do not take more than two courses at a time. I have never yet met a student who could successfully manage this, especially toward the end of the term as finals and projects come due.
- Keep up with the course week-to-week. Don't let yourself fall behind on readings, discussion posts, etc. Brandeis courses are not self-paced, and they depend on the collaboration of everyone. Participating late, or "trying to get ahead" is very disruptive.
- Take a look at course assignments early in the week and consider how you will approach the solutions. Ask questions early, so I have time to answer them. Don't wait until Tuesday night to begin work.
- If you are planning a vacation, plan to continue participating in the class. Thanks to LATTE, you can post discussions and submit homework from virtually anywhere in the world. I will not be able to accept homework late because of a scheduled vacation.

- If you do find yourself short of time, remember that discussion posts count for 30% of your grade. Do not forgo discussions, because it's impossible to complete the course successfully without them.
- If you experience a serious situation, such as a severe illness, contact me as soon as you can, or contact the GPS office.

IV. University and Division of Graduate Professional Studies Standards

Please review the policies and procedures of Graduate Professional Studies, found at http://www.brandeis.edu/gps/students/studentresources/policiesprocedures/index.html. We would like to highlight the following.

Learning Disabilities

If you are a student with a documented disability on record at Brandeis University and wish to have a reasonable accommodation made for you in this course, please contact me immediately.

Academic Honesty and Student Integrity

Academic honesty and student integrity are of fundamental importance at Brandeis University and we want students to understand this clearly at the start of the term. As stated in the Brandeis Rights and Responsibilities handbook, “Every member of the University Community is expected to maintain the highest standards of academic honesty. A student shall not receive credit for work that is not the product of the student’s own effort. A student's name on any written exercise constitutes a statement that the work is the result of the student's own thought and study, stated in the student’s own words, and produced without the assistance of others, except in quotes, footnotes or references with appropriate acknowledgement of the source." In particular, students must be aware that material (including ideas, phrases, sentences, etc.) taken from the Internet and other sources MUST be appropriately cited if quoted, and footnoted in any written work turned in for this, or any, Brandeis class. Also, students will not be allowed to collaborate on work except by the specific permission of the instructor. Failure to properly cite resources may result in a referral being made to the Office of Student Development and Judicial Education. The outcome of this action may involve academic and disciplinary sanctions, which could include (but are not limited to) such penalties as receiving no credit for the assignment in question, receiving no credit for the related course, or suspension or dismissal from the University.

Further information regarding academic integrity may be found in the following publications: "In Pursuit of Excellence - A Guide to Academic Integrity for the Brandeis Community", "(Students') Rights and Responsibilities Handbook", AND " Graduate Professional Studies Student Handbook". You should read these publications, which all can be accessed from the Graduate Professional Studies Web site. A student that is in doubt about standards of academic honesty (regarding plagiarism, multiple submissions of written work, unacknowledged or unauthorized collaborative effort, false citation or false data) should consult either the course instructor or other staff of the Rabb School Graduate Professional Studies.

University Caveat

The above schedule, content, and procedures in this course are subject to change in the event of extenuating circumstances. If you have questions or concerns about course content before the start of the course, please contact the instructor.