Syllabus (Fall 2019)

1 Official Yale course listing

CPSC 427 01 (13660) / CPSC 527 01 (13756) Fall 2019
Object-Oriented Programming
Michael Fischer
MW 4.00–5.15 WLH 119

Object-oriented programming as a means to efficient, reliable, modular, reusable code.
Use of classes, derivation, templates, name-hiding, exceptions, polymorphic functions, and other features of C++.

After CPSC 223.

2 Course Description

The goal of this course is to learn how to construct clean and elegant programs that not only work to solve complicated problems but that also reflect the underlying abstract structure of the problems they purport to solve. We call this industrial strength programming. The goal is to produce software that is correct and understandable, maintainable, efficient, reliable, secure, and deployable.

The course will use the C++ programming language as a vehicle for exploring the many concepts needed for successful industrial strength programming. C++ is chosen because it is widely used, gives the programmer considerable control over the underlying hardware, and has features such as classes and templates, data encapsulation and strong typing that support the goals of this course.

2.1 Industrial Strength Programming

Programming, broadly defined, is the activity of getting a computer to perform a desired task. It generally takes the form of constructing an artifact, called a program, which in turn instructs the computer in the sequence of steps needed to carry out the task. The program is expressed in a programming language.

The primary requirement of any program is that it correctly performs the desired task. For many small applications, the task is easily described, and the goal of the programmer is to get the job done as quickly and easily as possible. This is typical of homework assignments in beginning programming courses. The specification is provided by the instructor, and the overriding concern of the student is to have something to turn in by the deadline. Small throwaway jobs occur in the real world, too, where the primary goal is to get answers quickly to one-off problems. Succinct interpretive languages such as Python and JavaScript are often well-suited to such applications.

By way of contrast, large software systems typically have lifetimes measured in decades. They are built over time by teams of programmers. Programmers come and go. The people who create these systems are often not the same as those who maintain them over the years. The systems must run correctly in a variety of hardware and software environments. They continually evolve to meet changing needs. In addition to producing correct outputs, they must also be:
1. **Convincingly correct and understandable.** It’s not enough that the program be correct; one needs confidence that it is correct. Such confidence is achieved through a combination of proper use of language constructs such as type systems to enforce constraints, formal verification tools, human understanding of the code, and thorough testing.

2. **Maintainable.** The program must be understandable by humans other than the original developers. The program must be modular, clean, elegant, and well documented. It should be free of code replication since repeated code sections are particularly difficult to keep consistent. A bug that is fixed in one copy will remain unfixed in undiscovered replicas. As in any design process, style and judgment are important to the finished product.

3. **Efficient.** The program must perform its task within the available resources such as time, memory, communication bandwidth, budget, etc.

4. **Reliable.** The program must be robust in the face of unexpected program inputs, runtime errors, and changes in requirements during a program’s lifecycle. It must handle known risks predictability and unknown risks gracefully. It is rarely acceptable for a large system to crash in response to error conditions.

5. **Secure.** The program must resist a malicious adversary who deliberately attempts to cause it to fail or misbehave or to otherwise violate its intended properties.

6. **Deployable.** The program’s dependencies on its environment must be clearly specified and easily satisfied on target systems. Maintaining backwards compatibility as new features are added aids in achieving this goal.

Since good software is expensive to construct and maintain, an additional goal is that it be *reusable* in other applications.

This course focuses on *software design and construction*, namely, the process of defining and implementing the architecture, components, interfaces, and other characteristics of the software artifact that implements the design specification.

### 2.2 Topics and Emphasis

This course will use the version of the C++ programming language known as C++17. C++ is large and complicated. It contains many features that allow it to be used to satisfy the requirements stated above, but they don’t ensure good code. These same features can be misused to create code that is opaque and indecipherable. A good understanding of the language is necessary in order to reap its benefits.

The course will cover many C++ concepts. It will explain the purpose, intended uses, and possible pitfalls for each. Topics include design principles and standards, the C/C++ memory model, objects and classes, constructors and destructors, types, casts and conversions, functions and parameter passing, operator definitions, name-hiding and other restrictions on data access and modification, derivation and inheritance, abstract classes, polymorphism, virtual functions, multiple inheritance, templates, exceptions, and the C++ Standard Library. Other topics as time permits include design patterns, programming for efficiency and testability, performance measurement, and debugging.

These topics will be reinforced by frequent programming assignments. The goal of the assignments will be to learn how to apply design principles to actual code. Submissions will be judged on their design, style, cleanliness, and understandability as well as on their functionality and on their adherence to specific requirements of the assignments.
3 Course materials

This course has no required textbook. Course materials are available in several forms:

1. Lecture notes posted to the course web site.
2. Online textbooks available on the course web site or licensed through the library for free access by the Yale community.
3. Other publicly available reference materials on the internet.

See information about off campus access to learn how to access licensed materials when you are not on the Yale network.

Primary References:

   This covers basic material on C/C++ program that is typically covered in introductory and intermediate programming courses and in data structures. If you don’t know C well and would like a deeper understanding of it, this is a good book for getting up to speed.

   This book gives a comprehensive overview of the tools that C++ provides for writing industrial strength programs. It’s primary drawback is that it is already ten years old, so it doesn’t cover important new features added to the language by the C++11, C++14, and C++17, standards.

3. Internet website [http://cplusplus.com](http://cplusplus.com) is a good source of introductory, tutorial, and reference materials on C++. It is generally up to date and accurate, and I encourage you to become familiar with it.
   Registration is not required to view the site. Because the site does not support secure web connections (https://), I would avoid registering on this or any site that requires sending passwords over an insecure internet connection.

4. Internet website [https://cppreference.com](https://cppreference.com) is a comprehensive reference site for C++. I find it more precise but less readable than cplusplus.com, but both are definitive places to learn about fine points of C++ and are highly recommended.

Other References: The following books are licensed by Yale for use by the Yale community. The links below will give free access to the books when you are on the Yale network. To access from off-campus locations, you will need to use the Yale VPN. To know that you have licensed access, you should see “Yale University” in the blue menu bar next to the “Personal Sign In” menu. If you don’t see it, click on “Sign In”, then on the “Start Using Safari” under the Academic License, and then try the original link again.

   This book is rather out of date but gives some advice that is still relevant.

This book explains many of the important new features of C++11 and C++14. It will be mainly useful during the latter part of the term.

Beware of the many web sites out there that have C++ information that is outdated, incomplete, or just plain wrong. Not only are many people misinformed about how the language actually works, but some important things have changed with the advent of C++17, so you should also be careful about trusting out-of-date information.

4 Course Websites:

This class will use two websites:

- **Canvas**: https://yale.instructure.com/courses/49560
- **Zoo website**: https://zoo.cs.yale.edu/classes/cs427/2019f/index.html

Canvas will be used for homework assignments and submissions, grading feedback, and emailed announcements. The Zoo website will be used for the syllabus, handouts, lecture notes, general announcements, and other course-related materials.

5 Course Mechanics

**Prerequisite:** The prerequisite for this course is CPSC 223 (Data Structures) or equivalent. *The ability to write a significant program in C, C++, or Java is required.* This course also assumes a familiarity with basic computer science concepts such as are covered in CPSC 201 and CPSC 202. Graduate students should have an equivalent background.

**Requirements:** Course requirements include programming assignments and/or written problem sets (~50%) and quizzes/exams (50%). The approximate weights of each in determining the course grade are subject to change depending on the number and difficulty of the assignments and exams actually given. There will be no regular final exam, so you can use Reading Period to finish up the last programming assignment.

Graduate students taking the course will be expected to perform at a higher level than undergraduates and may be required to do additional work.

**Assignments and other announcements:** Written problem sets and programming assignments will be posted from time to time on the Zoo handouts page and will be announced using Canvas. Other course announcements will be posted on the Zoo website home page. It is your responsibility to check these pages frequently.

**Help with technical questions:** The graduate teaching fellows and undergraduate learning assistants will be holding scheduled office hours during the term as posted on the course web site. You are encouraged to meet with them with questions about the lectures, textbook, problem sets, and C++ programming generally. You may also send questions by email. Please copy the instructor on all such emails. This will often result in a quicker response, since whoever is available at the time can decide to answer it. The response will also go both to the TAs and to the instructor so everyone will know that the questions have been addressed.
Other Questions: All questions about assessment and grading should be taken first to a graduate TF. If the TF is unable to resolve your questions to your satisfaction, or if you wish to talk to me privately about any matter, you are always welcome to contact me, either by email or in person. Email is the preferred way to arrange an appointment with me.

6 Computing Facilities

The Zoo: This course will use the Computer Science Department’s educational computing facility, affectionately known as the Zoo. This facility contains modern workstations running Fedora Linux 28. You will need to use these machines to prepare coursework. Look at https://zoo.cs.yale.edu/help/ for information on getting started if you are new to the Zoo. A Zoo account will be automatically created for you if you don’t already have one when you register as a shopper for this course.

These days, most of you have your own laptops and may be wondering why you should be bothered with using a new computer system. The answer is because code development software is still not completely compatible across multiple platforms. If it works on your Mac or Windows PC but fails when the graders run it on the Zoo, you will lose points. If you ask for help with compiler errors on your personal machine, we might not be in a position to answer your questions. If you lack needed software that has been installed on the Zoo for your use, you’re on your own. In short, develop your code on the Zoo! Regardless of where the code is developed, your assignments will be graded according to how well they work on the Zoo. Submission of assignments will be through Canvas.

The Zoo machines support remote access via the SSH and VNC protocols. These enable you to do your work remotely when it is inconvenient to go in person to the Zoo. Instructions on how to configure your machine for remote access will be posted to the course web site.

Course directory: The shared course directory, /c/cs427, is located on the Zoo server. You can access it from your Zoo course account. It will contain any software needed for this course and miscellaneous documentation and files. Public files there can be also be accessed via the web.

7 Policies

Late policy: Assignments will be due at 11:55 pm on the night of the stated due date. Late work will generally be subject to a penalty of 5% per day late unless accompanied by a Dean’s excuse. A 2-hour grace period following the original due date will be granted during which no late penalty will be assessed. However, there will be no grace period in counting the number of days late for assignments turned in after the grace period. Work more than 4 days late will not be accepted, but alternative means for making up missed work may be arranged on an individual basis with a Dean’s excuse.

Please contact the instructor as soon as you find out that you are unable to submit work on time or to attend a scheduled exam so that suitable makeup arrangements can be made.

Policy on Working Together: This course follows the Yale College Undergraduate Regulations and the Yale Graduate School Professional Ethics and Regulations policies regarding cheating, plagiarism, and documentation, with which you should familiarize yourself. Briefly, if you use someone else’s work, you must acknowledge it. If it’s a piece of code, place the acknowledgment in your
source file and explain clearly what parts are not your own. Similarly, if it’s in a paper or written assignment, the acknowledgment belongs in the paper itself. All work not so acknowledged must be your own.

You may of course discuss the lectures and readings with your classmates in order to improve your understanding of the subject matter. Helping each other learn to use the tools in the Zoo is also okay. However, the design and implementation of all programs and all submitted work must be your own except where other sources are explicitly noted.

You must never let another student see your work, either before or after the due date of the assignment. Sometimes you may be tempted to “help” your friends by letting them see your solution. Don’t! This doesn’t help them. To the contrary, it allows them to avoid the hard work of learning the material and deprives them of the educational experience they came to Yale to get.

You are always free (and encouraged) to come in and ask the TAs or instructor for help about anything concerning the course. Please talk to the instructor if you have any questions about this policy.

Avoiding Plagiarism: You may neither copy from another student nor permit your own work to be copied, unless explicit permission is given for such collaborations. If your work is found in the possession of another student, you and the other student are equally guilty of plagiarism. To avoid unintended involvement in plagiarism, your work should never be in the possession of another student. Do not ask someone else to deliver or pick up your work. Do not let another student “borrow” your code to compare with theirs. Keep your files protected so that others cannot read them and carefully guard your password. Do not leave printed work in public areas such as the Zoo or in accessible wastebaskets. If you think your password may have been compromised, you must change it immediately and notify the instructor.

Policy on Computer Problems: The Yale College policy on “Use of Computers and Postponement of Work” in the Yale College Programs of Study, Academic Regulations, applies to this course. It is reproduced below.

“Problems that may arise from the use of computers, software, and printers normally are not considered legitimate reasons for the postponement of work. A student who uses computers is responsible for operating them properly and completing work on time. (It is expected that a student will exercise reasonable prudence to safeguard materials, including backing up data in multiple locations and at frequent intervals and making duplicate copies of work files.) Any computer work should be completed well in advance of the deadline in order to avoid last-minute technical problems as well as delays caused by heavy demand on shared computer resources in Yale College.”

Particularly relevant for this course are the cautions against leaving a programming assignment to the last minute when machines might be busy, printers broken, and so forth, and about safeguarding your data.

Policy on Technology in the Classroom: Cell phones are not to be used in class. Tablets and laptops are allowed only for course-related activities such as note-taking, reading slides and other materials from the course website, and quick internet searches on topics relevant to the lecture. Their use must limited so as to not distract you from paying attention in class. If in doubt, ask the instructor or TF first. Games, instant-messaging, reading email, and other diversions are not permitted. You may be asked to leave the class if these rules are not followed.