3. Object-Oriented Programming

CORE CURRICULUM

Assessment: System Monitor due by Jun 23rd | 32% VIEWED | PROJECTS

LESSON 1

Welcome

CONTINUE →

25% 45 minutes left

LESSON 2

Intro to OOP

In this lesson, you will explore some of the basic object oriented functionality of the C++ language.

CONTINUE →

33% 1 hour 20 minutes left

LESSON 3

Advanced OOP

In this lesson, we'll get into some of the more advanced topics in object oriented programming, including inheritance, polymorphism and templates.

CONTINUE →

48% 1 hour 3 minutes left

PROJECT

Project: System Monitor

Time to build the project! In this lesson, you'll get the tools you need to build the project for this course, a system monitor application similar to htop!

CONTINUE →

STARTED Due in 1 month

1) Polymorphism and Inheritance
   https://youtu.be/91JxGNiQdSE

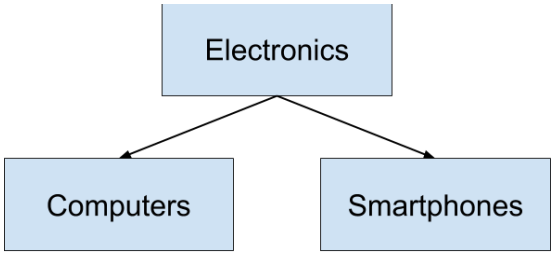
2) Bjarne on Inheritance
   https://youtu.be/pxDZ7VuyaHI

3) Inheritance
   https://youtu.be/qu4dDc-xARM

Inheritence

In our everyday life, we tend to divide things into groups, based on their shared characteristics. Here are some groups that you have probably used yourself: electronics, tools, vehicles, or plants.

Sometimes these groups have hierarchies. For example, computers and smartphones are both types of electronics, but computers and smartphones are also groups in and of themselves. You can imagine a tree with "electronics" at the top, and "computers" and "smartphones" each as children of the "electronics" node.



Object-oriented programming uses the same principles! For instance, imagine a `Vehicle` class:

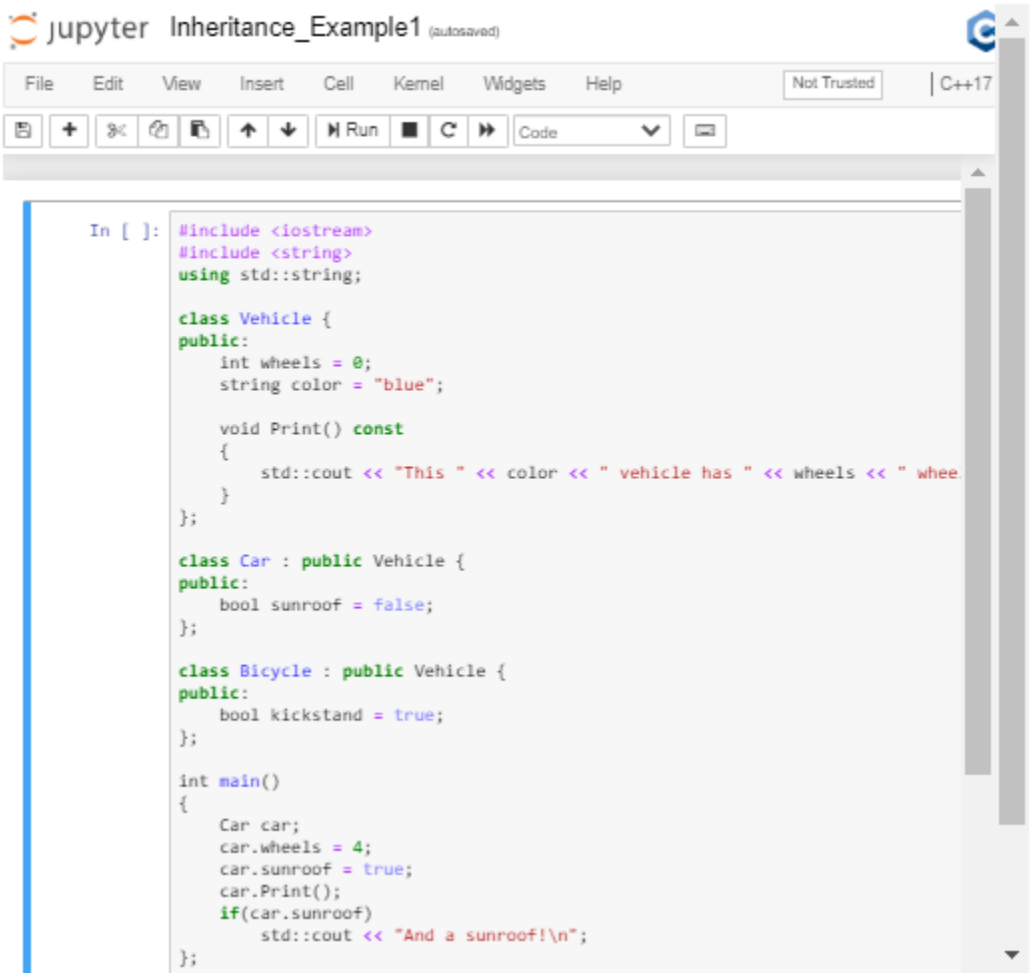
```
class Vehicle {
public:
  int wheels = 0;
  string color = "blue";

  void Print() const
  {
    std::cout << "This " << color << " vehicle has " << wheels << " wheels!\n";
  }
};
```

We can derive other classes from `Vehicle`, such as `Car` or `Bicycle`. One advantage is that this saves us from having to re-define all of the common member variables - in this case, `wheels` and `color` - in each derived class.
Another benefit is that derived classes, for example `Car` and `Bicycle`, can have distinct member variables, such as `sunroof` or `kickstand`. Different derived classes will have different member variables:

```
class Car : public Vehicle {
public:
  bool sunroof = false;
};

class Bicycle : public Vehicle {
public:
  bool kickstand = true;
};
```

Instructions

1. Add a new member variable to `class Vehicle`.
2. Output that new member in `main()`.
3. Derive a new class from `Vehicle`, alongside `Car` and `Bicycle`.
4. Instantiate an object of that new class.
5. Print the object.



4) Access Specifiers
https://youtu.be/LVWK1aJiN40

Inherited Access Specifiers

Just as access specifiers (i.e. `public`, `protected`, and `private`) define which class members *users* can access, the same access modifiers also define which class members *users of a derived classes* can access.

Public inheritance: the public and protected members of the base class listed after the specifier keep their member access in the derived class

Protected inheritance: the public and protected members of the base class listed after the specifier are protected members of the derived class

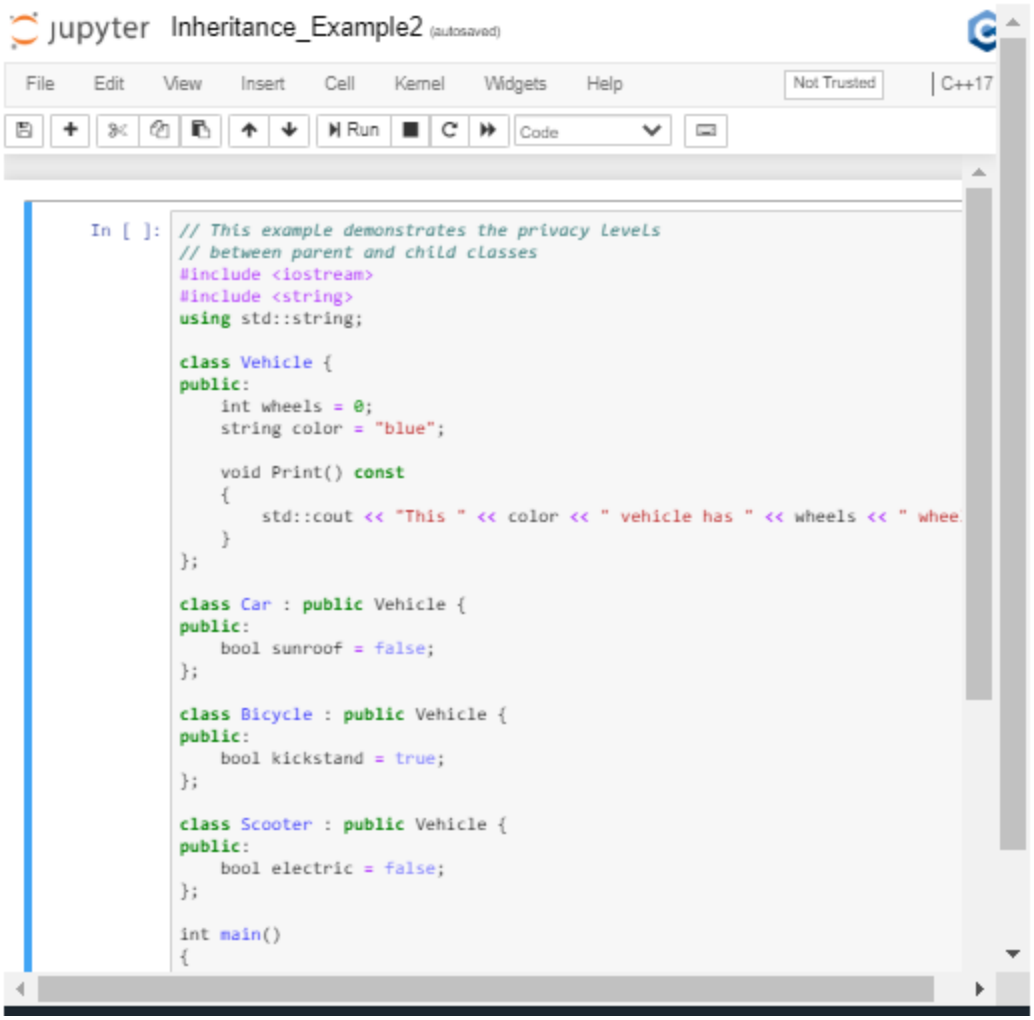
Private inheritance: the public and protected members of the base class listed after the specifier are private members of the derived class

Source: **C++ reference**

In the exercise below, you'll experiment with access modifiers.

Instructions

1. Update the derived classes so that one has `protected` inheritance and one has `private` inheritance.
2. Try to access a `protected` member from `main()`. Is it possible?
3. Try to access a `private` member from `main()`. Is it possible?
4. Try to access a member of the base class from within the derived class that has `protected` inheritance. Is it possible?
5. Try to access a member of the base class from within the derived class that has `private` inheritance. Is it possible?



5) Exercise: Animal Class

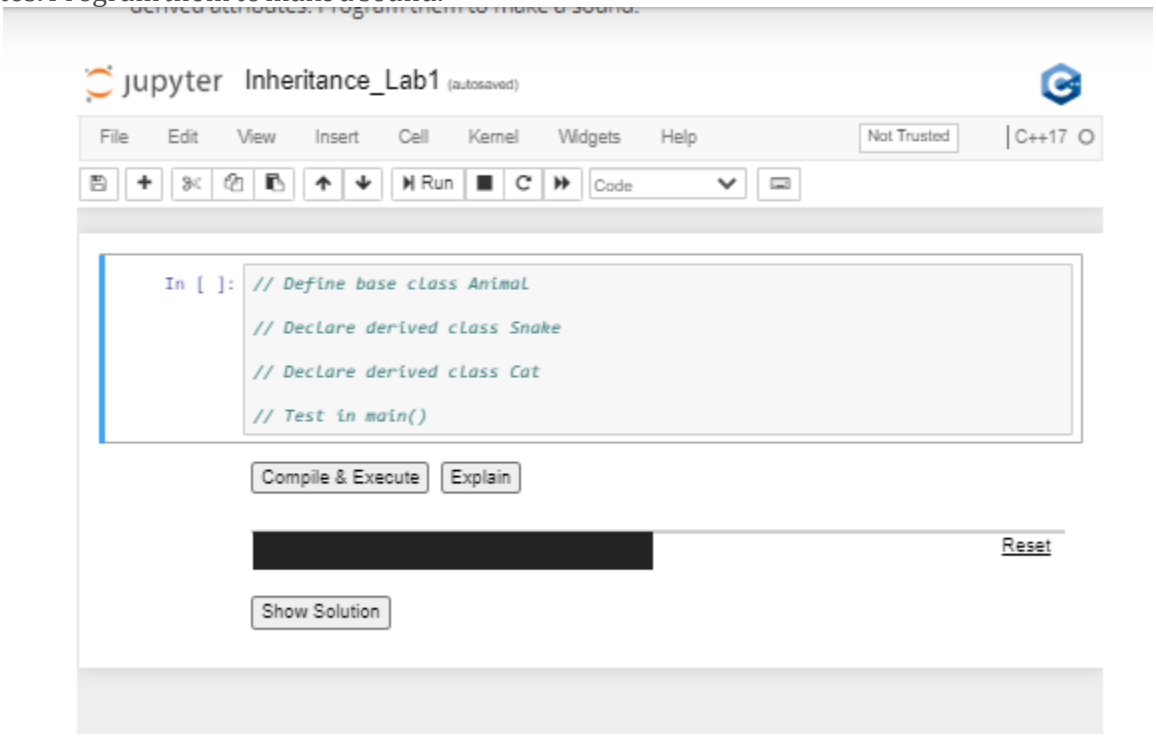
Inheritance

In this exercise you will practice building an inheritance hierarchy.

Instructions

1. Define a class `Animal`.
2. Define 3 member variables: `color`, `name`, `age`.
3. Define a derived class `Snake` that inherits from the base class `Animal`.
4. Create a member variable `length` for the `Snake` class.
5. Create a derived class `Cat` that inherits from the base class `Animal`.
6. Create a member variable `height` for the `Cat` class.
7. Create `MakeSound()` member functions for each of the derived classes.

8. In the `main()` function instantiate `Snake` and `Cat` objects. Initialize both their unique and derived attributes. Program them to make a sound.



6) Composition
https://youtu.be/iUkRGy6kK4A

Composition

Composition is a closely related alternative to inheritance. Composition involves constructing ("composing") classes from other classes, instead of inheriting traits from a parent class.
A common way to distinguish "composition" from "inheritance" is to think about what an object can do, rather than what it is. This is often expressed as **"has a"** versus **"is a"**.
From the standpoint of composition, a cat "has a" head and "has a" set of paws and "has a" tail.

From the standpoint of inheritance, a cat "is a" mammal.

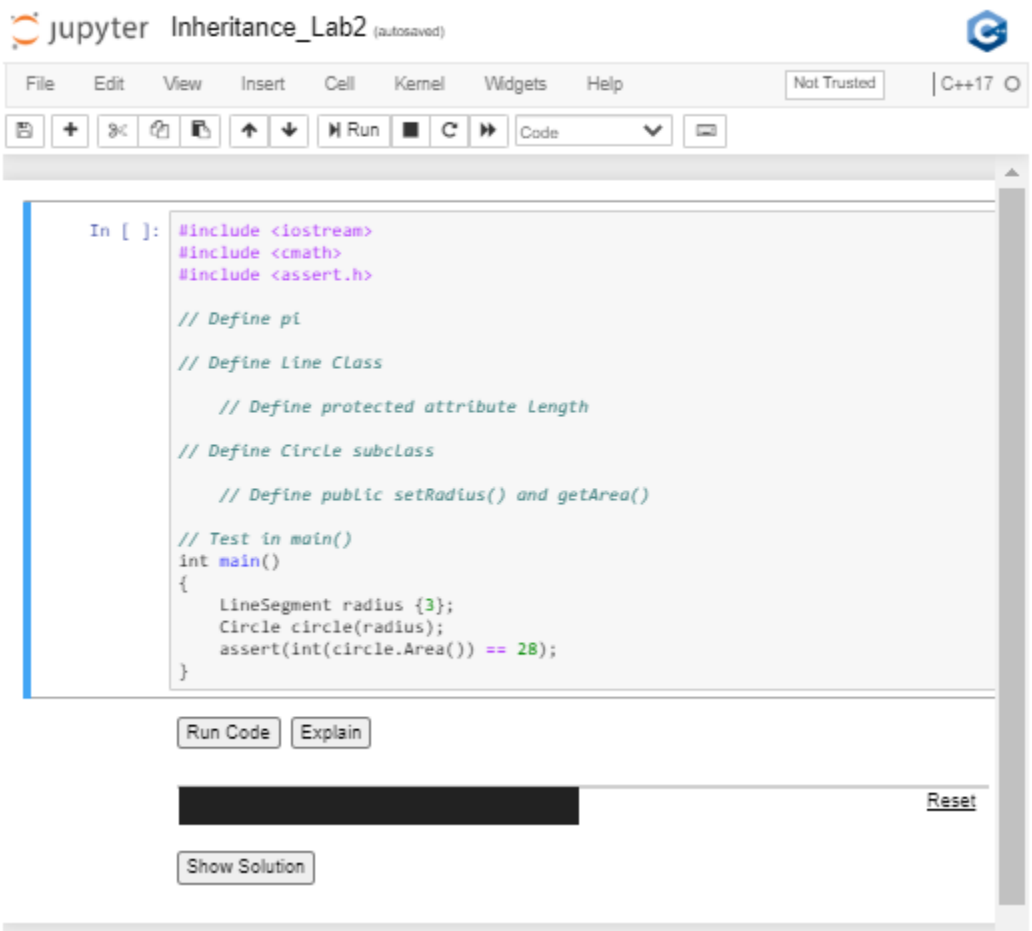
There is **no hard and fast rule** about when to prefer composition over inheritance. In general, if a class needs only extend a small amount of functionality beyond what is already offered by another class, it makes sense to **inherit** from that other class. However, if a class needs to contain functionality from a variety of otherwise unrelated classes, it makes sense to **compose** the class from those other classes.

In this example, you'll practice working with composition in C++.

Instructions

In this exercise, you will start with a `LineSegment` class and create a `Circle` class. Note that you will compose `Circle` from `LineSegment`, instead of inheriting `Circle` from `LineSegment`. Specifically, the `length` attribute from `LineSegment` will become the circle's radius.

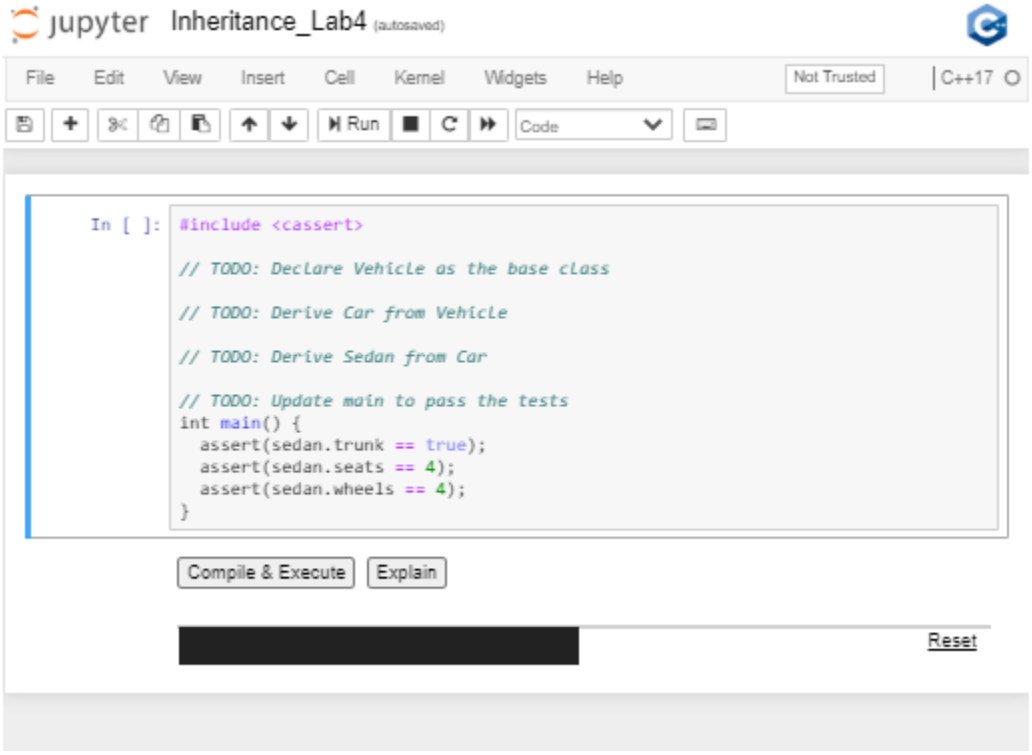
1. Create a class `LineSegment`.
2. Declare an attribute `length` in class `LineSegment`.
3. Define pi (3.14159) with a `macro`.
4. Create a class `Circle`, composed of a `LineSegment` that represent's the circle's radius. Use this radius to calculate the area of the circle (area of a circle = \pi r^2πr^2).
5. Verify the behavior of `Circle` in `main()`.



7) Exercise: Class Hierarchy

Exercise: Class Hierarchy

Multi-level inheritance is term used for chained classes in an inheritance tree. Have a look at the example in the notebook below to get a feel for multi-level inheritance.



8) Exercise: Friends
https://youtu.be/GxdPV4mz7wg

Friends

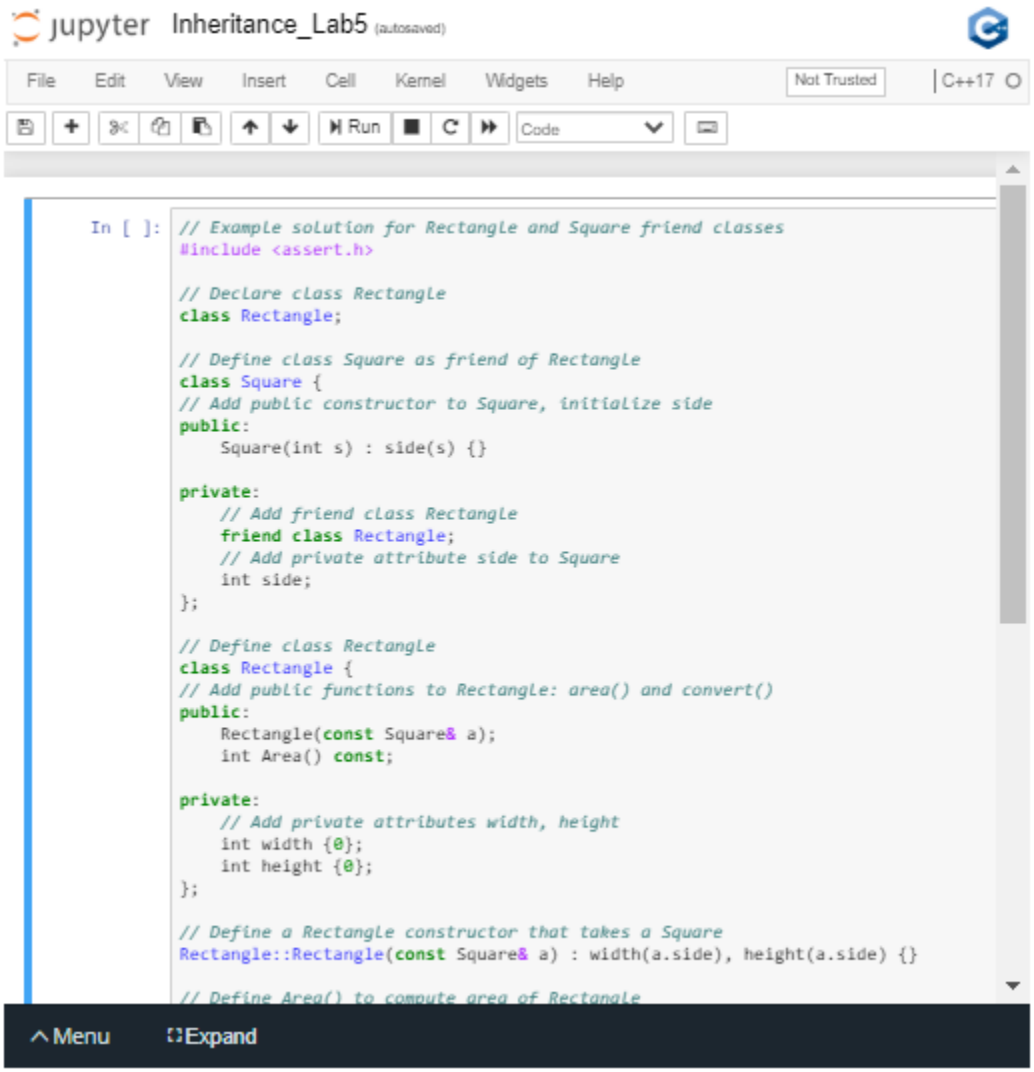
In C++, `friend` classes provide an alternative inheritance mechanism to derived classes. The main difference between classical inheritance and friend inheritance is that a `friend` class can access private members of the base class, which isn't the case for classical inheritance. In classical inheritance, a derived class can only access public and protected members of the base class.

Instructions

In this exercise you will experiment with friend classes. In the notebook below, implement the following steps:

1. Declare a class `Rectangle`.
2. Define a class `Square`.
3. Add class `Rectangle` as a friend of the class `Square`.

4. Add a private attribute `side` to class `Square`.
5. Create a public constructor in class `Square` that initializes the `side` attribute.
6. Add private members `width` and `height` to class `Rectangle`.
7. Add a `Rectangle()` constructor that takes a `Square` as an argument.
8. Add an `Area()` function to `class Rectangle`.



9) Polymorphism: Overloading
https://youtu.be/Y-SSHBtvPHo

Polymorphism

Polymorphism is means "assuming many forms".
In the context of object-oriented programming, **polymorphism**) describes a paradigm in which a function may behave differently depending on how it is called. In particular, the function will perform differently based on its inputs.

Polymorphism can be achieved in two ways in C++: overloading and overriding. In this exercise we will focus on overloading.

Overloading

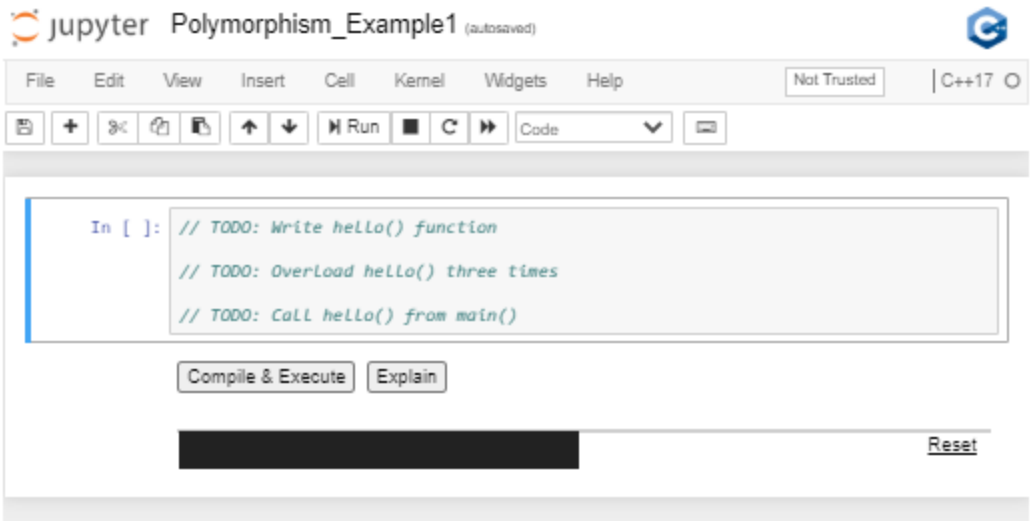
In C++, you can write two (or more) versions of a function with the same name. This is called **"overloading"**. Overloading requires that we leave the function name the same, but we modify the function signature. For example, we might define the same function name with multiple different configurations of input arguments.
This example of `class Date` overloads:

```
#include <ctime>

class Date {
public:
    Date(int day, int month, int year) : day_(day), month_(month), year_(year) {}
    Date(int day, int month) : day_(day), month_(month)  // automatically sets the Date to the c
urrent year
    {
        time_t t = time(NULL);
        tm* timePtr = localtime(&t);
        year_ = timePtr->tm_year;
    }

private:
    int day_;
    int month_;
    int year_;
};
```

Instructions

Overloading can happen outside of an object-oriented context, too. In this exercise, you will practice overloading a normal function that is not a class member.

1. Create a function `hello()` that outputs, "Hello, World!"
2. Create a `class Human`.
3. Overload `hello()` by creating a function `hello(Human human)`. This function should output, "Hello, Human!"
4. Create 2 more classes and use those classes to further overload the `hello()` function.



10) Polymorphism: Operator Overloading
https://youtu.be/ejJ8uoPtFoo

Operator Overloading

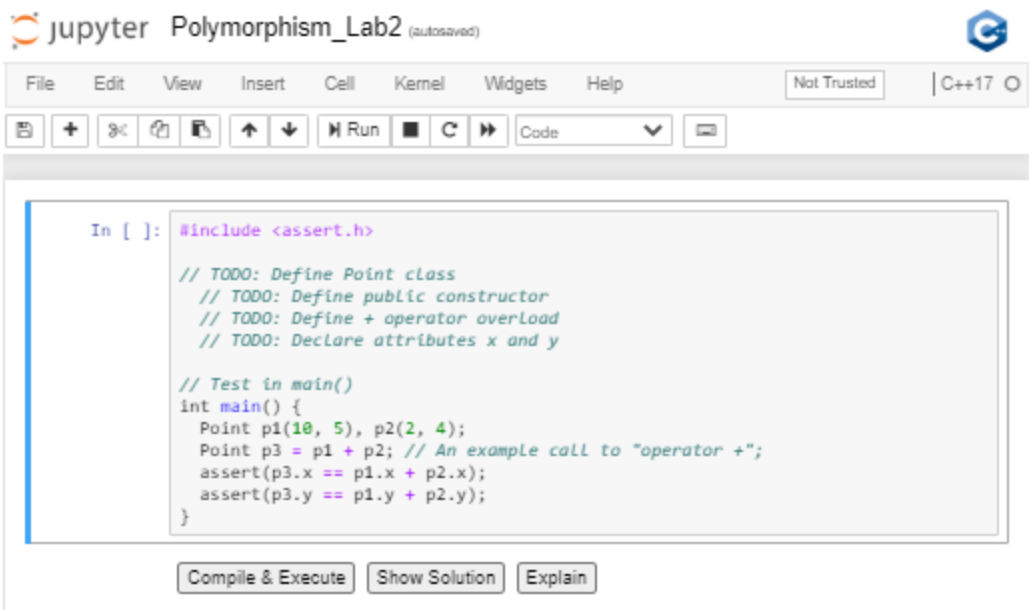
. In this exercise you'll see how to achieve polymorphism with **operator overloading**. You can choose any operator from the ASCII table and give it your own set of rules!
Operator overloading can be useful for many things. Consider the `+` operator. We can use it to add `int`s, `double`s, `float`s, or even `std::string`s.
In order to overload an operator, use the `operator` keyword in the function signature:

```
Complex operator+(const Complex& addend) {
  //...logic to add complex numbers
}
```

Imagine vector addition. You might want to perform vector addition on a pair of points to add their x and y components. The compiler won't recognize this type of operation on its own, because this data is user defined. However, you can overload the `+` operator so it performs the action that you want to implement.

Instructions

1. Define class `Point`.
2. Declare a prototype of overload method for `+` operator.
3. Confirm the tests pass.



11) Virtual Functions
https://youtu.be/2krvZ3-INUk

Virtual Functions

Virtual functions are a polymorphic feature. These functions are declared (and possibly defined) in a base class, and can be overridden by derived classes.

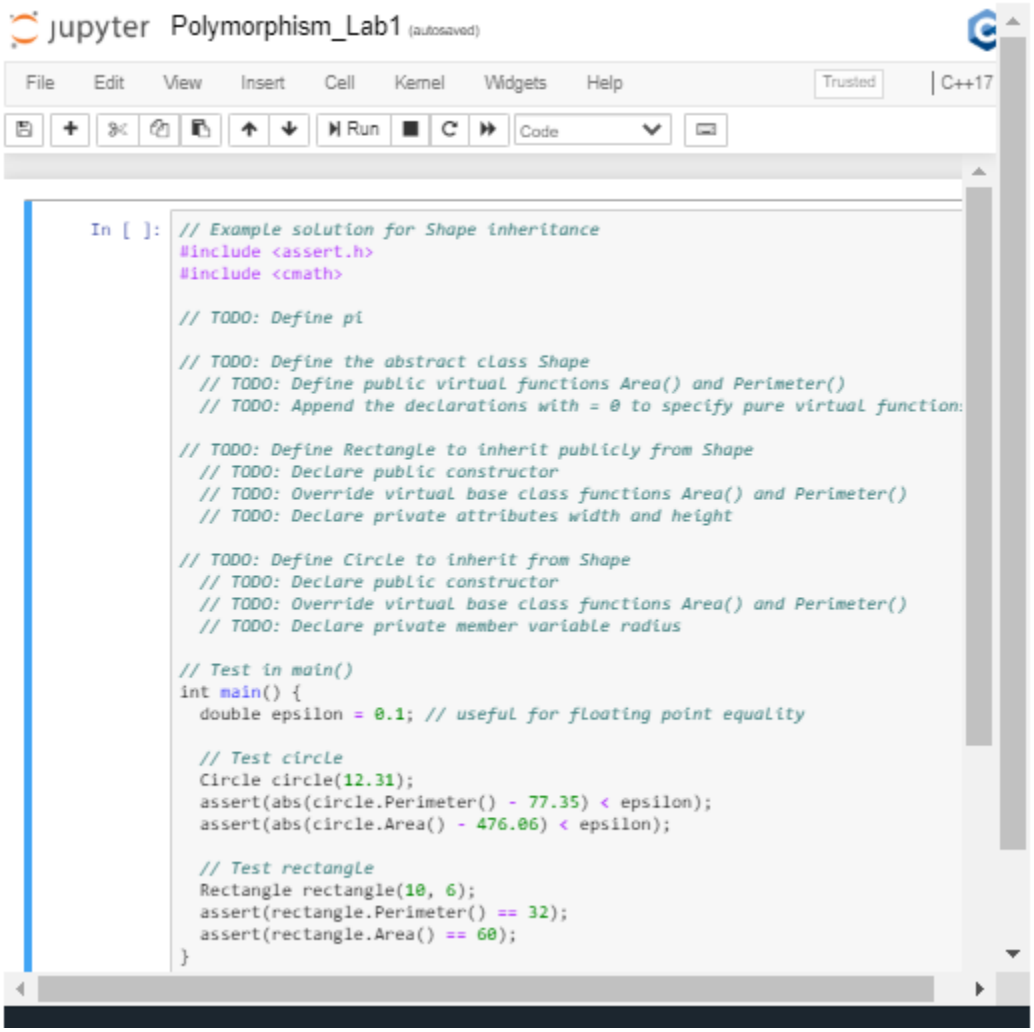
This approach declares an **interface** at the base level, but delegates the implementation of the interface to the derived classes.
In this exercise, `class Shape` is the base class. Geometrical shapes possess both an area and a perimeter. `Area()` and `Perimeter()` should be virtual functions of the base class interface. Append `= 0` to each of these functions in order to declare them to be "pure" virtual functions.
A **pure virtual function** is a **virtual function** that the base class **declares** but does not **define**.
A pure virtual function has the side effect of making its class **abstract**. This means that the class cannot be instantiated. Instead, only classes that derive from the abstract class and override the pure virtual function can be instantiated.

```
class Shape {
    public:
        Shape() {}
        virtual double Area() const = 0;
        virtual double Perimeter() const = 0;
};
```

Virtual functions can be defined by derived classes, but this is not required. However, if we mark the virtual function with `= 0` in the base class, then we are declaring the function to be a pure virtual function. This means that the base class does not define this function. A derived class must define this function, or else the derived class will be abstract.

Instructions

1. Create base class called `Shape`.
2. Define pure virtual functions (`= 0`) for the base class.
3. Write the derived classes.
- Inherit from `class Shape`.
- Override the pure virtual functions from the base class.
4. Test in `main()`



12) Polymorphism: Overriding
https://youtu.be/u15HcpiBeRc

Polymorphism: Overriding

"Overriding" a function occurs when:

1. A base class declares a `virtual` function.
2. A derived class *overrides* that virtual function by defining its own implementation with an identical function signature (i.e. the same function name and argument types).

```
class Animal {
public:
  virtual std::string Talk() const = 0;
};

class Cat {
public:
  std::string Talk() const { return std::string("Meow"); }
};
```

In this example, `Animal` exposes a `virtual` function: `Talk()`, but does not define it.
Because `Animal::Talk()` is undefined, it is called a ***pure virtual function***, as opposed to an ordinary (impure? 😉) ***virtual function***.
Furthermore, because `Animal` contains a pure virtual function, the user cannot instantiate an object of type `Animal`. This makes `Animal` an ***abstract class***.
`Cat`, however, inherits from `Animal` and overrides `Animal::Talk()` with `Cat::Talk()`, which is defined. Therefore, it is possible to instantiate an object of type `Cat`.

Instructions

1. Create a class `Dog` to inherit from `Animal`.
2. Define `Dog::Talk()` to override the virtual function `Animal::Talk()`.
3. Confirm that the tests pass.

Function Hiding

Function hiding is **closely related, but distinct from**, overriding.
A derived class hides a base class function, as opposed to overriding it, if the base class function is not specified to be `virtual`.

```
class Cat { // Here, Cat does not derive from a base class
public:
  std::string Talk() const { return std::string("Meow"); }
};

class Lion : public Cat {
public:
  std::string Talk() const { return std::string("Roar"); }
};
```

In this example, `Cat` is the base class and `Lion` is the derived class.
Both `Cat` and `Lion` have `Talk()` member functions.
When an object of type `Lion` calls `Talk()`, the object will run `Lion::Talk()`, not `Cat::Talk()`.
In this situation, `Lion::Talk()` is *hiding* `Cat::Talk()`. If `Cat::Talk()` were `virtual`, then `Lion::Talk()` would *override* `Cat::Talk()`, instead of *hiding* it. *Overriding* requires a `virtual` function in the base class.
The distinction between *overriding* and *hiding* is subtle and not terribly significant, but in certain situations *hiding* **can lead to bizarre errors**, particularly when the two functions have slightly different function signatures.

13) Override
https://youtu.be/C2DNR0Ao0VM

Override

"Overriding" a function occurs when a derived class defines the implementation of a `virtual` function that it inherits from a base class.
It is possible, but not required, to specify a function declaration as `override`.

```
class Shape {
public:
  virtual double Area() const = 0;
  virtual double Perimeter() const = 0;
};

class Circle : public Shape {
public:
  Circle(double radius) : radius_(radius) {}
  double Area() const override { return pow(radius_, 2) * PI; } // specified as an override fu
nction
  double Perimeter() const override { return 2 * radius_ * PI; } // specified as an override fu
nction
```

```
private:
  double radius_;
};
```

This specification tells both the compiler and the human programmer that the purpose of this function is to override a virtual function. The compiler will verify that a function specified as `override` does indeed override some other virtual function, or otherwise the compiler will generate an error.

Specifying a function as `override` is **good practice**, as it empowers the compiler to verify the code, and communicates the intention of the code to future users.

Exercise

In this exercise, you will build two **vehicle motion models**, and override the `Move()` member function.

The first motion model will be `class ParticleModel`. In this model, the state is `x`, `y`, and `theta` (heading). The `Move(double v, double theta)` function for this model includes instantaneous steering:

```
theta += phi
x += v * cos(theta)
y += v * cos(theta)
```

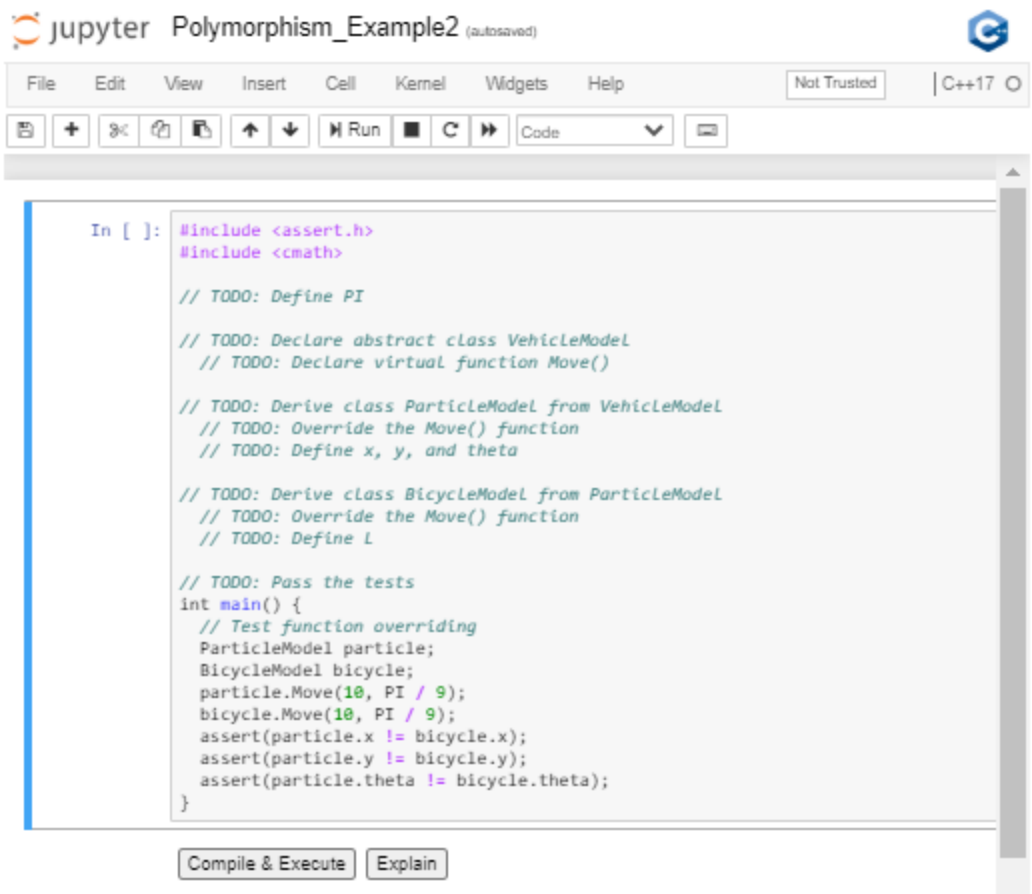
The second motion model will be `class BicycleModel`. In this model, the state is `x`, `y`, `theta` (heading), and `L` (the length of the vehicle). The `Move(double v, double theta)` function for this model is affected by the length of the vehicle:

```
theta += v / L * tan(phi)
x += v * cos(theta)
y += v * cos(theta)
```

You are encouraged to **read more** about vehicle motion, but for the purposes of practicing function overriding, the precise motion models are not so important. What is important is that the two models, and thus to the two `Move()` functions, are *different*.

Instructions

1. Define `class ParticleModel`, including its state and `Move()` function.
2. Extend `class BicycleModel` from `class ParticleModel`.
3. Override the `Move()` function within `class BicycleModel`.
4. Specify `BicycleModel::Move()` as **`override`**.
5. Pass the tests in `main()` by verifying that the two `Move()` functions override each other in different scenarios.



14) Multiple Inheritance
https://youtu.be/jEoPLBdLLsw

Multiple Inheritance

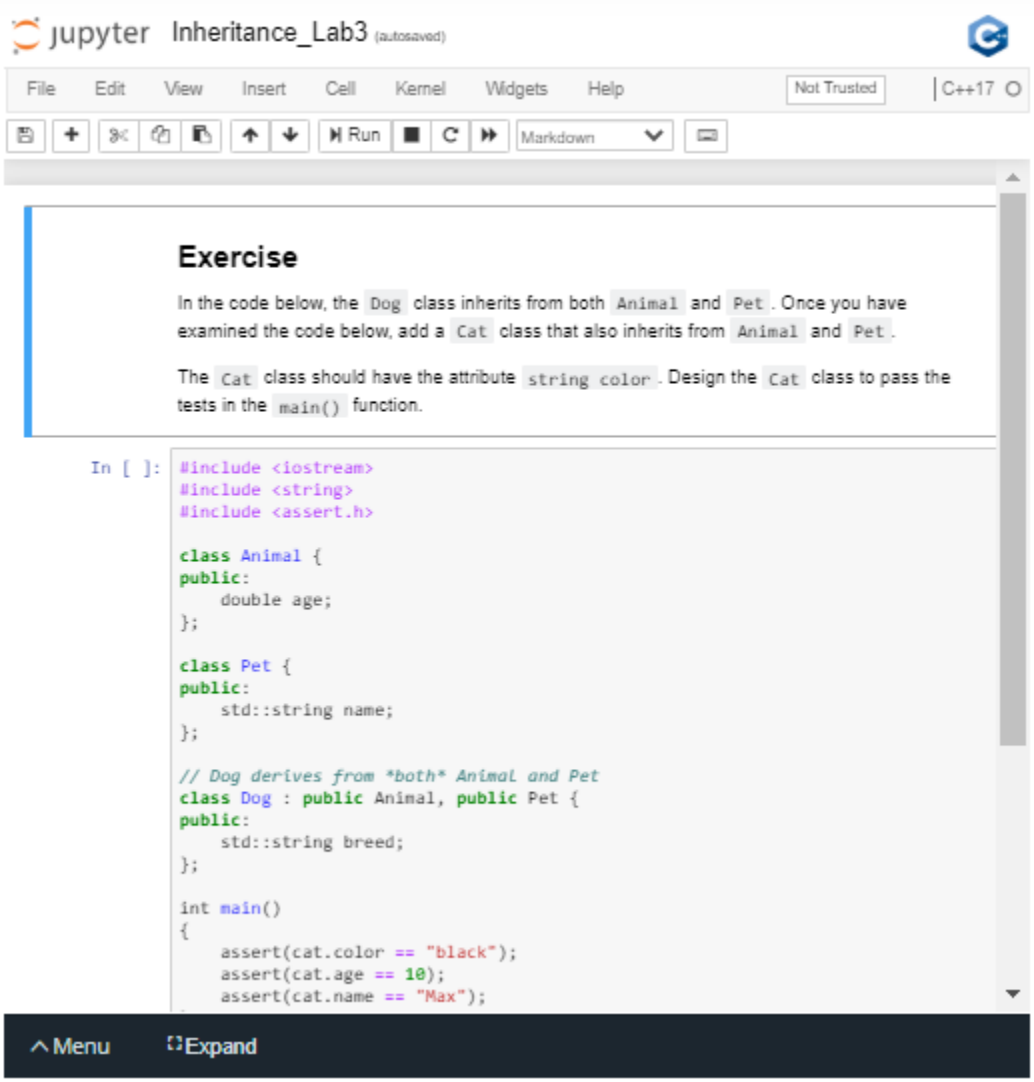
In this exercise, you'll get some practical experience with multiple inheritance. If you have class `Animal` and another class `Pet`, then you can construct a class `Dog`, which inherits from both of these base classes. In doing this, you are able to incorporate attributes of multiple base classes.
The Core Guidelines have some worthwhile recommendations about how and when to use multiple inheritance:

- **"Use multiple inheritance to represent multiple distinct interfaces"**
- **"Use multiple inheritance to represent the union of implementation attributes"**

Instructions

1. Review `class Dog`, which inherits from both `Animal` and `Pet`.

2. Declare a `class Cat`, with a member attribute `color`, that also inherits from both `Animal` and `Pet`.
3. Instantiate an object of `class Cat`.
4. Configure that object to pass the tests in `main()`.



https://youtu.be/p29phGPfKnQ

15) Generic Programming
https://youtu.be/k2Hai5sBemU

16) Bjarne on Generic Programming
https://youtu.be/m3a4ojP0dVQ

17) Templates
https://youtu.be/bUphr3EuM8A

Templates

Templates enable generic programming by generalizing a function to apply to any class. Specifically, templates use *types* as parameters so that the same implementation can operate on different data types.

For example, you might need a function to accept many different data types. The function acts on those arguments, perhaps dividing them or sorting them or something else. Rather than writing and maintaining the multiple function declarations, each accepting slightly different arguments, you can write one function and pass the argument types as parameters. At compile time, the compiler then expands the code using the types that are passed as parameters.

```
template <typename Type> Type Sum(Type a, Type b) { return a + b; }

int main() { std::cout << Sum<double>(20.0, 13.7) << "\n"; }
```

Because `Sum()` is defined with a template, when the program calls `Sum()` with `double`s as parameters, the function expands to become:

```
double Sum(double a, double b) {
    return a+b;
}
```

Or in this case:

```
std::cout << Sum<char>('Z', 'j') << "\n";
```

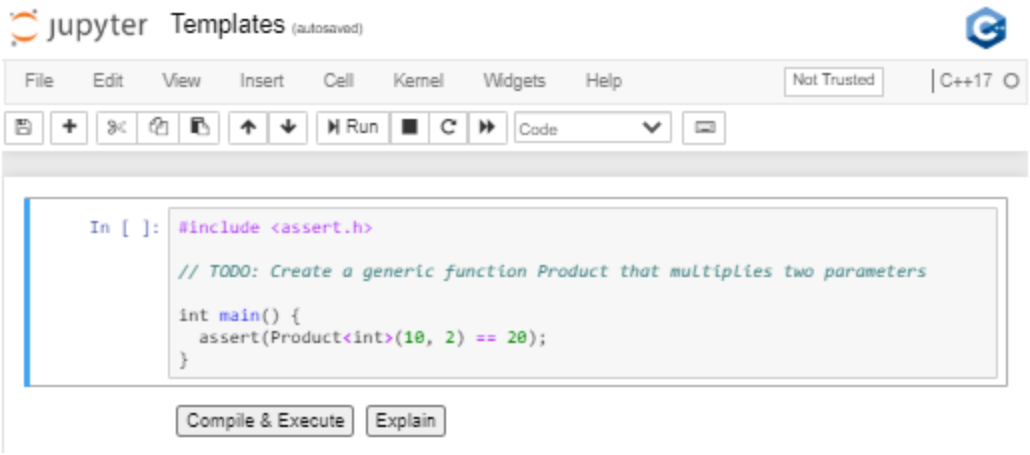
The program expands to become:

```
char Sum(char a, char b) {
    return a+b;
}
```

We use the keyword `template` to specify which function is generic. Generic code is the term for code that is independent of types. It is mandatory to put the `template<>` tag before the function signature, to specify and mark that the declaration is generic.

Besides `template`, the keyword `typename` (or, alternatively, `class`) specifies the generic type in the function prototype. The parameters that follow `typename` (or `class`) represent generic types in the function declaration.

In order to instantiate a templatized class, use a templatized constructor, for example: `Sum<double>(20.0, 13.7)`. You might recognize this form as the same form used to construct a `vector`. That's because `vector`s are indeed a generic class!

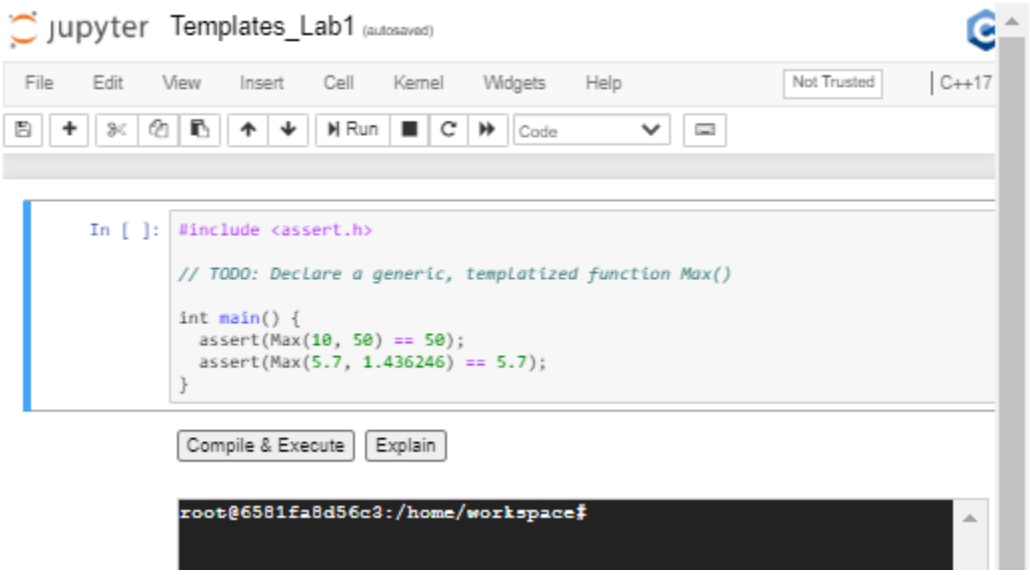


18) Bjarne on Templates
https://youtu.be/tnOsS8JEO0U

19) Exercise: Comparison Operation

Exercise: Comparison Operator

This exercise demonstrates how a simple comparison between two variables of unknown type can work using templates. In this case, by defining a template that performs a comparison using the `>` operator, you can compare two variables of any type (both variables must be of the same type, though) as long as the operator `>` is defined for that type.
Check out the notebook below to see how that works.



20) Deduction

Deduction

In this example, you will see the difference between total and partial **deduction**. Deduction occurs when you instantiate an object without explicitly identifying the types. Instead, the compiler "deduces" the types. This can be helpful for writing code that is generic and can handle a variety of inputs.
In this exercise, we will use templates to overload the '#' operator to average two numbers.

Instructions

1. Use a template to overload the # operator.
2. Confirm that the tests pass.

https://youtu.be/JJLGNlQ1QLk

21) Exercise: Class Templates

Exercise: Class Template

Classes are the building blocks of object oriented programming in C++. Templates support the creation of generic classes!

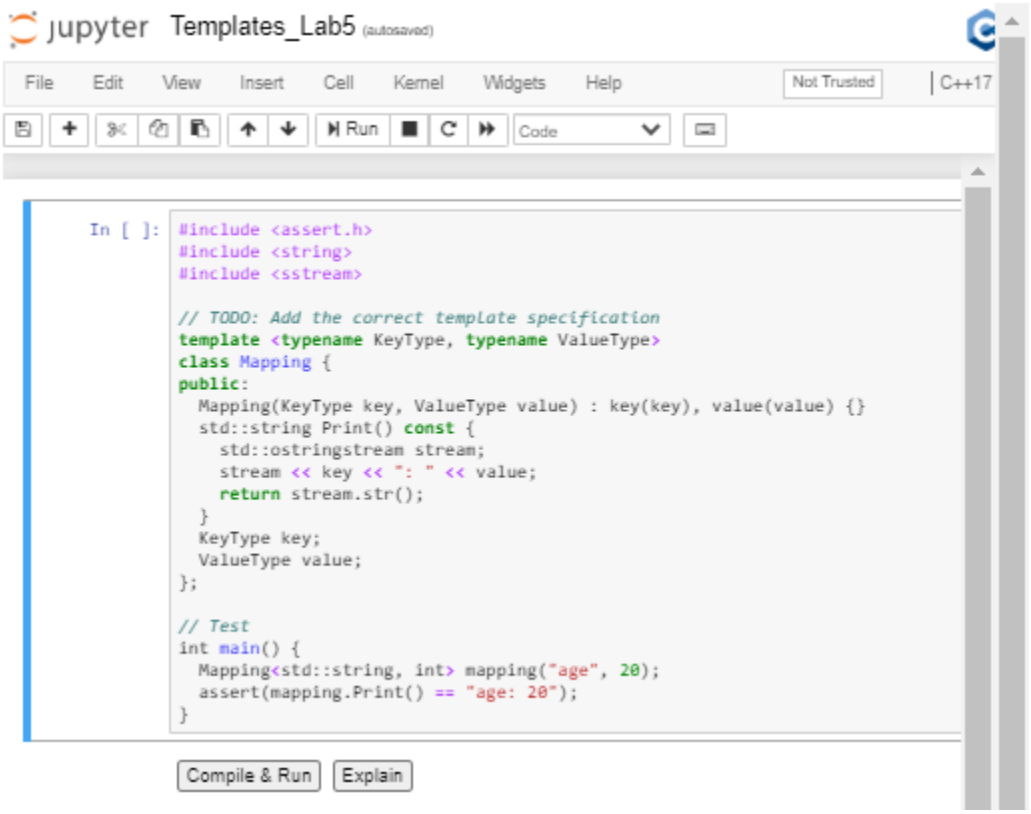
Class templates can declare and implement generic attributes for use by generic methods. These templates can be very useful when building classes that will serve multiple purposes.

In this exercise you will create a `class Mapping` that maps a generic key to a generic value.
All of the code has been written for you, except the initial template specification.

In order for this template specification to work, you will need to include two generic types: `KeyName` and `ValueName`. Can you imagine how to do that?

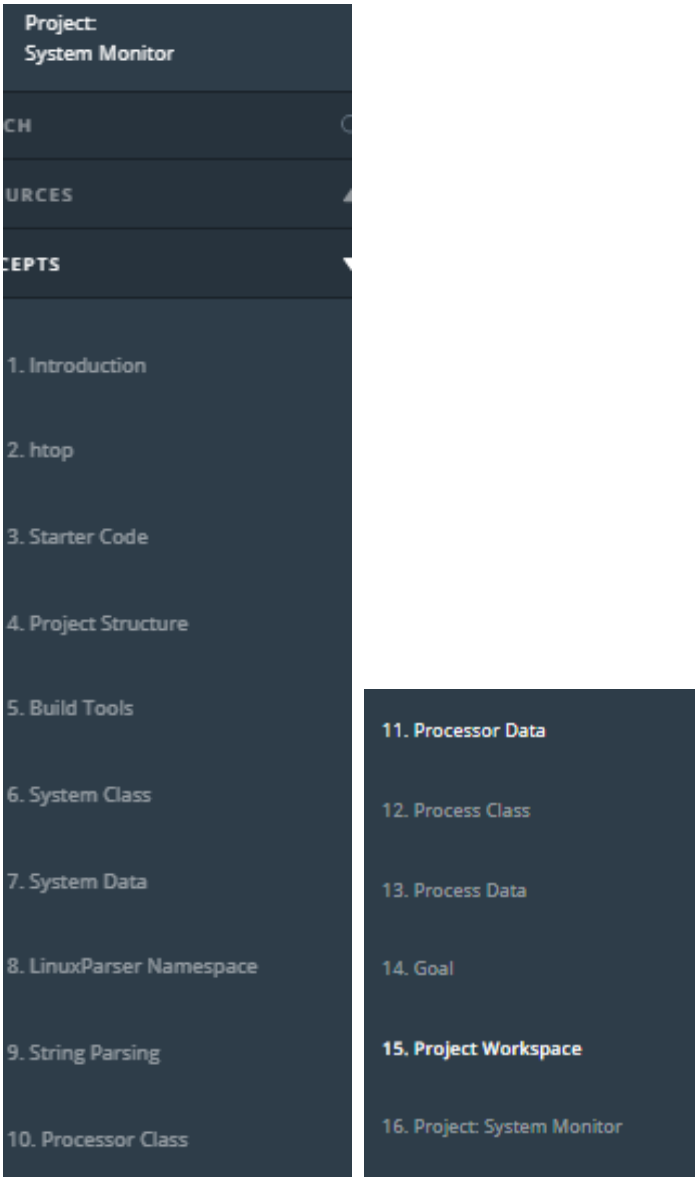
Instructions

1. Write the template specification.
2. Verify that the test passes.



22) Summary
https://youtu.be/QR68Vcr-XTw

23) Bjarne on Best Practices with Classes
https://youtu.be/gWcAMxhNOcg



1) Introduction

Updates!

Udacity has updated and improved the System Monitor Project!

These updates help organize and clarify the project.

The new project version is available right now in this lesson.

Students who have already completed the System Monitor Project are all set! There is no requirement to revisit this lesson and complete the new version of the project.
https://youtu.be/EbgJYBZ4QDA

2) Htop
   https://youtu.be/Cz4rDC-WecA

3) Starter Code
   https://youtu.be/eguBVmzhTS4

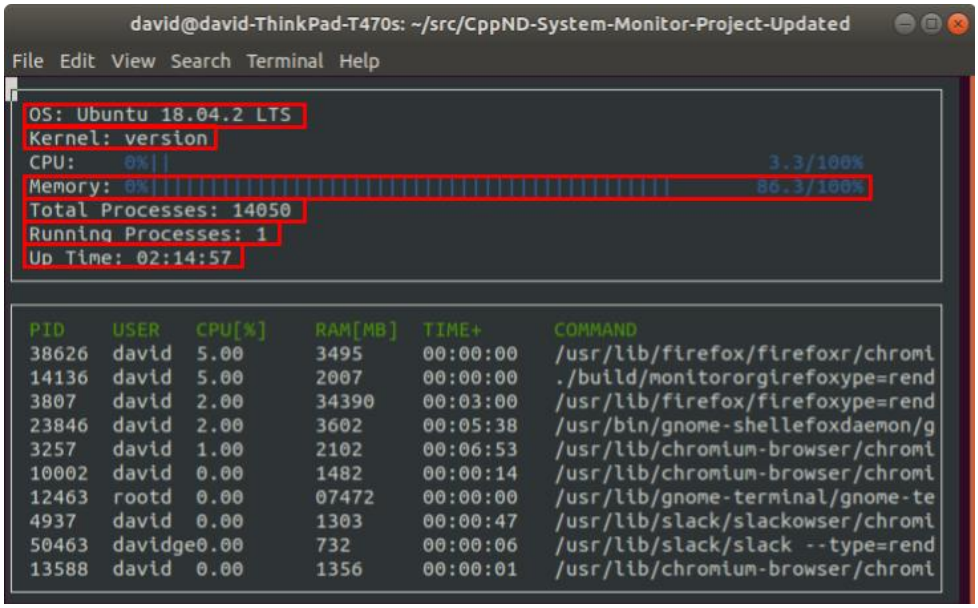
4) Project Structure
   https://youtu.be/dOnUD8UUhMg
   https://youtu.be/10HWAXzY_90

5) Build Tools
   https://youtu.be/PSPI33rKQas

6) System Class
   https://youtu.be/M6tpsAZWnjI

7) System Data

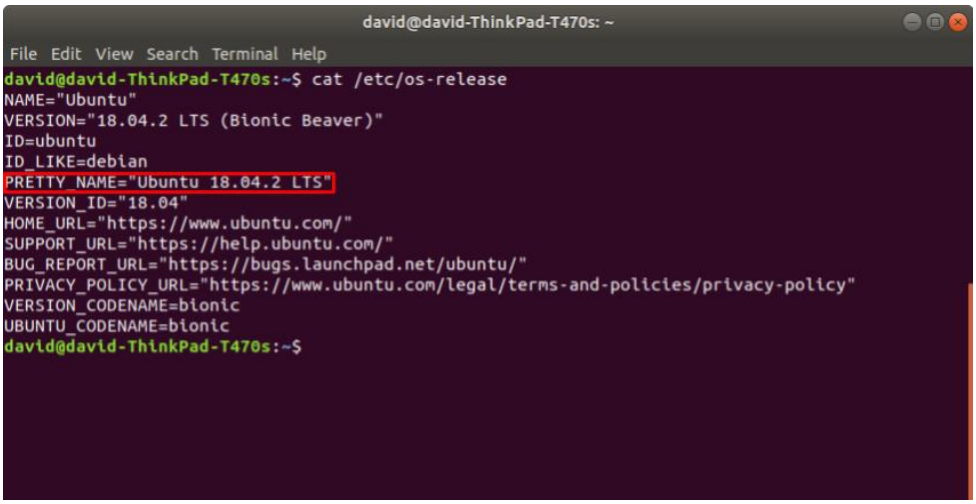
System Data



Linux stores a lot of system data in files within the `/proc` directory. Most of the data that this project requires exists in those files.

Operating System

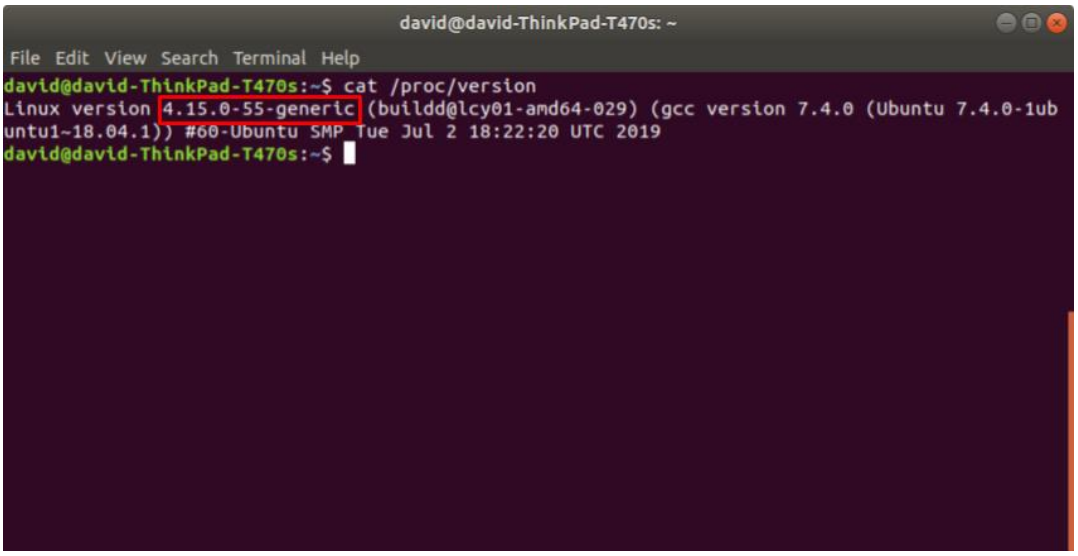
Information about the operating system exists outside of the `/proc` directory, in the `/etc/os-release` file.



There are several strings from which to choose here, but the most obvious is the value specified by "PRETTY_NAME".

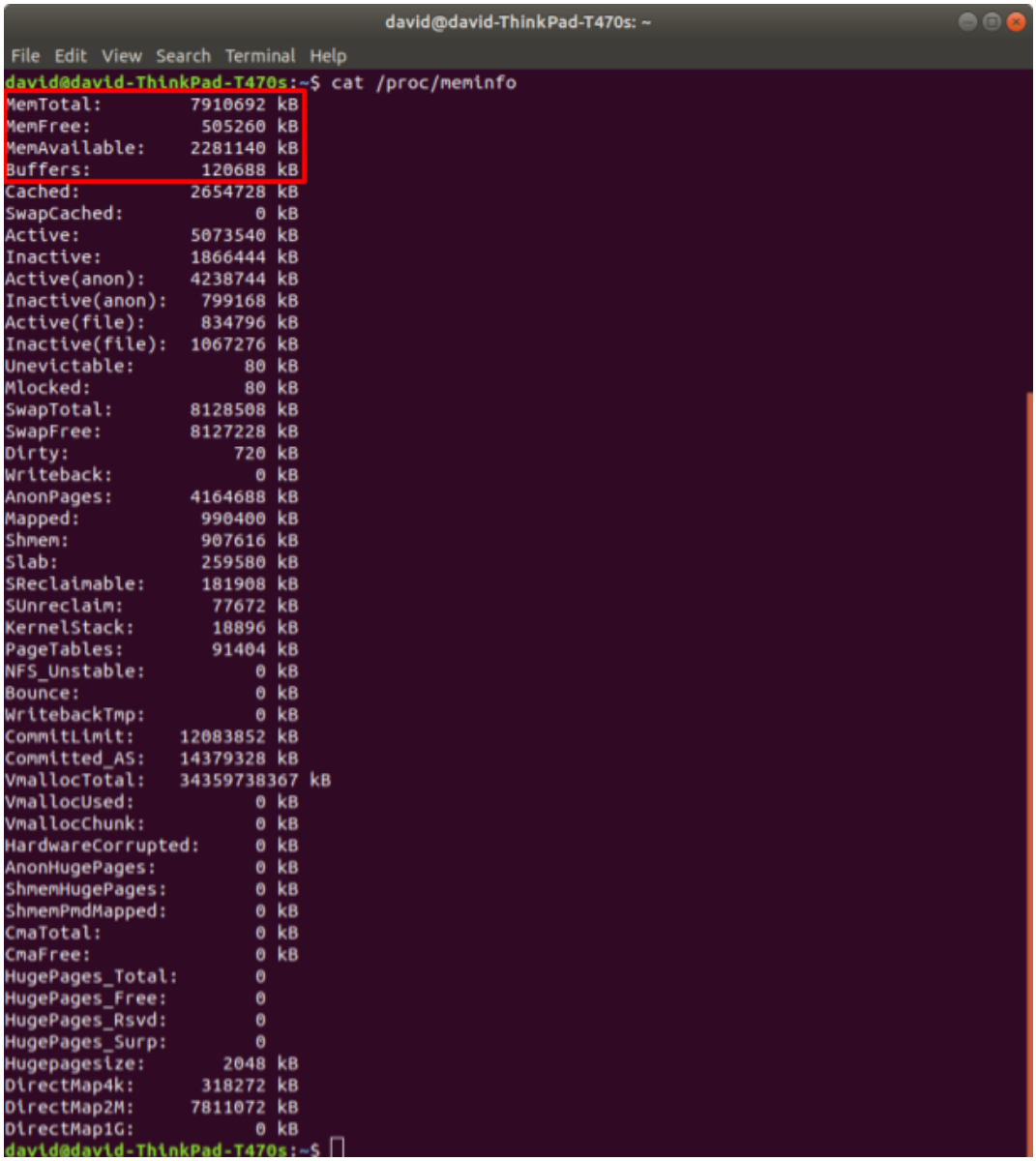
Kernel

Information about the kernel exists `/proc/version` file.



Memory Utilization

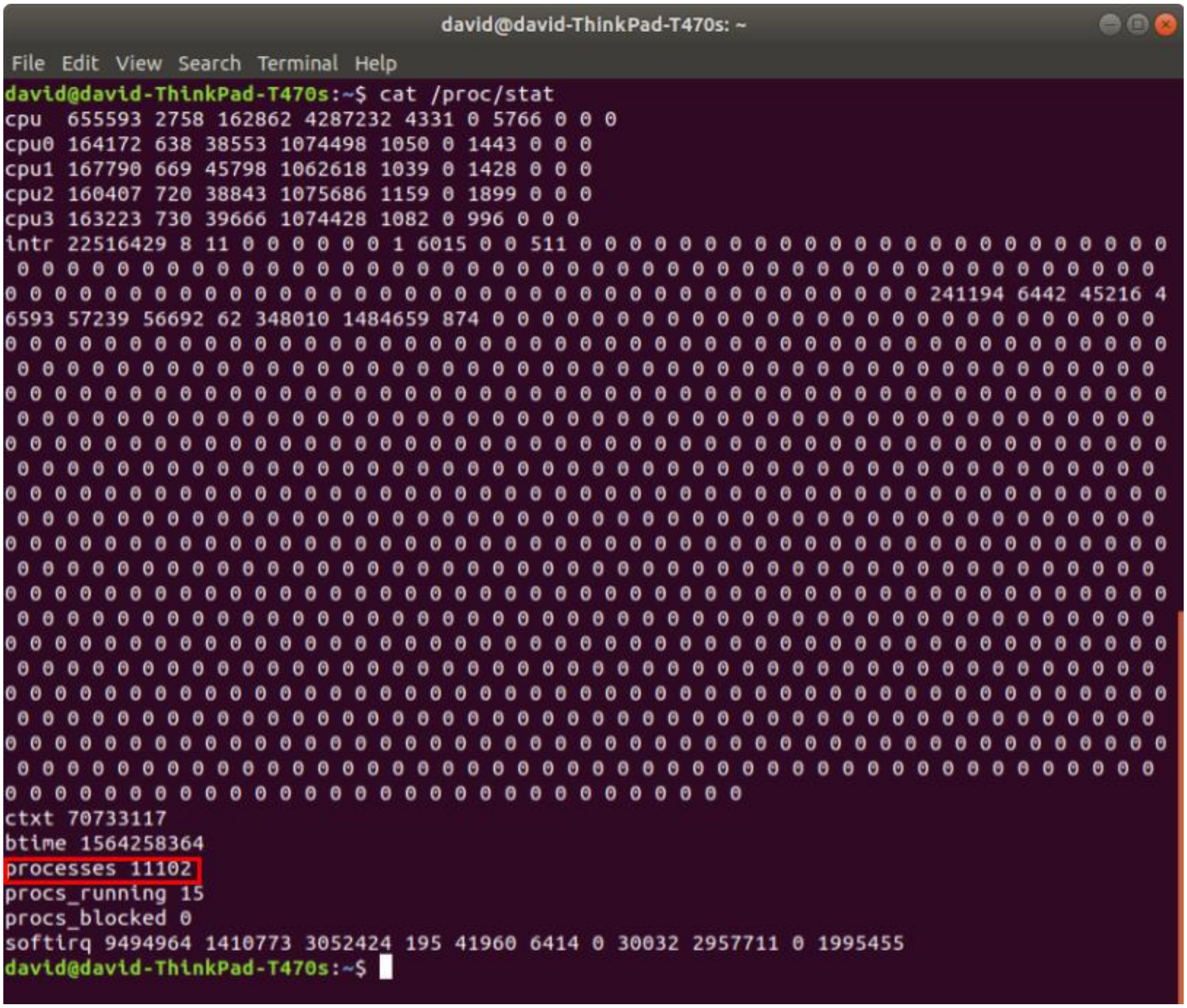
Information about memory utilization exists in the `/proc/meminfo` file.



There are a variety of ways to use this data to calculate memory utilization.
Hisham H. Muhammad, the author of htop, wrote a Stack Overflow answer about how htop calculates memory utilization from the data in `/proc/meminfo`.
Use the formula that makes the most sense to you!

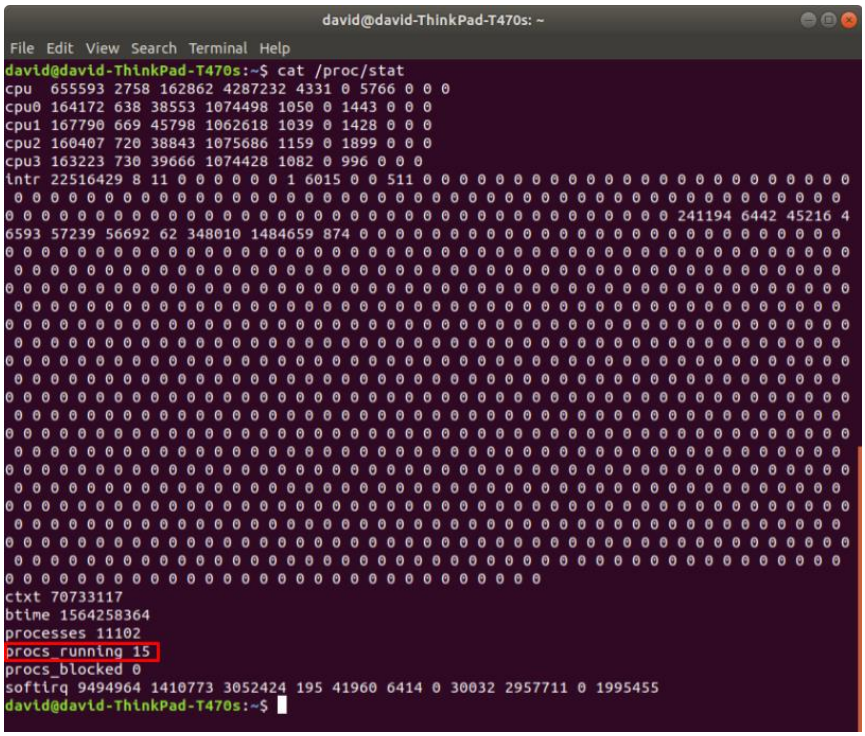
Total Processes

Information about the total number of processes on the system exists in the `/proc/meminfo` file.



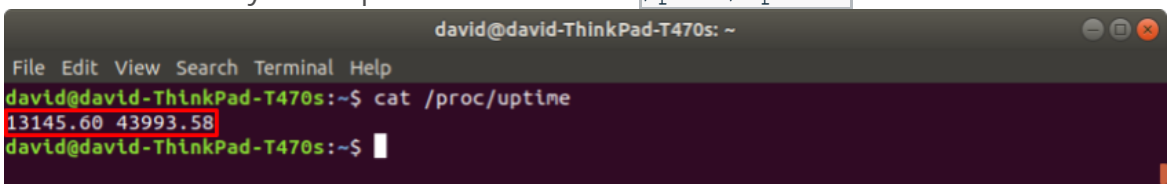
Running Processes

Information about the number of processes on the system that are currently running exists in the `/proc/meminfo` file.



Up Time

Information about system up time exists in the `/proc/uptime` file.



This file contains two numbers (values in seconds): the uptime of the system (including time spent in suspend) and the amount of time spent in the idle process.

From the *man* page for `proc`

8) LinuxParser Namespace
   https://youtu.be/f9Qt2AlPQeE

Relationship To System Class

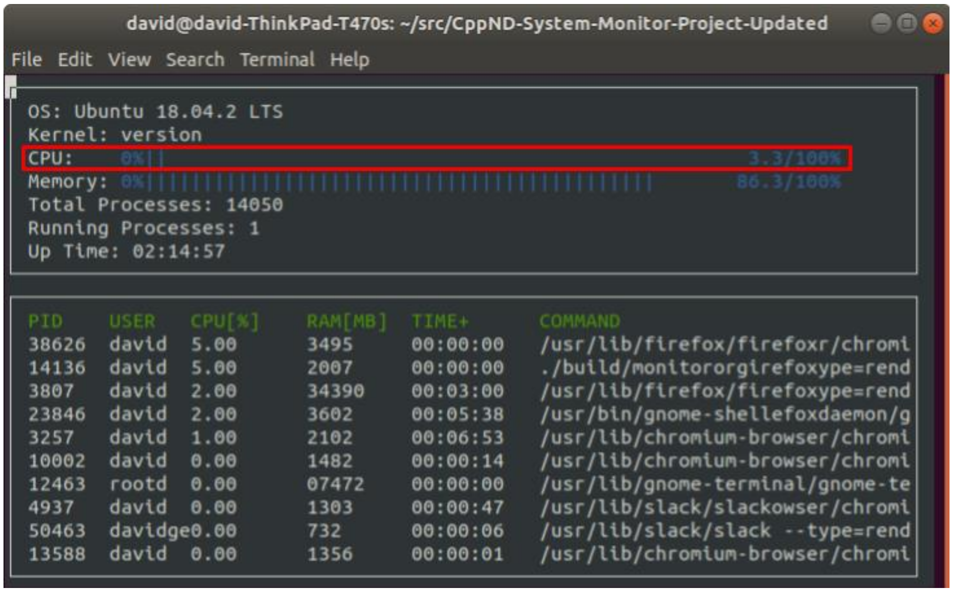
https://youtu.be/XQrAStOlZCQ

9) String Parsing
   https://youtu.be/vFhTd8HyiJw

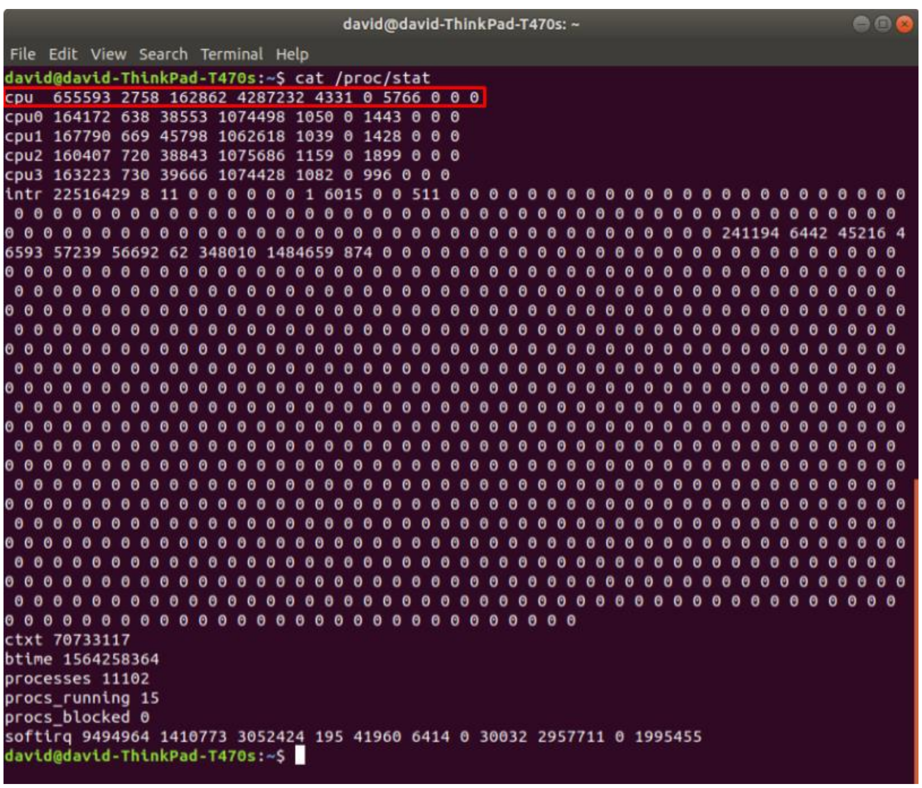
10) Processor Class
    https://youtu.be/eMkJE3y9bwo

11) Processor Data

Processor Data

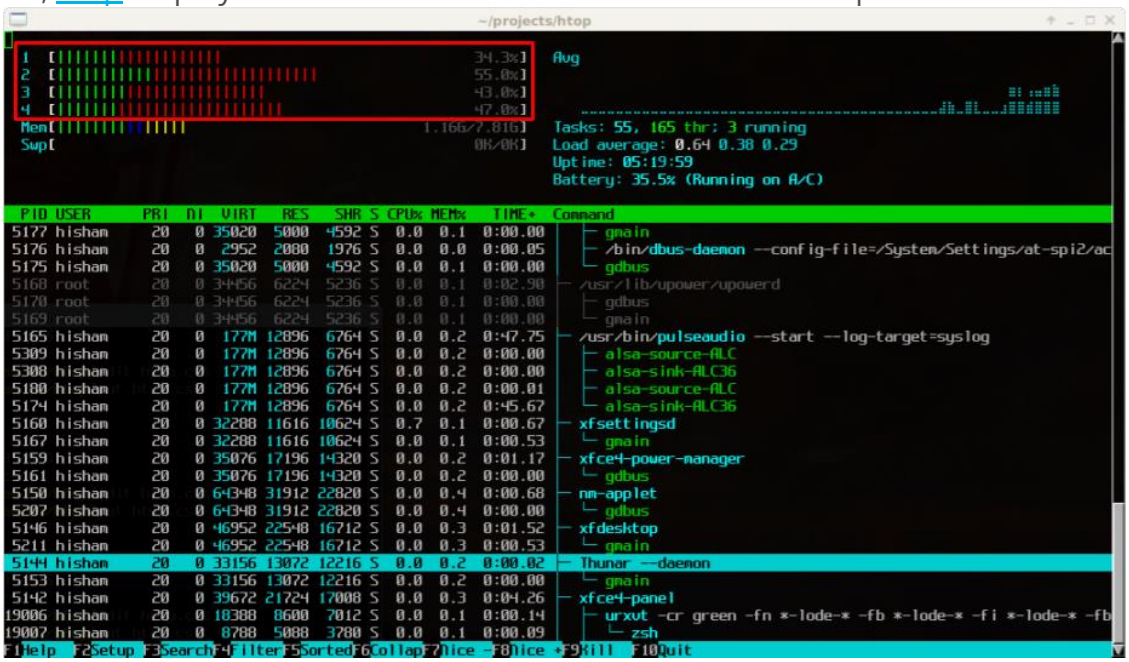


Linux stores processor utilization data within the `/proc/stat` file.



This data is more complex than most of the other data necessary to complete this project.

For example, `/proc/stat` contains aggregate processor information (on the "cpu" line) and individual processor information (on the "cpu0", "cpu1", etc. lines). Indeed, htop displays utilization information for each individual processor.



For this project, however, you only need to display aggregate CPU information, which you can find on the "cpu" line of `/proc/stat`.

If you would like to add individual processor information to your system monitor project, go for it!

Data

`/proc/stat` contains 10 integer values for each processor. The Linux source code documents each of these numbers:
The very first "cpu" line aggregates the numbers in all of the other "cpuN" lines. These numbers identify the amount of time the CPU has spent performing different kinds of work. Time units are in USER_HZ (typically hundredths of a second). The meanings of the columns are as follows, from left to right:

- *user: normal processes executing in user mode*
- *nice: niced processes executing in user mode*
- *system: processes executing in kernel mode*
- *idle: twiddling thumbs*

- *iowait: In a word, iowait stands for waiting for I/O to complete. But there are several problems:*

1. *Cpu will not wait for I/O to complete, iowait is the time that a task is waiting for I/O to complete. When cpu goes into idle state for outstanding task io, another task will be scheduled on this CPU.*
2. *In a multi-core CPU, the task waiting for I/O to complete is not running on any CPU, so the iowait of each CPU is difficult to calculate.*
3. *The value of iowait field in /proc/stat will decrease in certain conditions. So, the iowait is not reliable by reading from /proc/stat.*

- *irq: servicing interrupts*
- *softirq: servicing softirqs*
- *steal: involuntary wait*
- *guest: running a normal guest*
- *guest_nice: running a niced guest*

  Even once you know what each of these numbers represents, it's still a challenge to determine exactly how to use these figures to calculate processor utilization. This guide and this StackOverflow post are helpful.

Measurement Interval

Once you've parsed `/proc/stat` and calculated the processor utilization, you've got what you need for this project. Congratulations!

However, when you run your system monitor, you might notice that the process utilization seems very stable. Too stable.

That's because the processor data in `/proc/stat` is measured since boot. If the system has been up for a long time, a temporary interval of even extreme system utilization is unlikely to change the long-term average statistics very much. This means that the processor could be red-lining *right now* but the system monitor might still show a relatively underutilized processor, if the processor has spent most of the time since boot in an idle state.

You might want to update the system monitor to report the current utilization of the processor, rather than the long-term average utilization since boot. You would need to measure the difference in system utilization between two points in time relatively close to the present. A formula like:

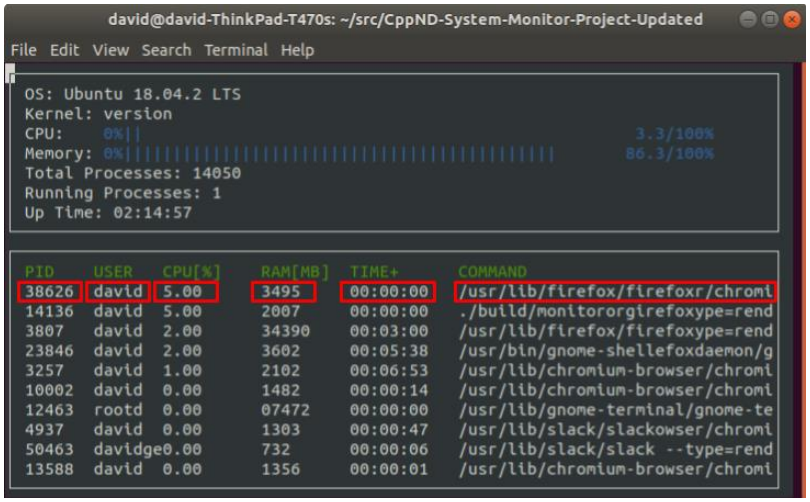
Δ active time units / Δ total time units

Consider this a bonus challenge that is not required to pass the project.

https://youtu.be/sEkf6TqLKBk

13) Process Data

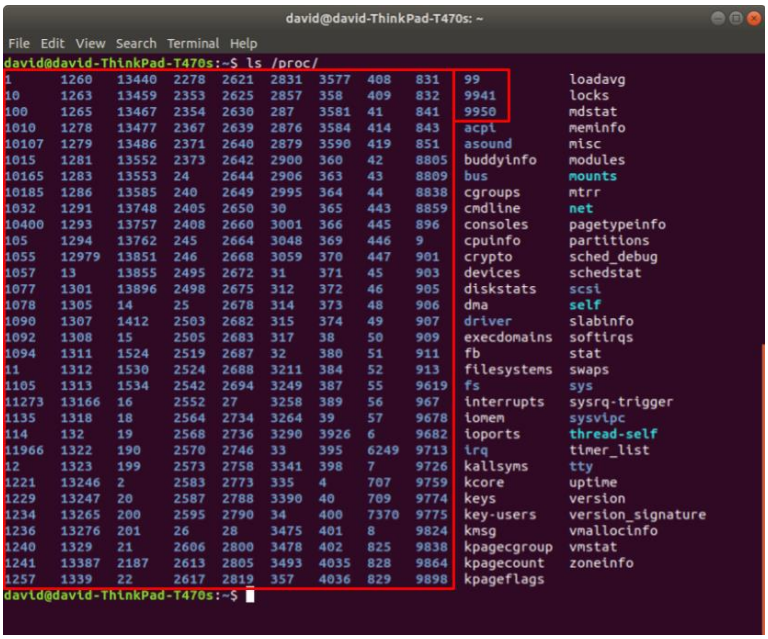
Process Data



Linux stores data about individual processes in files within subdirectories of the `/proc` directory. Each subdirectory is named for that particular process's identifier number. The data that this project requires exists in those files.

PID

The process identifier (PID) is accessible from the `/proc` directory. Typically, all of the subdirectories of `/proc` that have integral names correspond to processes. Each integral name corresponds to a process ID.



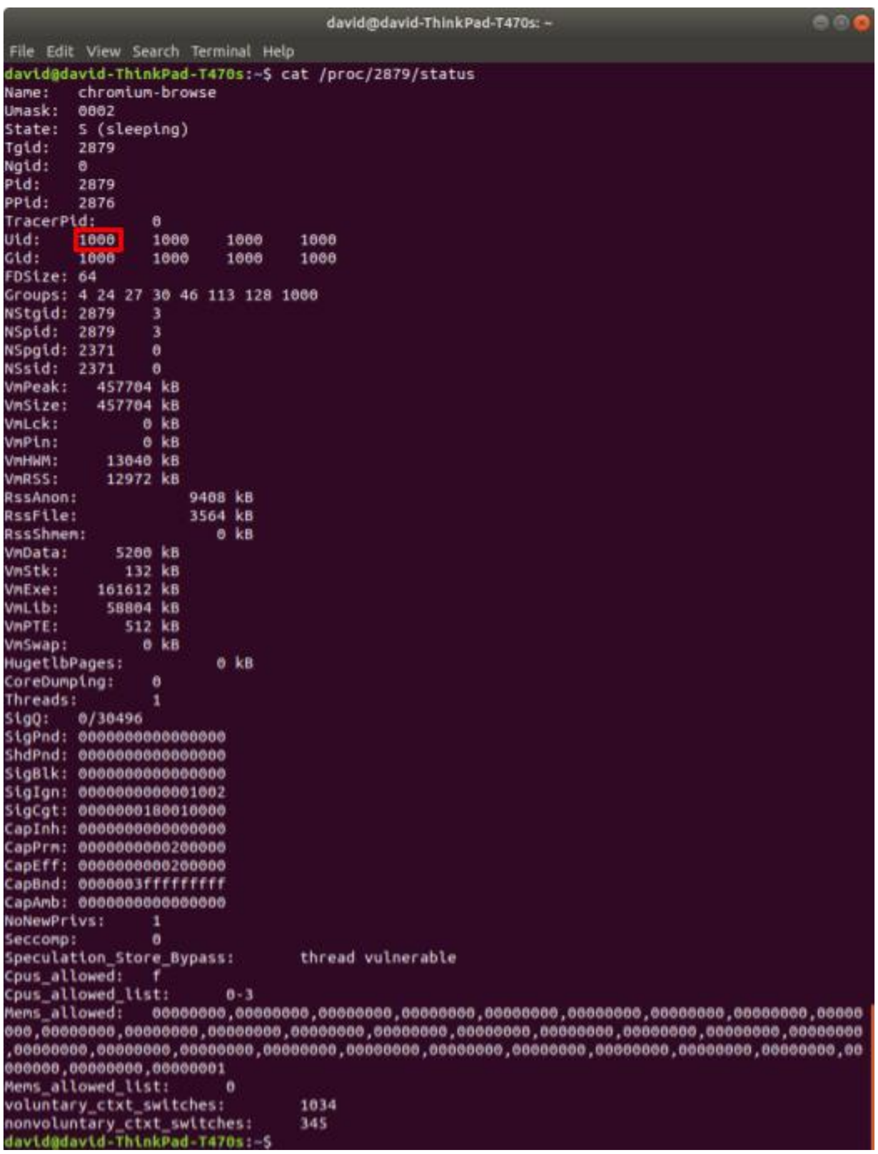
Parsing directory names with C++ is tricky, so we have provided in the project starter code a pre-implemented function to capture the PIDs.

User

Each process has an associated [user identifier (UID)](), corresponding to the process owner. This means that determining the process owner requires two steps:

1. Find the UID associated with the process
2. Find the user corresponding to that UID

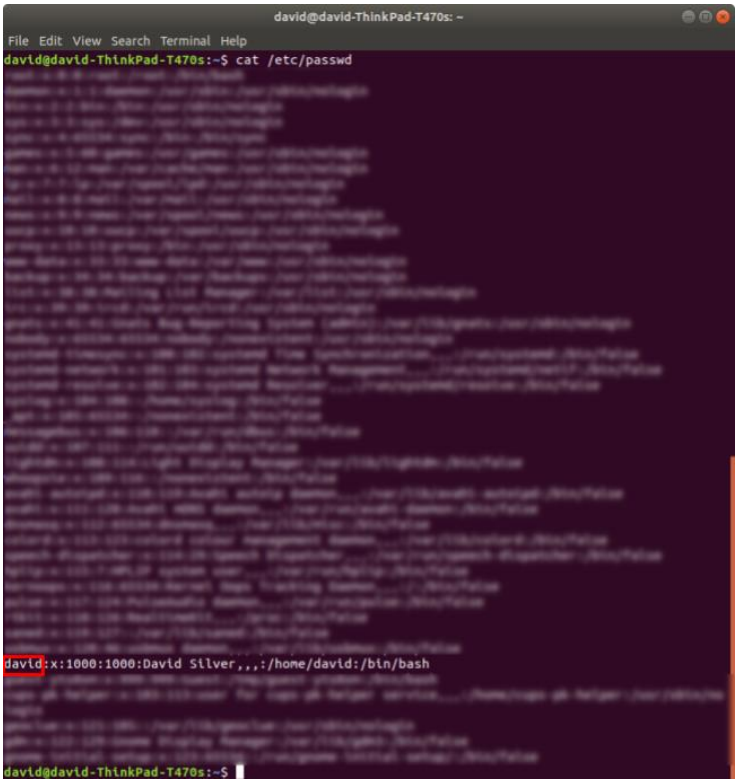
The UID for a process is stored in `/proc/[PID]/status`.



The *man* page for `proc` contains a "/proc/[pid]/status" section that describes this file. For the purposes of this project, you simply need to capture the first integer on the "Uid:" line.

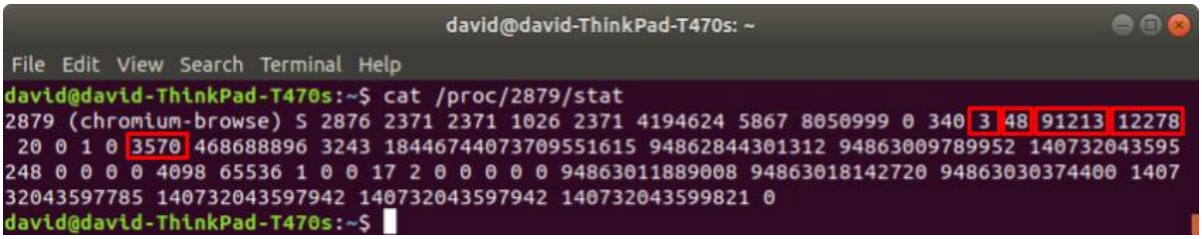
Username

`/etc/passwd` contains the information necessary to match the UID to a username.



Processor Utilization

Linux stores the CPU utilization of a process in the `/proc/[PID]/stat` file.

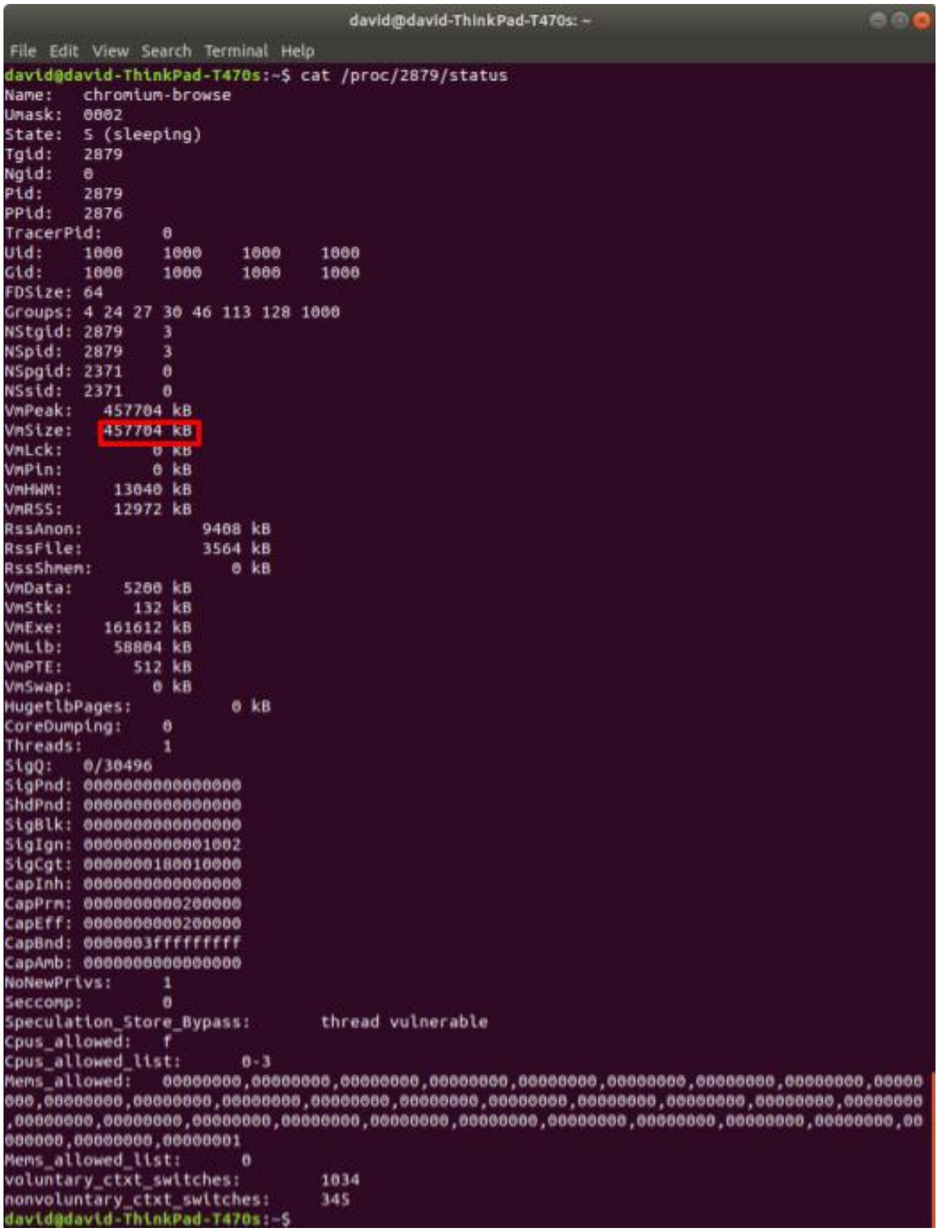


Much like the calculation of aggregate processor utilization, half the battle is extracting the relevant data from the file, and the other half of the battle is figuring out how to use those numbers to calculate processor utilization.

The "/proc/[pid]/stat" section of the `proc` *man* page describes the meaning of the values in this file. This StackOverflow answer explains how to use this data to calculate the process's utilization.
As with the calculation of aggregate processor utilization, it is sufficient for this project to calculate the average utilization of each process since the process launched. If you would like to extend your project to calculate a more current measurement of process utilization, we encourage you to do that!

Memory Utilization

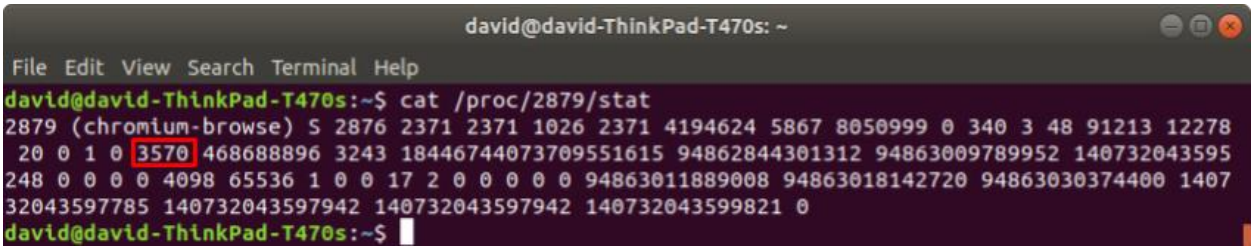
Linux stores memory utilization for the process in `/proc/[pid]/status`.



In order to facilitate display, consider converting the memory utilization into megabytes.

Up Time

Linux stores the process up time in `/proc/[pid]/stat`.



The "/proc/[pid]/stat" section of the `proc` *man* page describes each of the values in this file.

(22) starttime %llu

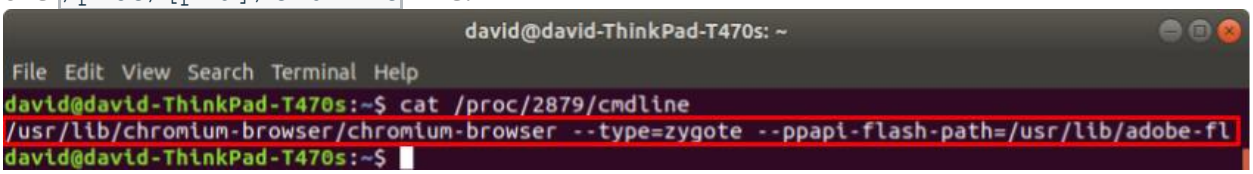
The time the process started after system boot. In kernels before Linux 2.6, this value was expressed in jiffies. Since Linux 2.6, the value is expressed in clock ticks (divide by sysconf(_SC_CLK_TCK)).
Note that the "starttime" value in this file is measured in "clock ticks". In order to convert from "clock ticks" to seconds, you must:

- #include <unistd.h>
- divide the "clock ticks" value by `sysconf(_SC_CLK_TCK)`

Once you have converted the time value to seconds, you can use the `Format::Time()` function from the project starter code to display the seconds in a "HH:MM:SS" format.

Command

Linux stores the command used to launch the function in the `/proc/[pid]/cmdline` file.



14) Goal
https://youtu.be/xw6_Mz3O54Y

15) Project workspace

Udacity Workspace

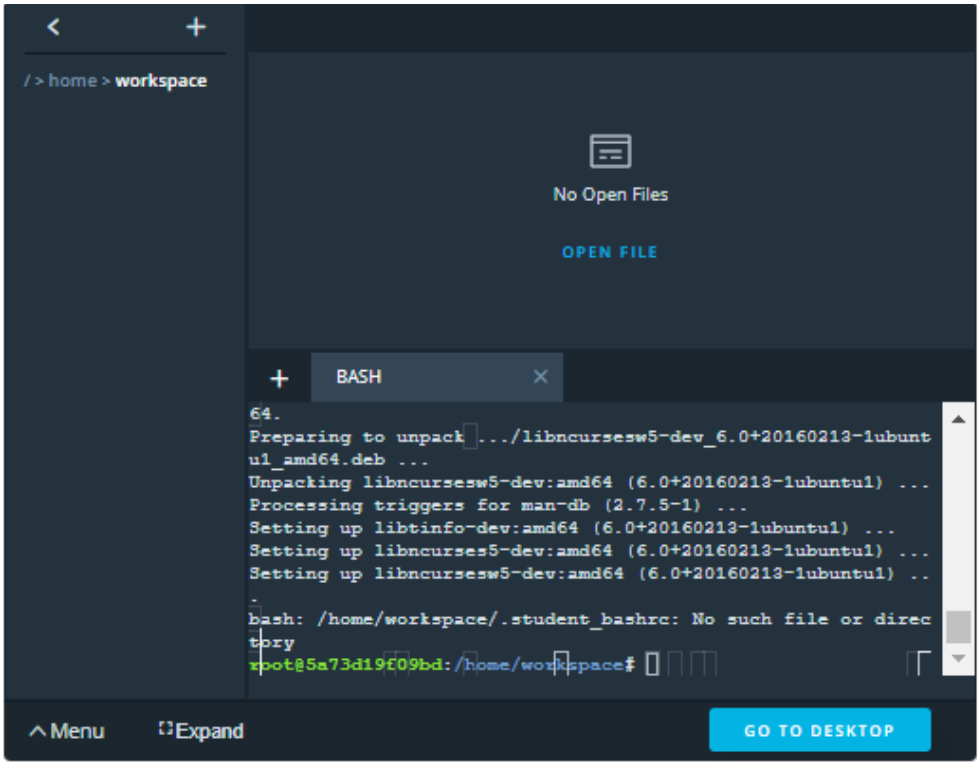
You are welcome to use this Udacity Workspace to complete the project. Or you can use your own Linux development environment, if you have one.

GitHub Repo

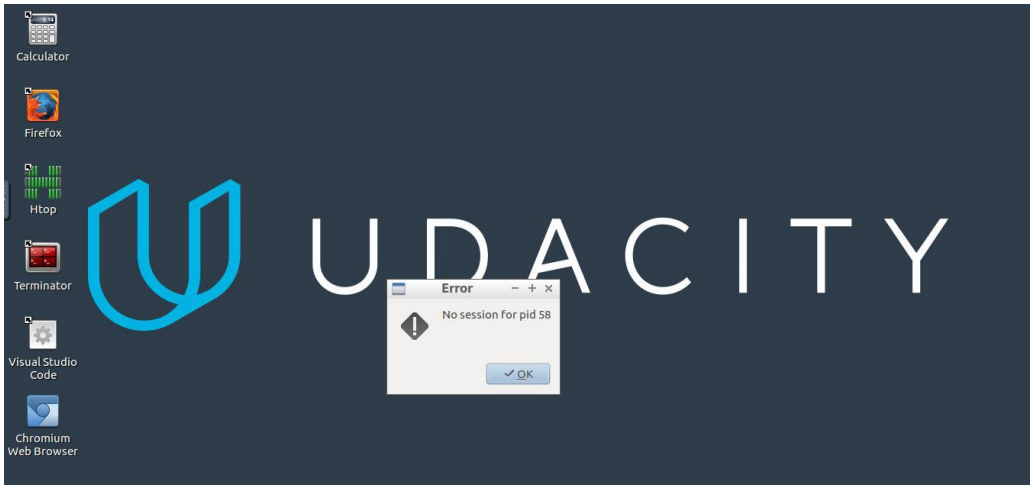
The starter code is available on GitHub: https://github.com/udacity/CppND-System-Monitor

You can clone the starter code repository, either into the Udacity Workspace or into your own development environment, by running:

```
git clone https://github.com/udacity/CppND-System-Monitor
```



When u click desktop , this is what happens



16) Project: system monitor

Project Submission

DUE DATE

Jun 23

STATUS

Not submitted

Due at: Tue, Jun 23 3:00 pm

CppND-System-Monitor

Starter code for System Monitor Project is provided on GitHub: **https://github.com/udacity/CppND-System-Monitor-Project-Updated**
Follow along with the classroom lesson to complete the project!

Udacity Linux Workspace

Udacity provides a browser-based Linux **Workspace** for students.
You are welcome to develop this project on your local machine, and you are not required to use the Udacity Workspace. However, the Workspace provides a convenient and consistent Linux development environment we encourage you to try.

ncurses

ncurses is a library that facilitates text-based graphical output in the terminal. This project relies on ncurses for display output.
Within the Udacity Workspace, `.student_bashrc` automatically installs ncurses every time you launch the Workspace.
If you are not using the Workspace, install ncurses within your own Linux environment: `sudo apt install libncurses5-dev libncursesw5-dev`

Make

This project uses **Make**. The Makefile has four targets:

- `build` compiles the source code and generates an executable
- `format` applies **ClangFormat** to style the source code
- `debug` compiles the source code and generates an executable, including debugging symbols
- `clean` deletes the `build/` directory, including all of the build artifacts

Rubric

Before you start the project, read the **project rubric**.
https://review.udacity.com/#!/rubrics/2518/view

Mentor

We suggest you schedule a check in call with your mentor before you start this project. Your mentor can help you develop a plan to successfully complete the project.

Instructions

1. Clone the project repository: `git clone https://github.com/udacity/CppND-System-Monitor-Project-Updated.git`
2. Build the project: `make build`
3. Run the resulting executable: `./build/monitor`
4. Follow along with the lesson.
5. Implement the `System`, `Process`, and `Processor` classes, as well as functions within the `LinuxParser` namespace.
6. Verify that your submission meets all of the criteria in the **project rubric**.
7. Submit!