Lecture 20 — Object-Oriented Programming

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Structuring a Program

Up to this point we have organized our program using procedural programming: the use of functions to give us program structure.

We can break down a larger problem into smaller problems, each of which we can accomplish in a re-usable sequence of steps (function).

The painful reality is that most software projects fail.
- They are often late, unreliable, and/or expensive.

This is because software is extremely complex.
- We need to manage this complexity if a project is to succeed.
- Procedural programming is not adequate to the task.

Re-usable Components

Idea: if an electrical engineer needs a transistor, she does not need to build one from scratch; just go to the bin and use an existing one.

Now take the idea of re-usable components and apply it to software.

We've already had re-usable functions, so why not components?

What we'd like is to package up data and functions that manipulate that data into single, self-contained, re-usable unit.

Objects are the way of packaging & managing our data and functions.

They are the building blocks of an object-oriented program.

Objects

An object models a tangible item or some abstract concept:
What properties does an object have? What can the object do?

The world is full of “things” (objects). Imagine a dog.
A dog has characteristics like colour, weight, age...
A dog also has behaviours like bark, move, sleep...

To represent a dog in software, create an object that possesses both characteristics (**data variables**) and behaviours (**functions**) of a dog.

Object Oriented Programming

Objects interact with other objects through their functions, and not by manipulating another object's data directly.

Modelling the system as objects and their interactions is known as Object Oriented Programming.

C# supports and encourages this programming paradigm as an approach to designing useful, modular, reusable software systems.

Appropriate use of object oriented programming as a design technique will allow us to create and maintain complex software.

Example: Variable Voltage

Suppose we want to model a variable voltage source: an electric component that provides several different voltage output levels.

Let's say it has a selector to choose one of the following levels:
Off, 6V, 12V, 18V, and 24V.

What variables will we need to model this?
Some constants to hold the possible settings.
A variable to represent the current setting.

We also have some functions to represent voltage source behaviour:
Increase the voltage by one level.
Decrease the voltage by one level.
Shut it off.

The Blueprints

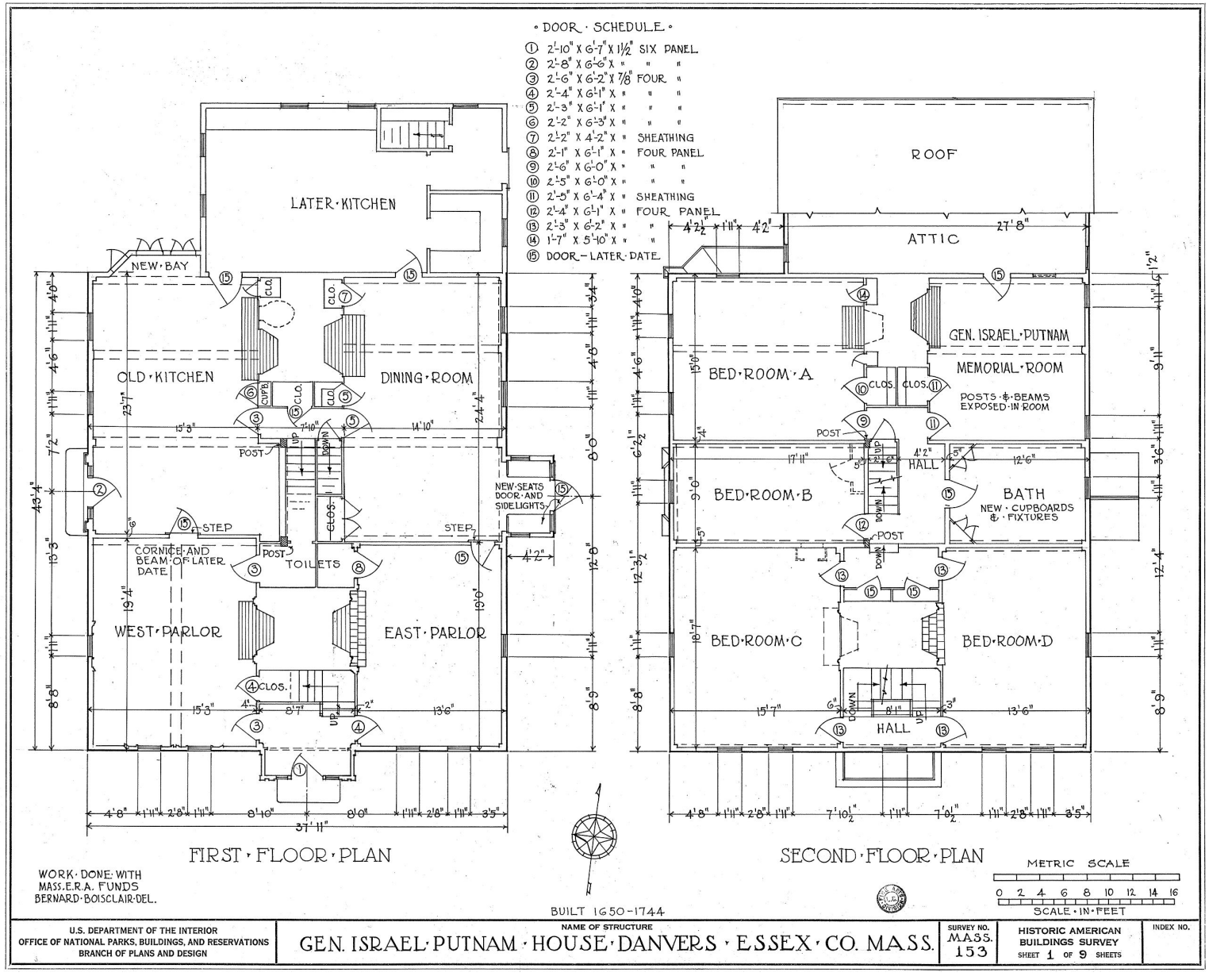
We have an idea now about how to model the variable voltage source.
Now, to represent that in the program.

Analogy: building “blueprints” (architectural plan).

Before a building is built, architects and civil engineers draft a document that describes in detail the structure of the building.

The construction team uses the document when building a structure.
It tells them what to do (though not generally how to do it).

Building Blueprints Example



Class Definition

To tell the system how to build an object, we need to provide it the blueprints for that object.

The blueprints for an object is a `class` definition.

This code tells the system how to create an object of that type.

The `class` definition specifies the variables and methods.

Classes are therefore programmer-defined types.

The Structure

We've already seen programmer-defined types: the `struct`.

The `struct` can contain different variables of different types.

The `class` is an expanded version of the `struct`: it contains functions in addition to variables.

In C#, a `struct` may also contain functions, but this is not true in all programming languages.

The data and functions of an object are referred to as members.

Member functions are called methods.
Member variables are called fields.

Voltage Source Blueprints

Let's draw up the blueprints for the voltage source:

```
public class VoltageSource
{
  public int currentVoltage;
  public int[] voltageLevels = {0, 6, 12, 18, 24};

  public void IncreaseVoltage()
  {
    // ...
  }

  public void DecreaseVoltage()
  {
    // ...
  }

  public void TurnOff()
  {
    // ...
  }
}
```

Voltage Source Blueprints Comments

The previous slide gave the structure for the voltage source we wanted to model: it showed the member fields and methods.

Given this definition, the system now knows how to make a `VoltageSource` object.

The implementations of the functions are not shown for space reasons, but in defining the class, we would normally fill them in.

Of course, defining the structure of the object is the first step, but if we want to use a `VoltageSource`, we will need to create one.

Instances

A specific realization of a class is called an instance.
A program may create many distinct instances of the same class.

Classes are programmer-defined **types**, so this is no surprise.
We can have many distinct `double`s in the program.

The process of creating an instance of a class is called instantiation.

Now we can see an overview of terminology of structures and classes:

	Structure Term	**Object Term**
Variable	Field	Field
Function	Method (if allowed)	Method
Instance	Record	Object

Classes are Reference Types

Like arrays, classes are reference types.
   This means the `new` keyword is needed to create an instance.

The declaration
```
   VoltageSource source;
```
is the same as
```
   VoltageSource source = null;
```

It creates a reference to an instance of `VoltageSource`.
   ... but does not allocate memory or create the instance.

Instantiation: `VoltageSource source = new VoltageSource( );`

When creating an instance, the name of the class is followed by brackets, like a function call. We'll see why soon.

Car Example

Let's look at another object example: a car.

- Data: make, model, year,...
- Functions: `HonkHorn()`, `FlashLights()`...

Given a `class Car`, you can make several instances:

- Toyota Corolla, Chevrolet Corvette, BMW 335i, Volkswagen Jetta...

Car Class

Here's a basic version of the `Car` class, that looks much like a `struct`:

```
public class Car
{
    public string make;
    public string model;
    public int year;

    public void HonkHorn() {
        // ...
    }
    public void FlashLights() {
        // ...
    }
    // Other methods not shown for space reasons
}
```

As we learn more about OOP, we will improve this definition to be more useful and consistent with good programming practices.

Using the Dot Operator

Just like the `struct`, variables of an instance are accessed using the Dot Operator (`.`).

`Car prius = new Car( );`
Declares and instantiates a `Car` object.

After creation with `new`, we may access the variables of the instance:

```
prius.make = "Toyota";
prius.model = "Prius";
prius.year = 2010;
```

Trying to use the dot operator if the instance is `null` will result in a `NullReferenceException`.

Classes are Reference Types, II

Let's keep using this instance: `Car prius = new Car( );`

Note that the declaration `Car prius2 = prius;` creates a second reference to the same memory location of `prius`.

Thus, the statement `prius2.year = 2011;` has the same effect as `prius.year = 2011;`

Recall from arrays: a reference is directions to a memory location.

References `prius` and `prius2` are directions to the same spot.

`prius.year` and `prius2.year` are at the same place in memory.

Making a Copy of an Instance

If we have an instance of an object like a `struct`, we created a copy with the assignment operator (`point2 = point1;`).

This won't work; we must allocate and create another instance.

To create another instance of `Car`, use the `new` keyword again.

```
Car prius2 = new Car( );
```

To make a copy, create a new instance, and copy the data from the original object to the new instance, one variable at a time.

(In the next lecture, we'll learn a better way to do this.)

Building on the Car Example

Let's build on the example of the `Car` class and look at a dealership.

A car dealership has zero or more cars on its parking lot.
A good way to implement this might be an array of `Car` objects.

Just like the `struct` we can have an array of objects.

When a sales associate wants to find a car to show a customer, they make the lights flash and the horn honk to find the car in the lot.

The Car Dealership

Suppose the parking lot has 42 spaces.

```
public class CarDealership
{
    public Car[] availableCars = new Car[42];

    public void ParkCar( Car newCar, int position )
    {
        availableCars[position] = newCar;
    }
    // Other methods and variables not shown
}
```

Of course, this example ignores what happens if someone tries to park a car in a position that is already occupied.

Finding a Specific Car

Now let's write a method to find a specific car in the lot when we know the make, model, and year.

```
public void FindCar( String make, String model, int year )
{
    for ( int i = 0; i < availableCars.Length; i++ )
    {
        if ( availableCars[i] != null &&
             availableCars[i].make == make &&
             availableCars[i].model == model &&
             availableCars[i].year == year)
             {
                 availableCars[i].HonkHorn();
                 availableCars[i].FlashLights();
             }
    }
}
```

Use of Methods and Variables

A common mistake when working with classes is a method call like:

```
Car.HonkHorn();
```

The compiler identifies this as an error.

To call the `HonkHorn()` method, an instance of the class is needed.

Which instance of `Car` do we mean? The Prius? The Jetta?

Correct usage: `prius.HonkHorn();`

Why? These are instance methods: they belong to an instance.

You may have noticed that `HonkHorn()` doesn't have the `static` keyword in front of them like methods we have written so far.

The `static` Keyword

What does the `static` keyword mean? The member applies to the type, not an instance.

The keyword `static` may apply to a field or method.

Consider this very simple class definition:

```
public class ExampleClass
{
    public int value;
    public static int count;
}
```

Static vs. Instance Members

In this class, `value` is an instance member: a new `int` variable is created whenever a new instance of `ExampleClass` is created.

But `count` is a static member: there is only one `int` variable created, regardless of how many instances of `ExampleClass` there are.

- This variable is shared between all instances.
- It can even be accessed without an instance.

Invalid: `ExampleClass.value = 1;`
Valid: `ExampleClass.count = 1;`

Static vs. Instance Members

Consider this code:

```
ExampleClass e1 = new ExampleClass( );
ExampleClass e2 = new ExampleClass( );

e1.value = 7;
e2.value = -8;

e1.count = 2;

Console.WriteLine( "e1 value: " + e1.value );
Console.WriteLine( "e2 value: " + e1.value );
Console.WriteLine( "e1 count: " + e1.count );
Console.WriteLine( "e2 count: " + e2.count );
```

Static vs. Instance Members

In the previous slide, we used an instance, `e1`, to assign the variable `count`, even though `count` is `static`.

This practice is discouraged; if a variable is `static`, it should be accessed using the `class` name, not an instance reference.

```
ExampleClass.count = 2;
```

The compiler may identify this as a warning.

Static vs. Instance Members

A `static` method can make use of static variables and call other static methods, but cannot use instance variables/methods.

Why? Inside the static method, there is no instance to reference.

This is why, to use a function we have defined from within `static void Main( )` we must declare that function `static` as well.

An instance method can make use of both instance and static variables and can call both static and instance methods.

Why? Static methods and variables are always available, as they belong to the type itself.

Static Members

In the `VoltageSource` class is an array of the different voltage levels:

```
public int[] voltageLevels = {0, 6, 12, 18, 24};
```

This is a good candidate to be declared `static` since the voltage levels will be the same in all of the instances of the class.

```
public static int[] voltageLevels = {0, 6, 12, 18, 24};
```

In general, any constant is likely to be a good candidate to be declared `static`.