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High-Quality Classes and Class Hierarchies

Best Practices in the Object-Oriented Design

Telerik Software Academy
Learning & Development
http://academy.telerik.com

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Basic Principles

Cohesion, Coupling, Inheritance and Polymorphism

Cohesion

- Cohesion measures how closely are all the routines in a class/module
  - Cohesion must be strong
  - Classes must contain strongly related functionality and aim for single purpose
- Strong cohesion is a useful tool for managing complexity
  - Well-defined abstractions keep cohesion strong
  - Bad abstractions have weak cohesion

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Good and Bad Cohesion

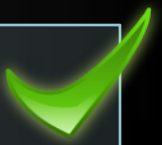
- Good: hard disk, CD-ROM, floppy

- Bad: spaghetti code

Strong Cohesion

- Strong cohesion example
  - Class System.Math
    - Sin(), Cos(), Asin()
    - Sqrt(), Pow(), Exp()
    - Math.PI, Math.E

```
double sideA = 40, sideB = 69;
double angleAB = Math.PI / 3;
double sideC =
  Math.Pow(sideA, 2) + Math.Pow(sideB, 2)
  - 2 * sideA * sideB * Math.Cos(angleAB);
double sidesSqrtSum = Math.Sqrt(sideA) +
  Math.Sqrt(sideB) + Math.Sqrt(sideC);
```



Coupling

- Coupling describes how tightly a class or routine is related to other classes or routines
- Coupling must be kept loose
  - Modules must depend little on each other
  - All classes and routines must have
    - Small, direct, visible, and flexible relationships to other classes and routines
  - One module must be easily used by other modules, without complex dependencies

Loose and Tight Coupling

- Loose Coupling
  - Easily replace old HDD
  - Easily place this HDD to another motherboard

- Tight Coupling
  - Where is the video adapter?
  - Can you change the video controller on this MB?

Loose Coupling – Example

```
class Report
{
  public bool LoadFromFile(string fileName) {…}
  public bool SaveToFile(string fileName) {…}
}

class Printer
{
  public static int Print(Report report) {…}
}

class Program
{
  static void Main()
  {
    Report myReport = new Report();
    myReport.LoadFromFile("C:\\DailyReport.rep");
    Printer.Print(myReport);
  }
}
```

Tight Coupling – Example

```
class MathParams
{
  public static double operand;
  public static double result;
}

class MathUtil
{
  public static void Sqrt()
  {
    MathParams.result = CalcSqrt(MathParams.operand);
  }
}

…

MathParams.operand = 64;
MathUtil.Sqrt();
Console.WriteLine(MathParams.result);
```

Inheritance

- Inheritance is the ability of a class to implicitly gain all members from another class
  - Inheritance is principal concept in OOP
  - The class whose methods are inherited is called base (parent) class
  - The class that gains new functionality is called derived (child) class
- Use inheritance to:
  - Reuse repeating code: data and program logic
  - Simplify code maintenance

Inheritance in C# and JS

- In C# all class members are inherited
  - Fields, methods, properties, etc.
  - Structures cannot be inherited, only classes
  - No multiple inheritance is supported
  - Only multiple interface implementations
- In JS inheritance is supported indirectly
  - Several ways to implement inheritance
  - Multiple inheritance is not supported
  - There are no interfaces (JS is typeless language)

Polymorphism

- Polymorphism is a principal concept in OOP
- The ability to handle the objects of a specific class as instances of its parent class
  - To call abstract functionality
- Polymorphism allows to create hierarchies with more valuable logical structure
- Polymorphism is a tool to enable code reuse
  - Common logic is taken to the base class
  - Specific logic is implemented in the derived class in a overridden method

Polymorphism in C# and JS

- In C# polymorphism is implemented through:
  - Virtual methods (`virtual`)
  - Abstract methods (`abstract`)
  - Interfaces methods (`interface`)
- In C# `override` overrides a virtual method
- In JavaScript all methods are virtual
  - The child class can just "override" any method from any object
  - There are no interfaces (JS is typeless language)

Polymorphism – Example

```
class Person
{
  public virtual void PrintName()
  {
    Console.Write("I am a person.");
  }
}

class Trainer : Person
{
  public override void PrintName()
  {
    Console.Write(
      "I am a trainer. " + base.PrintName());
  }
}

class Student : Person
{
  public override void PrintName()
  {
    Console.WriteLine("I am a student.");
  }
}
```

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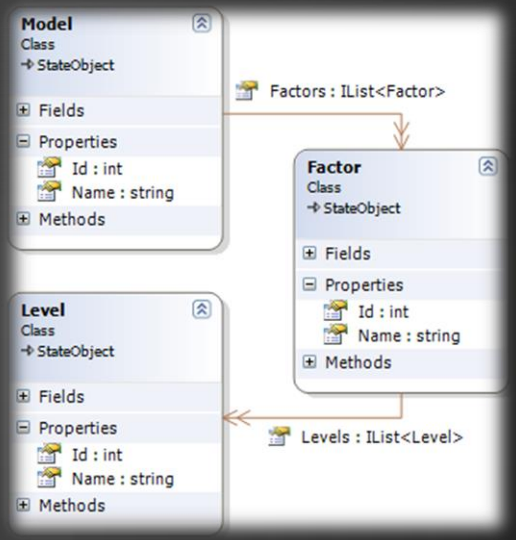

High-Quality Classes

How to Design High-Quality Classes? Abstraction, Cohesion and Coupling

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High-Quality Classes: Abstraction

- Present a consistent level of abstraction in the class contract (publicly visible members)
  - What abstraction the class is implementing?
  - Does it represent only one thing?
  - Does the class name well describe its purpose?
  - Does the class define clear and easy to understand public interface?
  - Does the class hide all its implementation details?

Good Abstraction – Example

```
public class Font
{
    public string Name { get; set; }
    public float SizeInPoints { get; set; }
    public FontStyle Style { get; set; }
    public Font(
        string name, float sizeInPoints, FontStyle style)
    {
        this.Name = name;
        this.SizeInPoints = sizeInPoints;
        this.Style = style;
    }
    public void DrawString(DrawingSurface surface,
        string str, int x, int y) { … }
    public Size MeasureString(string str) { … }
}
```

Bad Abstraction – Example

```
public class Program
{
  public string title;
  public int size;
  public Color color;
  public void InitializeCommandStack();
  public void PushCommand(Command command);
  public Command PopCommand();
  public void ShutdownCommandStack();
  public void InitializeReportFormatting();
  public void FormatReport(Report report);
  public void PrintReport(Report report);
  public void InitializeGlobalData();
  public void ShutdownGlobalData();
}
```

Does this class really represents a "program"? Is this name good?

Does this class really have a single purpose?

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Establishing Good Abstraction

- Define operations along with their opposites, e.g.
  - `Open()` and `Close()`
- Move unrelated methods in another class, e.g.
  - In class `Employee` if you need to calculate `Age` by given `DateOfBirth`
  - Create a static method `CalcAgeByBirthDate(…)` in a separate class `DateUtils`
- Group related methods intro a single class
- Does the class name correspond to the class content?

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Establishing Good Abstraction (2)

- Beware of breaking the interface abstraction due to evolution
  - Don't add public members inconsistent with abstraction
  - Example: in class called `Employee` at some time we add method for accessing the DB with SQL

```
class Employee
{
  public string FirstName { get; set; }
  public string LastName; { get; set; }
  …
  public SqlCommand FindByPrimaryKeySqlCommand(int id);
}
```

Encapsulation

- Minimize visibility of classes and members
  - In C# start from `private` and move to `internal`, `protected` and `public` if required
- Classes should hide their implementation details
  - A principle called encapsulation in OOP
  - Anything which is not part of the class interface should be declared `private`
  - Classes with good encapsulated classes are: less complex, easier to maintain, more loosely coupled
- Classes should keep their state clean → throw an exception if invalid data is being assigned

Encapsulation (2)

- Never declare fields public (except constants)
  - Use properties / methods to access the fields
- Don't put private implementation details in the public interface
  - All public members should be consistent with the abstraction represented by the class
- Don't make a method public just because it calls only public methods
- Don't make assumptions about how the class will be used or will not be used

Encapsulation (3)

- Don't violate encapsulation semantically!
  - Don't rely on non-documented internal behavior or side effects
  - Wrong example:
    - Skip calling `ConnectToDB()` because you just called `FindEmployeeById()` which should open connection
  - Another wrong example:
    - Use `String.Empty` instead of `Titles.NoTitle` because you know both values are the same

Inheritance or Containment?

- Containment is "has a" relationship
  - Example: `Keyboard` has a set of `Keys`
- Inheritance is "is a" relationship
  - Design for inheritance: make the class `abstract`
  - Disallow inheritance: make the class `sealed`
  - Subclasses must be usable through the base class interface
    - Without the need for the user to know the difference

Inheritance

- Don't hide methods in a subclass
  - Example: if the class `Timer` has private method `Start()`, don't define `Start()` in `AtomTimer`
- Move common interfaces, data, and behavior as high as possible in the inheritance tree
  - This maximizes the code reuse
- Be suspicious of base classes of which there is only one derived class
  - Do you really need this additional level of inheritance?

Inheritance (2)

- Be suspicious of classes that override a routine and do nothing inside
  - Is the overridden routine used correctly?
- Avoid deep inheritance trees
  - Don't create more than 6 levels of inheritance
- Avoid using a base class's protected data fields in a derived class
  - Provide protected accessor methods or properties instead

Inheritance (3)

- Prefer inheritance to extensive type checking:

```
switch (shape.Type)
{
  case Shape.Circle:
    shape.DrawCircle();
    break;
  case Shape.Square:
    shape.DrawSquare();
    break;
  ...
}
```

- Consider inheriting `Circle` and `Square` from `Shape` and override the abstract action `Draw()`

Class Methods and Data

- Keep the number of methods in a class as small as possible → reduce complexity
- Minimize direct methods calls to other classes
  - Minimize indirect methods calls to other classes
  - Less external method calls == less coupling
  - Also known as "fan-out"
- Minimize the extent to which a class collaborates with other classes
  - Reduce the coupling between classes

Class Constructors

- Initialize all member data in all constructors, if possible
  - Uninitialized data is error prone
  - Partially initialized data is even more evil
  - Incorrect example: assign `FirstName` in class `Person` but leave `LastName` empty
- Initialize data members in the same order in which they are declared
- Prefer deep copies to shallow copies (`ICloneable` should make deep copy)

Use Design Patterns

- Use private constructor to prohibit direct class instantiation
- Use design patterns for common design situations
  - Creational patterns like Singleton, Factory Method, Abstract Factory
  - Structural patterns like Adapter, Bridge, Composite, Decorator, Façade
  - Behavioral patterns like Command, Iterator, Observer, Strategy, Template Method

Top Reasons to Create Class

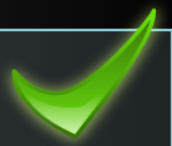
- Model real-world objects with OOP classes
- Model abstract objects, processes, etc.
- Reduce complexity
  - Work at higher level
- Isolate complexity
  - Hide it in a class
- Hide implementation details → encapsulation
- Limit effects of changes
  - Changes affect only their class

Top Reasons to Create Class (2)

- Hide global data
  - Work through methods
- Group variables that are used together
- Make central points of control
  - Single task should be done at single place
  - Avoid duplicating code
- Facilitate code reuse
  - Use class hierarchies and virtual methods
- Package related operations together

Namespaces

- Group related classes together in namespaces
- Follow consistent naming convention



```
namespace Utils
{
  class MathUtils { … }
  class StringUtils { … }
}

namespace DataAccessLayer
{
  class GenericDAO<Key, Entity> { … }
  class EmployeeDAO<int, Employee> { … }
  class AddressDAO<int, Address> { … }
}
```

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Typical Mistakes to Avoid

Lessons Learned from the OOP Exam at Telerik Software Academy

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Plural Used for a Class Name

- Never use plural in class names unless they hold some kind of collection!
- Bad example:

Singular: Teacher (a single teacher, not several).

```
public class Teachers : ITeacher
{
  public string Name { get; set; }
  public List<ICourse> Courses { get; set; }
}
```

- Good example:

```
public class GameFieldConstants
{
  public const int MIN_X = 100;
  public const int MAX_X = 700;
}
```

Throwing an Exception without Parameters

- Don't throw exception without parameters:

```
public ICourse CreateCourse(string name, string town)
{
  if (name == null)
  {
    throw new ArgumentNullException();
  }
  if (town == null)
  {
    throw new ArgumentNullException();
  }
  return new Course(name, town);
}
```

Which parameter is `null` here?

Parameters Checked in the Getter

- Check for invalid data in the setters and constructors, not in the getter!

```
public string Town
{
    get
    {
        if (string.IsNullOrWhiteSpace(this.town))
            throw new ArgumentNullException();
        return this.town;
    }
    set
    {
        this.town = value;
    }
}
```

Put this check in the setter!

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Missing this for Local Members

- Always use this.XXX instead of XXX to access members within the class:

```
public class Course
{
  public string Name { get; set; }

  public Course(string name)
  {
    Name = name;
  }
}
```

Use this.Name

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Empty String for Missing Values

- Use `null` when a value is missing, not `0` or `""`
  - Make a field / property nullable to access `null` values or just disallow missing values
- Bad example:

```
Teacher teacher = new Teacher("");
```

Empty name is very bad idea! Use `null`.

- Correct alternatives:

```
Teacher teacher = new Teacher();
```

```
Teacher teacher = new Teacher(null);
```

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Magic Numbers in the Classes

- Don't use "magic" numbers
  - Especially when the class has members related to those numbers:

```
public class Wolf : Animal
{
  …
  bool TryEatAnimal(Animal animal)
  {
     if (animal.Size <= 4)
     {
       return true;
     }
  }
}
```

This if statement is very wrong. 4 is the size of the `Wolf`, which has a `Size` property inherited from `Animal`. Why not use `this.Size` instead of 4?

Base Constructor Not Called

- Call the base constructor to reuse the object's state initialization code:

```
public class Course
{
  public string Name { get; set; }
  public Course(string name)
  { this.Name = name; }
}

public class LocalCourse
{
  public string Lab { get; set; }
  public Course(string name, string lab)
  {
    this.Name = name;
    this.Lab = lab;
  }
}
```

: base (name)

Call the base constructor instead!

Repeating Code in the Base and Child Classes

- Never copy-paste the code of the base in the inherited class

```
public class Course
{
  public string Name { get; set; }
  public ITeacher Teacher { get; set; }
}

public class LocalCourse
{
  public string Name { get; set; }
  public ITeacher Teacher { get; set; }
  public string Lab { get; set; }
}
```

Why are these fields duplicated and not inherited?

Broken Encapsulation through a Parameterless Constructor

- Be careful to keep fields well encapsulated

```
public class Course
{
  public string Name { get; private set; }
  public ITeacher Teacher { get; private set; }

  public Course(string name, ITeacher teacher)
  {
    if (name == null)
      throw ArgumentNullException("name");
    if (teacher == null)
      throw ArgumentNullException("teacher");
    this.Name = name;
    this.Teacher = teacher;
  }

  public Course() { }
}
```

Breaks encapsulation: Name & Teacher can be left null.

Coupling the Base Class with Its Child Classes

- Base class should never know about its children!

```
public class Course
{
  public override string ToString()
  {
    StringBuilder result = new StringBuilder();
    …
    if (this is ILocalCourse)
    {
      result.Append("Lab = " + ((ILocalCourse)this).Lab);
    }
    if (this is IOffsiteCourse)
    {
      result.Append("Town = " + ((IOffsiteCourse)this).Town);
    }
    return result.ToString();
  }
}
```

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Hidden Interpretation of Base Class as Its Specific Child Class

- Don't define `IEnumerable<T>` fields and use them as `List<T>` (broken abstraction)

```
public class Container<T>
{
  public IEnumerable<T> Items { get; }

  public Container()
  {
    this.Items = new List<T>();
  }

  public void AddItem (T item)
  {
    (this.Items as List<T>).Add(item);
  }
}
```

Bad practice: hidden `List<T>`

Hidden Interpretation of Base Class as Its Specific Child Class (2)

- Use `List<T>` in the field and return it where `IEnumerable<T>` is required:

```
public class Container<T>
{
  private List<T> items = new List<T>();

  public IEnumerable<T> Items
  {
     get { return this.items; }
  }

  public void AddItem (T item)
  {
    this.Items.Add(item);
  }
}
```

This partially breaks encapsulation. Think about cloning to keep your items safe.

Repeating Code Not Moved Upper in the Class Hierarchy

```
public abstract class Course : ICourse
{
  public string Name { get; set; }
  public ITeacher Teacher { get; set; }
}

public class LocalCourse : Course, ILocalCourse
{
  public string Lab { get; set; }
  public override string ToString()
  {
    StringBuilder sb = new StringBuilder();
    sb.Append(this.GetType().Name);
    sb.AppendFormat("(Name={0}", this.Name);
    if (!(this.Teacher == null))
      sb.AppendFormat("; Teacher={0}", this.Teacher.Name);
    sb.AppendFormat("; Lab={0})", this.Lab);
    return sb.ToString();
  }
}
```

Repeating code

// continues at the next slide

Repeating Code Not Moved Upper in the Class Hierarchy (2)

```
public class OffsiteCourse : Course, ILocalCourse
{
  public string Town { get; set; }

  public override string ToString()
  {
    StringBuilder sb = new StringBuilder();
    sb.Append(this.GetType().Name);
    sb.AppendFormat("(Name={0}", this.Name);
    if (!(this.Teacher == null))
      sb.AppendFormat("; Teacher={0}", this.Teacher.Name);
    sb.AppendFormat("; Town={0})", this.Town);
    return sb.ToString();
  }
}
```

Repeating code

- When overriding methods, call the base method if you need its functionality, don't copy-paste it!

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Move the Repeating Code in Upper in the Class Hierarchy

```
public abstract class Course : ICourse
{
  public string Name { get; set; }
  public ITeacher Teacher { get; set; }

  public override string ToString()
  {
    StringBuilder sb = new StringBuilder();
    sb.Append(this.GetType().Name);
    sb.AppendFormat("(Name={0}", this.Name);
    if (!(this.Teacher == null))
      sb.AppendFormat("; Teacher={0}", this.Teacher.Name);
    return sb.ToString();
  }
}
```

// continues at the next slide

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Move the Repeating Code in Upper in the Class Hierarchy (2)

```
public class LocalCourse : Course, ILocalCourse
{
  public string Lab { get; set; }

  public override string ToString()
  {
    return base.ToString() + "; Lab=" + this.Lab + ")";
  }
}

public class OffsiteCourse : Course, ILocalCourse
{
  public string Town { get; set; }

  public override string ToString()
  {
    return base.ToString() + "; Town=" + this.Town + ")";
  }
}
```

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Homework

- Use the provided source code "High-Quality-Classes-Homework.zip".
  1. Take the VS solution "`Abstraction`" and refactor its code to provide good abstraction. Move the properties and methods from the class `Figure` to their correct place. Move the common methods to the base class's interface. Remove all duplicated code (properties / methods / other code).
  2. Establish good encapsulation in the classes from the VS solution "`Abstraction`". Ensure that incorrect values cannot be assigned in the internal state of the classes.

Homework (2)

3. Take the VS solution "`Cohesion-and-Coupling`" and refactor its code to follow the principles of good abstraction, loose coupling and strong cohesion. Split the class `Utils` to other classes that have strong cohesion and are loosely coupled internally.
4. Redesign the classes and refactor the code from the solution "`Inheritance-and-Polymorphism`" to follow the best practices in high-quality classes. Extract abstract base class and move all common properties in it. Encapsulate the fields and make sure required fields are not left without a value. Reuse the repeating code though base methods.

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