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präsentiert

Effective C#

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Agenda

- Some Points about Idioms and Patterns in C#/.NET
- C# Idioms
- Design Patterns
- Summary
- Books

Patterns and Platforms

- Most patterns are independent of specific platforms, languages, paradigms, ...
- Reason: Patterns are only blueprints.
- However, the platform used has an impact on pattern implementations.
- Object-Orientation as example:
  - On one hand, patterns are not restricted to OO environments.
  - On the other hand, OO features are really helpful for implementing patterns:
    - encapsulation, polymorphism, inheritance, interfaces

.NET/C# Features

- Runtime System: Garbage Collection is really useful. Mind its non-determinism!
- Language Interoperability: E.g. Strategy: you may provide different strategies in different languages.
- Uniform Type System: Helps to build containers and ease implementations.
- Multithreading Support: Important for patterns such as Leaders/Followers.

.NET/C# Features (cont‘d)

- Reflection is important for dynamic reconfiguration. Example: Component Configurator, (Dynamic) Proxy.
- Delegates and Events: Many patterns use Observer as sub-pattern.
- v2 Generics: E.g., parametrization with strategies.
- v2 Partial Types: Separate concerns on the class level.

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Pattern Variations

- Depending on architectural granularity and context we can differentiate the following styles:
  - **Idioms**
  - Design Patterns
  - Architectural Patterns
  - Best Practice Patterns
- There are even more styles but we won't cover other flavors in this talk.

Idioms

- Idioms represent patterns applicable to a specific paradigm, language, or system architecture.
- Thus, idioms are less focused on application domains.
- Often, idioms are only useful in one concrete context.
- Examples: Explicit Termination Method, Object Resurrection in .NET.

Explicit Termination Method

- Problem: Assure that resources are freed.
- Forces:
  - .NET Garbage Collection is non-deterministic with respect to finalization.
  - Resources denote limited entities that should be only acquired for a minimum time.
- Solution idea: Make resource release explicit.

ETM Idiom

```
class ResourceHolder: System.IDisposable {
             ResourceHandle h; // a limited resource
             // ... further parts
             public void Dispose() {
                    Dispose(true);
                    GC.SuppressFinalize(this);
             }
             protected void Dispose(bool isDisposing) {
                    // free resource
                    // depending on isDisposing
             }
             ~ResourceHolder () {
                    Dispose(false);
             }
}
```

Client Code

```
try {
      r = new ResourceHolder();
      // use the resource here …
}
finally {
      r.Dispose();
}
```

```
// Optimization:

using (r = new ResourceHolder()) {
      // using resource
}
```


Object Resurrection Idiom

- Problem: Resurrection of large objects.
- Forces:
  - Large structures are expensive to create and to keep in memory.
  - Reallocation and deletion of these structures is non-deterministic.
- Solution: Use weak references to free objects and recreate them when necessary.

Object Resurrection Idiom

```
// Resource Allocation:
LargeObject large = new LargeObject(/* params */);
...
// Introduce weak reference:
WeakReference weak = new WeakReference(large);
...
// When object is not used anymore deallocate it:
large = null;

// Later on object is re-used. Try if it still exists:
large = wr.Target;
if (null == large) large = new LargeObject(/* params */);
// ... otherwise object is resurrected
```


Static Factory Methods

```
class Wrapper {
        private int val;
        public int Value { get { return val; } }
        private Wrapper(int i) { val = i; }
        public static Wrapper valueOf(int arg) {
            return new Wrapper(arg);
        }
    }
```

- Static factory methods have several advantages:
  - They have names
  - For optimization reasons they are not required to create objects each time (but can use caching and other means)
  - They can also return sub-types
- Disadvantage: Classes with inaccessible constructors can not be subclassed

Immutable Classes

- Immutable classes are classes
  - where instances cannot be modified
  - are easier to design, implement, and use
  - Example:

```
 class Point { // example class
       private readonly double a;
       private readonly double b;
       public Point(double op1, double op2)
       {   a = op1; b = op2; }
       public Point add(Point rhs) {
             return new Point(a + rhs.a, b + rhs.b);
       }
       public double A { get { return a;  } }
       public double B { get { return b;  } }
}
```

Immutable Classes – Rules (1)

- Don‘t provide setters or mutator methods
- Make the class sealed to prevent malicious subclassing
- Make all fields readonly and private; use constructors or static factory methods
- Make defensive copies of mutable arguments passed by clients:

```
    class Argument { public int val; }
    sealed class Wrapper {
        private readonly Argument arg;
        public Wrapper(Argument a) {
            arg = a; // wrong: this should have been copied
        }
        public Argument A { get { return arg; } }
    }
    Argument a = new Argument(); a.val = 4711;
    Wrapper w = new Wrapper(a);
    a.val = 42; // external client changes w
    Console.WriteLine(w.A.val); // 42 => immutability
violated!
```

Immutable Classes – Rules (2)

- Don‘t let clients obtain references to internal mutable fields. Make defensive copies:

```
class Argument { public int val; }
sealed class Wrapper {
    private readonly Argument arg;
    public Wrapper(Argument a) {
        arg = new Argument(); arg.val = a.val;
    }
    public Argument A {
       get {
             Argument tmp = new Argument();
             tmp.val = arg.val;
             return tmp;
       }
    }
}
```


Immutable Types – Companion Idiom

- Strings are immutable objects; every operation yields a new string instance.
  - Using the string class is expensive:

```
System.String s; // 4 instances are created
s = "Hello"; s += " "; s += "Universe"; s += "!";
```

  - Prefer StringBuilder instead:

```
StringBuilder sb = new StringBuilder(15);
sb.Append("Hello"); sb.Append(" "); sb.Append("Universe");
sb.Append("!");
String s = sb.ToString();
```

- Consider similar strategy for your own custom immutable types

Value Types versus Reference Types

- Use value types for transfer objects (lightweight data aggregates) that focus on data but not on behavior
- Value types are not polymorphic and don‘t have sub-types
- It is non-trivial to migrate between both types:

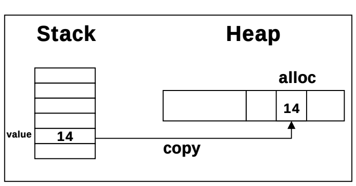
```
/* class */ struct UserType
{
    private int s;
    public UserType(int secret) { s = secret; }
    public int Secret {
        set { s = value; }
        get { return s; } }
}
static void changer(UserType u) { u.Secret += 1; }
static void Main(string[] args){
    UserType u = new UserType(42);
    changer(u);
    Console.WriteLine(u.Secret); // result depends on u
}
```

Minimize Boxing/Unboxing

- Boxing between value types and reference parts involves copy operations

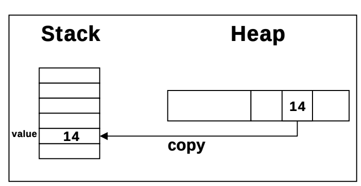
Boxing

```
System.Int32 value = 14;
System.Object o = value;
```



Unboxing

```
System.Int32 value =
(System.Int32) o;
```



Different Means to Prevent Boxing / Unboxing

- Use conversions:

```
int i = 42;
Console.Writeline(i); // i will be boxed
Console.Writeline(i.ToString()); // no boxing
```

- Use generic collections:

```
ArrayList al = new ArrayList(10);
al.Add(1); // implicit boxing;
al.Add(2); // implicit boxing
foreach (int el in al) { // implicit unboxing
       Console.WriteLine(el);
}
List<int> l = new List<int>();
l.Add(1); // no boxing
l.Add(2); // no boxing
foreach (int el in l) { // no unboxing
       Console.WriteLine(el);
}
```

Some Objects Are Equal

- It is important to understand the equality contract
- Never override:
  - `static bool Equals(object lhs, object lhs)`
    - **returns true when objects have same identity**
    - **Otherwise, returns false if one of them is null**
    - **Otherwise, delegates to equals-method of left argument**
  - `static bool ReferenceEquals (object a, object b)`
    - **true iff objects have same identity**
    - **returns false when a and b are the same value object (boxing!)**
- Overriding the two other methods is recommended:
  - `virtual bool Equals(object o)`
  - `public static bool operator==(MyType lhs, MyType rhs)`

Equals

- `virtual bool Equals()` should be symmetric, reflective, transitive

```
class MyClass {
        double d;
        public MyClass(double init) { d = init; }
        override public bool Equals(object rhs) {
            // check for identity:
            if (ReferenceEquals(this, rhs)) return true;
            // check null - this can't be null:
            if (rhs == null) return false;
            // check for same types:
            if (this.GetType() != rhs.GetType()) return false;
            // compare for base class quality if not derived
            // from Object or ValueType directly
             // if (!base.Equals(rhs)) return false;
            MyClass right = rhs as MyClass;
            // do same for fields:
            if (this.d.Equals(right.d)) return true;
            return false;
        } }
```

Operator==

- `Operator==` should be overridden for value types
- Otherwise, operator implementation is generated that relies on reflection

```
struct MyStruct
   {
       // further details omitted
       public int i; // don't do this normally
       static public bool operator==(MyStruct lhs, MyStruct rhs){
           return lhs.i == rhs.i;
       }
       static public bool operator !=(MyStruct lhs, MyStruct rhs)
       {
           return lhs.i != rhs.i;
       }
   }
```

GetHashCode

- Implement `GetHashCode` whenever overriding Equals
- Otherwise, Hashtables/Dictionaries won't work as expected:

```
MyClass x = new MyClass(1.0);
MyClass y = new MyClass(1.0);
Console.WriteLine(x.Equals(y)); // => true
Hashtable h = new Hashtable();
h.Add(x,42);
Console.WriteLine(h.Contains(y)); // => false
```

- In the sample class include:

```
public override int GetHashCode() {
     return (int)d;
}
```


Rules for Hash Code Generation

- Must be instance invariant
- If `a.equals(b)` is true, then both objects should return the same hash code
- The generated hash codes should be evenly distributed

Always Override ToString()

- Overriding ToString()
  - Makes your class more pleasant to use
  - Helps to return all interesting information
  - Should by accompanied by documentation of ToString()
  - Example:

```
class Person {
     int age;
     string name;
     public Person(string n, int a) { age = a; name = n; }
     public override string ToString() {
         return "Person " + name + " " + age;
     }
}
```

  - Return useful text instead of just ApplicationName.ClassName

Comparisons

- Two interfaces
  - IComparable used to define natural ordering of a type
  - IComparer implements additional ordering: not shown in this talk
- IComparable contains only one method:
  - public int CompareTo(object rhs)
  - o1.CompareTo(o2) yields
    - 0, if both objects are equal with respect to ordering
    - \- 1, if o1 < o2
    - +1, if o1 > o2

Example: IComparable

```
class OrderedPair<S, T> : IComparable
                    where S : IComparable<S>
                    where T : IComparable<T> {
       private S s; private T t;
       public OrderedPair(S sArg, T tArg) {
           s = sArg; t = tArg;
       }
       public int CompareTo(object o) {
           if (!(o is OrderedPair<S,T>))
               throw new ArgumentException("bad type");
           OrderedPair<S, T> tmp = o as OrderedPair<S, T>;
           if (this.s.CompareTo(tmp.s) == 0)
               return (this.t.CompareTo(tmp.t));
           else
               return (this.s.CompareTo(tmp.s));

       }
   }
```

Exception Handling 101

- Instead of introducing your own exception types first try using existing exception types
  - Makes your API simpler to learn and to read
- Use most derived exception that matches your need
- Return exceptions according to abstraction level:

```
static object get() {
    try {
        // access file system
    }
    catch (LowerLevelException lle) {
        throw new HigherLevelException(lle);
    }
}
```

Defensive Event Publishing

- Problem: If a subscriber throws an exception during event handling the publisher does not care
- However:
  - Event publishing is interrupted
  - Manually iterating over subscriber list is tedious

```
public delegate void SomeDelegate(int num, string str);

public class MySource
{
    public event SomeDelegate SomeEvent;
    public void FireEvent(int num, string str)
    {
        if (SomeEvent != null)
            SomeEvent(num, str);// interrupted on exception
     }
}
```


Defensive Event Publishing - EventsHelper

- Solution: Introduce Events Helper

```
public class EventsHelper
{
   public static void Fire(Delegate del,params object[] args)
   {
      if(del == null)
      {
         return;
      }
      Delegate[] delegates = del.GetInvocationList();
      foreach(Delegate sink in delegates)
      {
         try
         {
            sink.DynamicInvoke(args);
         }
         catch{}
      }
   }
}
```

Defensive Event Publishing – Code

- Here is the re-factored solution:

```
public delegate void SomeDelegate(int num,string str);

public class MySource
{
   public event SomeDelegate SomeEvent;
   public void FireEvent(int num, string str)
   {
      EventsHelper.Fire(SomeEvent,num,str);
   }
}
```


Reflection: Prefer Custom Attributes

- Custom Attributes help where otherwise configuration files or marker interfaces are used

```
interface IPrintable { void print(); }
class MyDocument : IPrintable {
    public void print() { }
}
[AttributeUsage(AttributeTargets.Class)]
class PrintableAttribute : Attribute { /* ... */ };
[AttributeUsage(AttributeTargets.Method)]
class Print : Attribute { /* ... */ };
[Printable]
class MyDocumentAttr {
    [Print]
    void prettyPrint() { }
}
```

Performance Matters: String Interning

- Consider the following code:

```
String x = "42";
String y = "42";
Console.WriteLine(Object.Equals(x,y)); // returns true
Console.WriteLine(Object.ReferenceEquals(x,y)); // returns true
```

- Guess, why this happens.
- Answer: CLR internally uses a hash map which is filled by JIT compiler: Reuse of string literals! Note: interned strings will not be freed by GC.
- You can leverage it yourself:

```
String x = "Micha "; x += "Stal";
String y = String.Intern(x);
```

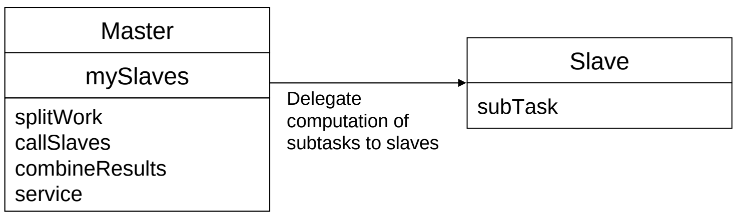

Performance Matters: foreach loops

- Foreach loops are optimized in that they don't check array bounds multiple times

```
static void Main(string[] args)
        {
            int [] list = new int[] { 1,2,3,4,5,6,7,8,9,10};
            // slow:
            for (int index = 0; index < list.Length; index++)
                Console.WriteLine(list[index]);
            // fast:
            foreach (int el in list)
                Console.WriteLine(el);
        }
```

Design Pattern Example: Master Slave

- Problem: Supporting fault-tolerance and parallel computation.
- Idea: *Divide et Impera* - partition tasks into subtasks and let components compute subtasks in parallel.



Slaves

- Slaves calculate sub arrays. They are supposed to be executed within threads:

```
class Slave {
        private double m_result;
        private double[] m_dList;
        private int m_start;
        private int m_end;
        public Slave(double[] dList, int start, int end) {
                m_start = start; m_end = end; m_dList = dList;
        }
        public double Result { get { return m_result; }}
        public void DoIt() {
                m_result = 0.0;
                for (int i = m_start; i <= m_end; i++)
                        m_result += m_dList[i];
        }
}
```

Master

- The master uses slaves to calculate sub-arrays:

```
class Master  {
        public double CalculateSum(double[] dList, int start, int end) {
                if (start > end ) throw new ArgumentException();
                if (start == end) return dList[start];
                int mid = (end - start) / 2;
                Slave s1 = new Slave(dList, start, mid);
                Slave s2 = new Slave(dList, mid+1, end);
                Thread t1 = new Thread(new ThreadStart(s1.DoIt));
                Thread t2 = new Thread(new ThreadStart(s2.DoIt));
                t1.Start(); // start first slave
                t2.Start(); // start second slave
                t1.Join();  // wait for first slave
                t2.Join();  // wait for second slave
                return s1.Result + s2.Result; // combine results
}
```


Putting it together

- The manager class illustrates the configuration of the participants at runtime:

```
class Manager {
        static void Main(string[] args) {
                double[] d = {1,2,3,4,5,6,7,8,9,10};
                Console.WriteLine(new Master().CalculateSum(d, 0, 9));
        }
}
```

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Singleton

- Intent
  ensure a class only ever has one instance, and provide a global point of access to it
- Applicability
  - when there must be exactly one instance of a class
  - when sole instance should be extensible by subclassing
- Structure

Singleton
method() method()
static instance() static instance

- Consequences
  - reduced name space pollution
- Implementation
  - C#: declare constructor as protected to guard against multiple singleton instances

Singleton – General Approach

- First variant of Singleton using static initialization:

```
class MyClass1 /* statically initialized */ {
       private static MyClass1 m_Instance = new MyClass1();
       private MyClass1 () {}

       public static MyClass1 Instance
       {
              get { return m_Instance; }
       }
}
```

Static Singleton in .NET

- Now, the solution is refined:

```
sealed class MyClass1b /* statically initialized */ {
      public static readonly MyClass1b m_Instance
                                        = new MyClass1b();
      private MyClass1b () {}
}
```


Singleton with dynamic Initialization

- Object is created on demand:

```
class MyClass2 /* dynamically initialized on demand */ {
      private static MyClass2 m_Instance;
      private MyClass2() {}
      public static MyClass2 Instance
      {
            get {
                  if (null == m_Instance) {
                        m_Instance = new MyClass2();
                  }
                  return m_Instance;
            }
      }
}
```

Singleton - Threadsafe

- Multithreading – naive solution:

```
class MyClass3a /* dynamically initialized on demand */ {
    private static MyClass3a m_Instance;
    private MyClass3a() {}
    public static MyClass3a Instance
    {
        get { lock(typeof(MyClass3a)) {
                if (null == m_Instance) {
                m_Instance = new MyClass3a();
              }
              return m_Instance;
            }
        }
    }
}
```


Singleton – Threadsafe

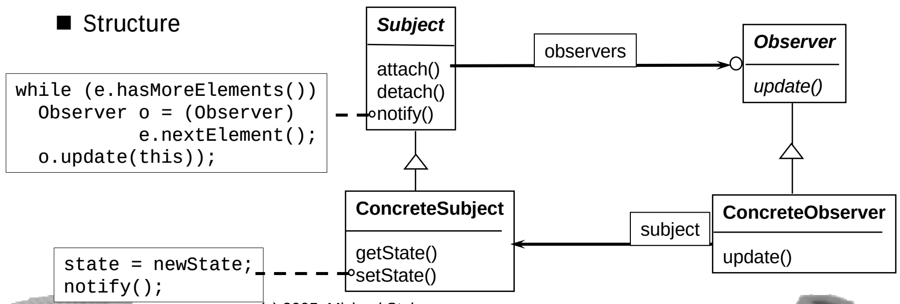
- Efficient solution:

```
class MyClass3b /* double checked locking */ {
       private static MyClass3b m_Instance;
       private MyClass3b() {}
       public static MyClass3 Instance  {
              get {
                     if (null == m_Instance) {
                            lock(typeof(MyClass3b))
                            {
                             if (null == m_Instance)
                             m_Instance = new MyClass3b();
                            }
                     }
                     return m_Instance;
              }
       }
}
```

Observer

- Intent

  Define a dependency between objects so that when one object changes state then all its dependents are notified
- Applicability
  - When a change to one object requires changing others
  - Decouple notifier from other objects
- Structure



Observer (cont'd)

- Consequences
  - abstract coupling of subject and observer
  - object is responsible only for its own state Þ reusability
  - unexpected updates, update overhead
- Implementation
  - push/pull model for notifications
  - change interests
- Known Uses
  - Smalltalk MVC
  - MFC
  - MacApp, ET++

Observer in C#

- Subject that emits events:

```
public class Subject {
	public delegate void Notify();
	public event Notify OnNotify;
	public void DoSomething() {
		// now create an event
		if (null != OnNotify)
		{
			Console.WriteLine("Subject fires event");
			OnNotify();
		}
	}
}
```


Observer in C# (cont'd)

- Observer that registers with Subject:

```
class ObserverDemo {
	class Observer {
		public Observer(Subject s) {
			s.OnNotify += new Subject.Notify(TellMe);
		}
		public void TellMe() {}
	}

	static void Main(string[] args) {
		Subject s = new Subject();
		Observer o1 = new Observer(s);
		Observer o2 = new Observer(s); ...
	}
}
```

Summary

- C# idioms and styles useful to achive C# mastership
- Idioms are patterns that leverage intrinsic knowledge of C# and .NET specialties
- This talk could just scratch the surface
- There are lots of more issues to discuss such as multi-threading, resource management issues, distribution
- Unfortunately, wisdom is spread across many books
- Developer community should spend much more efforts on this
- Future evolution of C# (e.g., lambdas) will lead to new idioms and styles

Books

- Bill Wagner, Effective C#, Addison-Wesley, 2005
- Jeff Richter, Applied Microsoft .NET Framework Programming, Microsoft Press, 2002
- Joshua Bloch, Effective Java, Addison-Wesley, 2001

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Wir sehen uns wieder...

ASP konferenz — Juni 2006

Advanced Developers Conference — November 2006

VS one — Februar 2007