ETH Zürich
Chair of Software Engineering

C# Programming in Depth

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Lecture 4: Garbage Collection & Exception Handling

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Overview

- Scope and lifetime
- Garbage collection mechanism
- Exception handling

Scope and lifetime

- Scope of a variable is portion of program text within which it is declared
  - Need not be contiguous
  - In C#, is static: independent of data
- Lifetime or extent of storage is portion of program execution during which it exists
  - Always contiguous
  - Generally dynamic: dependent on data
- Class of lifetime
  - Static: entire duration of program
  - Local or automatic: duration of call or block execution (local variable)
  - Dynamic: From time of allocation statement (new) to deallocation, if any.

Object lifetime in C#

- Memory allocation for an object should be made using the "new" keyword
- Objects are allocated onto the managed heap, where they are automatically deallocated by the runtime at "some time in the future"
- Garbage collection is automated in C#

Rule: Allocate an object onto the managed heap using the **new** keyword and forget about it

Object creation

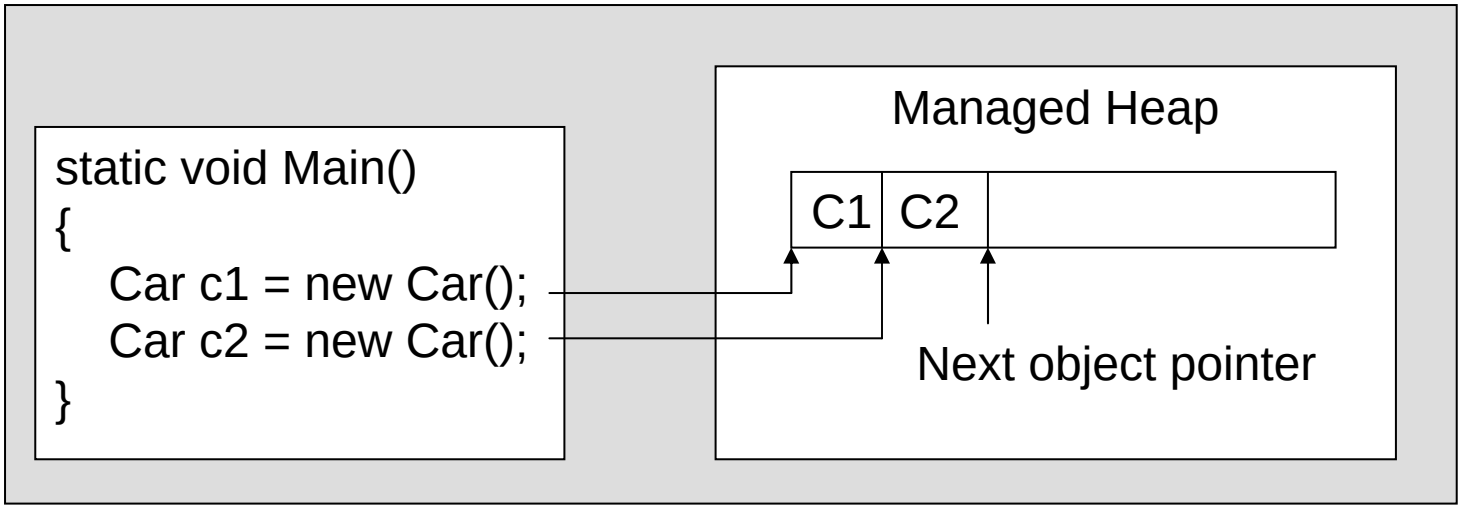
- When a call to new is made, it creates a CIL "newobj" instruction to the code module

```
public static int Main (string[] args)
{
    Car c = new Car("Viper", 200, 100);
}
```

IL_000c: newobj instance void CilNew.Car::.ctor (string, int32, int32)

Tasks taken by CIL newobj instruction

- Calculate the total amount of memory required for the object
- Examine the managed heap to ensure enough room for the object
- Return the reference to the caller, advance the next object pointer to point to the next available slot on the managed heap



Rule: If the managed heap does not have sufficient memory to allocate a requested object, a garbage collection will occur.

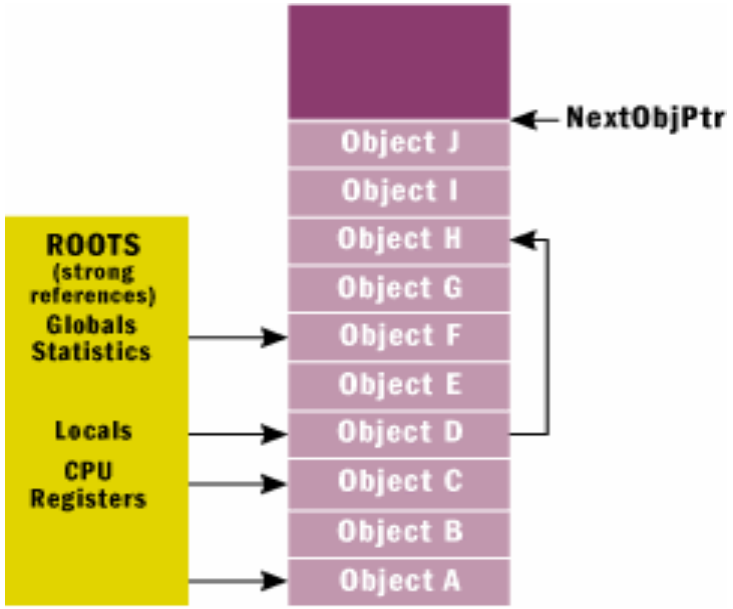
Garbage collection steps

1. The garbage collector searches for managed objects that are referenced in managed code — mark
2. The garbage collector attempts to finalize objects that are unreachable
3. The garbage collector frees objects that are unmarked and reclaims their memory

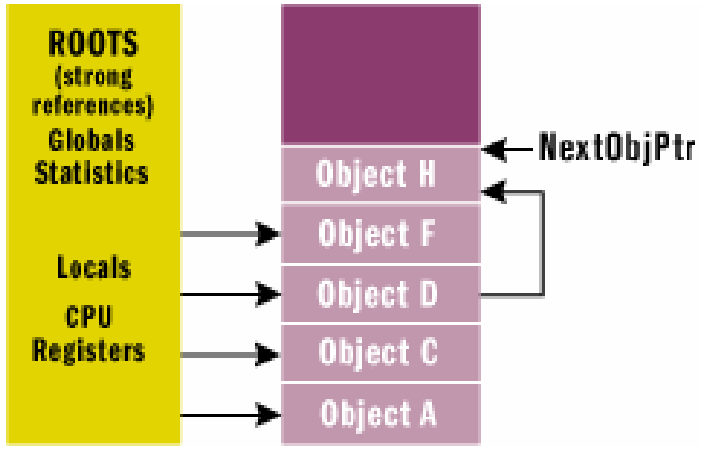
sweep

How to decide an object is unreachable

- Object graph
  represents each reachable object on the heap



Allocated objects on the heap



Managed heap after collection

Optimize the decision process

- Object generations
  - Each object on the heap is assigned to a specific "generation" (0 ~ 2)
    - Generation 1: newly allocated objects
    - Generation 2: objects that survived a garbage collection
    - Generation 3: objects that survived more than one garbage collection
  - The garbage collector first investigate generation 0 objects. If marking and sweeping these objects can result in required amount of free memory, any surviving objects' generation are promoted by 1

The System.GC type

- Provide a set of static method for interacting with garbage collection
- Use this type when you are creating types that make use of unmanaged resource

Building finalizable objects

```
//System.Object
public class Object
{
    ...
    protected virtual void Finalize() { }

}
```

- Override Finalize() to perform any necessary memory cleanup for your type
- A call to Finalize () occurs:
  - natural garbage collection
  - GC.Collect()
  - Application domain is unloaded from the memory

Override System.Object.Finalize()

```
// Override System.Object.Finalize() via destructor syntax
class MyResourceWrapper
{
    ~MjyResourceWrapper()
    {
        // Clean up unmanaged resource here

        ...

    }
}
```

When to override System.Object.Finalize()

Rule: The only reason to override Finalize() is if your C# class is making use of unmanaged resources via PInvoke or complex COM interoperability tasks (typically via the System.Runtime, InteropServices.Marshal type).

It is illegal to override Finalize() on structure types.

Building Disposable Objects

- Another approach to handle an object's cleanup.
- Implement the IDisposable interface
- Object users should manually call Dispose() before allowing the object reference to drop out of scope
- Structures and classes can both support IDisposal (unlike overriding Finalize())

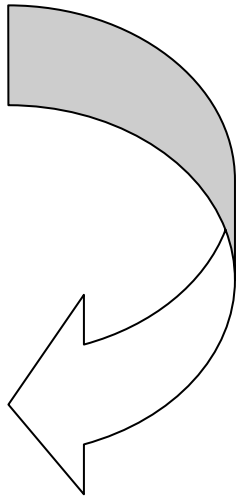
```
// Implementing IDisposable
public class MyResourceWrapper : IDisposable
{
    // The object user should call this method
    // when they finished with the object.
    public void Dispose()
    {
        // Clean up unmanaged resources here.
        // Dispose other contained disposable objects.

    }
}
```

Rule: Always call Disposal() on any object you directly create if the objects supports IDisposable.

Reusing the C# using Keyword

```
MyResourceWrapper rw = new MyResourceWrapper();
try
{
    // Use the member of rw
}
finally
{
        rw.Dispose()
}
```



```
// Dispose() is called automatically when the
// using scope exits.
using (MyResourceWrapper rw2 = new
MyResourceWrapper())
{
        // Use rw2 object.
}
```

Questions

- What's the difference between Finalize and Dispose?
- What's the difference between Dispose and Using?

.Net exception handling

- When your application encounters an exceptional circumstance, such as a division by zero or low memory warning, an exception is generated.
- Once an exception occurs, the flow of control immediately jumps to an associated exception handler, if one is present.
- If no exception handler for a given exception is present, the program stops executing with an error message.
- Actions that may result in an exception are executed with the try keyword.
- An exception handler is a block of code that is executed when an exception occurs. In C#, the catch keyword is used to define an exception handler.
- Exceptions can be explicitly generated by a program using the throw keyword.
- Exception objects contain detailed information about the error, including the state of the call stack and a text description of the error.
- Code in a finally block is executed even if an exception is thrown, thus allowing a program to release resources.

C# exception handling structure

```
try
{
    // Code to try here.
}
catch (System.Exception ex)
{
    // Code to handle exception here.
}
finally
{
    // Code to execute after try (and possibly catch) here.
}
```

System.Exception base class

```
public class Exception: ISerializable, _Exception
{
    public virtual IDictionary Data { get; }
    protected Exception (SerializationInfo info, StreamingContext context);
    public Exception (string message);
    public Exception ()
    public virtual Exception GetBaseException ();
    public virtual void GetObjectData (SerializationInfo info, StreamingContext
context);
    public System.Type GetType ();
    protected int HResult {get; set;}
    public virtual string HelpLink {get; set;}
    public System.Exception InnerException {get;}
    public virtual string Message {get;}
    public virtual string Source {get; set;}
    public virtual string StackTrace {get;}
    public MethodBase TargetSite {get;}
    public override string ToString ();
}
```

```
static void Main (string[] args)
{
    string[] strFiles;
    try
    {
        strFiles = Directory.GetFiles (args[0]);
    }
    catch (Exception e)
    {
        Console.WriteLine ("Method: {0}", e.TargetSite);
        Console.WriteLine ("Message: {0}", e.Message);
        Console.WriteLine ("Source: {0}", e.Source);
        Console.WriteLine (“StackTrace: {0}”, e.StackTrace);
    }
    Console.WriteLine ("Remaining part");
}
```

Unhandled exceptions

Exception categories

- System-level exceptions (System.SystemException)
  - Exceptions thrown by the CLR and are regarded as nonrecoverable, fatal errors (derive from System.SystemException)

- Application-level exceptions (System.ApplicationException)
  - Exceptions thrown by your application (derive from System.ApplicationException)

Building custom Exception

- A strongly typed exception that represents the unique details of the problem regarding the type
- Best practice
  - Derive from Exception / ApplicationException
  - Is marked with the [System.Serializable] attribute
  - Defines a default constructor
  - Defines a constructor that sets the inherited Message property
  - Defines a constructor to handle "inner exceptions"
  - Defines a constructor to handle the serialization of your type

Questions?