Of Lambdas and LINQ

James Michael Hare
2012 Visual C# MVP
Application Architect
Scottrade

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http://www.BlackRabbitCoder.net

Twitter: @BlkRabbitCoder

Contact Information

Me:

- Blog: http://www.BlackRabbitCoder.net
- Twitter: @BlkRabbitCoder

Information on Scottrade Careers:

- http://jobs.scottrade.com
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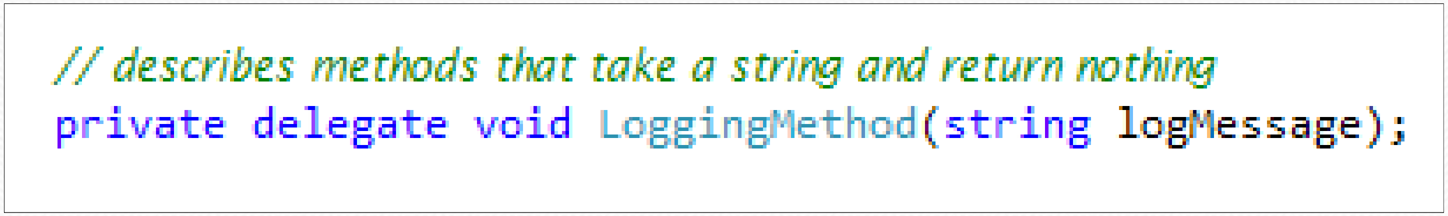
Introduction

- LINQ and lambdas are becoming much more prevalent in our codebases and it's important for all of our developers to have ***at least*** a basic understanding.
- This presentation is designed to be a brief introduction to both lambda expressions and the more common LINQ extension methods.
- In addition, we will give a brief overview of the optional query syntax.

A brief history…

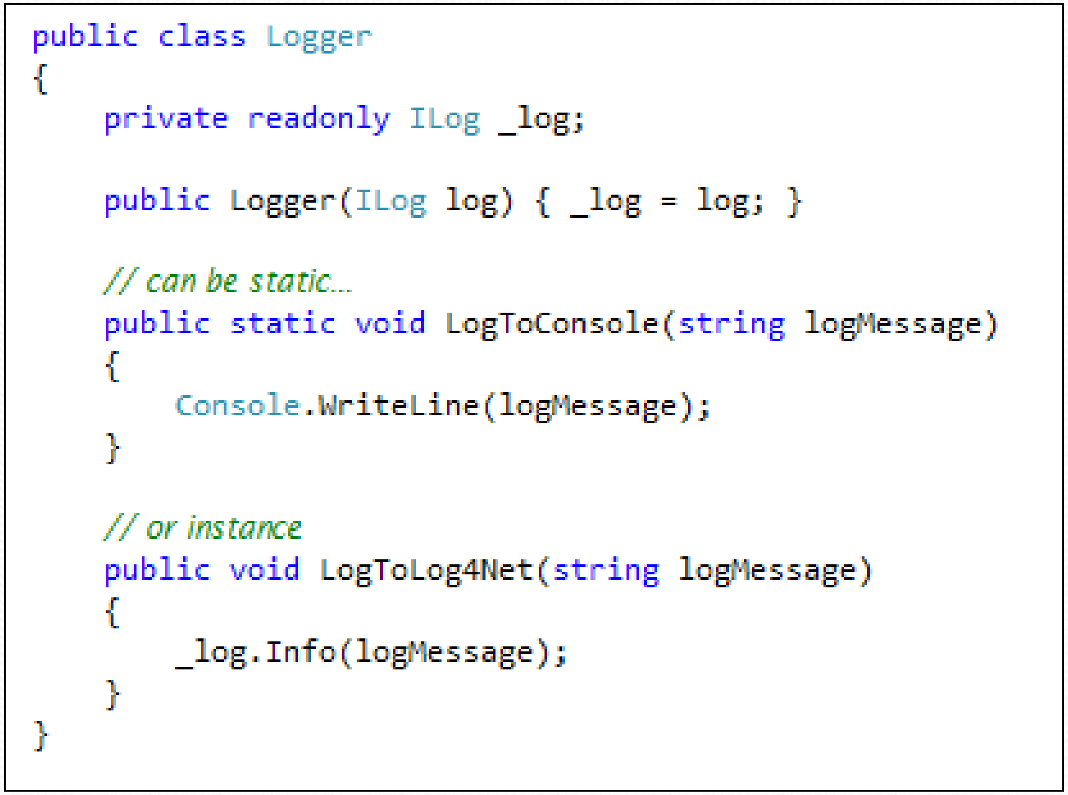
- Before we look at lambdas, let's take a look at how delegates work in C#.
- A delegate is similar to a pointer to a function in C++.
- Delegate describe the signature of a method.
- Define delegates using the keyword **`delegate`**.
- The following delegate describes methods that have no return value and take a string parameter:



```
// describes methods that take a string and return nothing
private delegate void LoggingMethod(string logMessage);
```

Defining matching methods

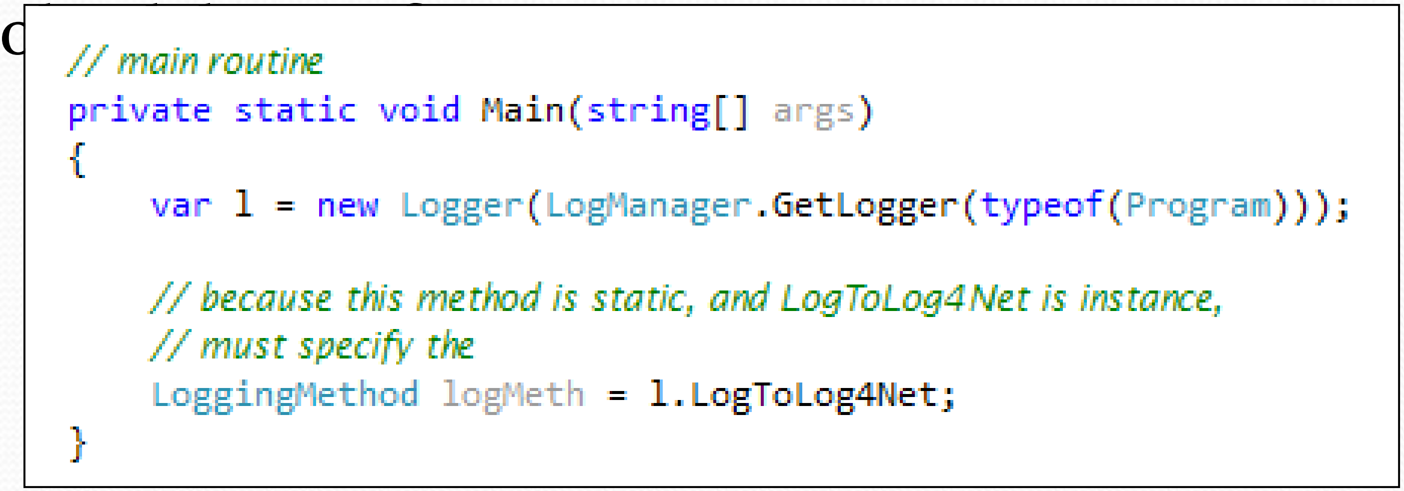
- Method can be static or instance.
- These methods match our **`LoggingMethod`** delegate



```
public class Logger
{
    private readonly ILog _log;

    public Logger(ILog log) { _log = log; }

    // can be static...
    public static void LogToConsole(string logMessage)
    {
        Console.WriteLine(logMessage);
    }

    // or instance
    public void LogToLog4Net(string logMessage)
    {
        _log.Info(logMessage);
    }
}
```

Assigning instance methods

- Delegate instances can be assigned method references.
- If instance method assigned, provide the instance to invo

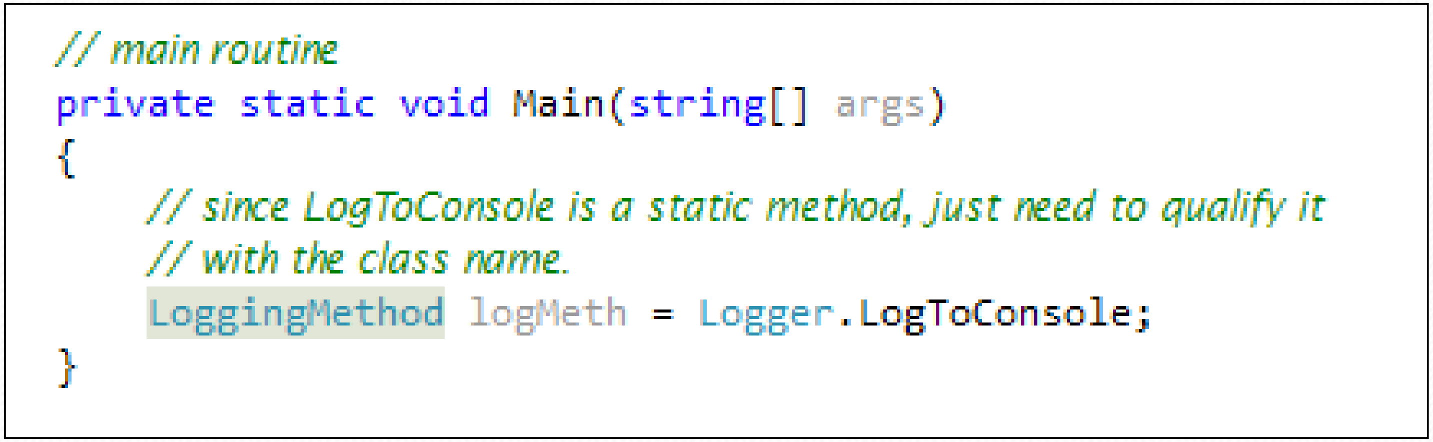


```
// main routine
private static void Main(string[] args)
{
    var l = new Logger(LogManager.GetLogger(typeof(Program)));

    // because this method is static, and LogToLog4Net is instance,
    // must specify the
    LoggingMethod logMeth = l.LogToLog4Net;
}
```

- The instance may be omitted if assigned from an instance member of the same instance.

Assigning static methods

- Since static methods require no instance to be invoked upon, just the class name.

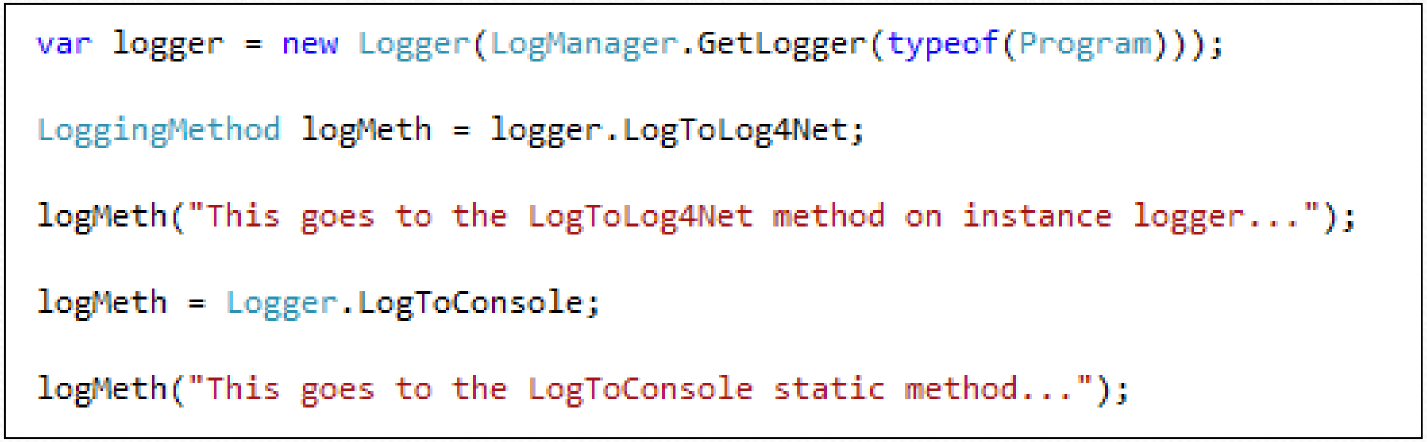


```
// main routine
private static void Main(string[] args)
{
    // since LogToConsole is a static method, just need to qualify it
    // with the class name.
    LoggingMethod logMeth = Logger.LogToConsole;
}
```

- The class name may be omitted if the current class is the class that contains the method to be assigned.

Invoking a delegate

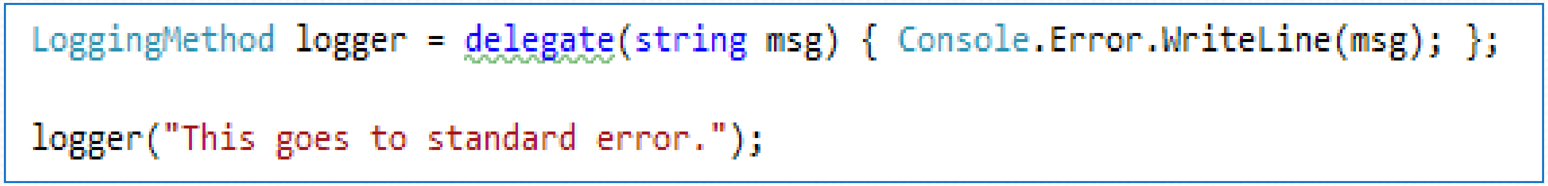
- The beauty of delegates is that they allow methods to be assigned to variables.
- This means you can easily change the behavior of a piece of code without needing to subclass.
- You invoke by calling the delegate like the method:



```
var logger = new Logger(LogManager.GetLogger(typeof(Program)));

LoggingMethod logMeth = logger.LogToLog4Net;

logMeth("This goes to the LogToLog4Net method on instance logger...");

logMeth = Logger.LogToConsole;

logMeth("This goes to the LogToConsole static method...");
```

Anonymous methods

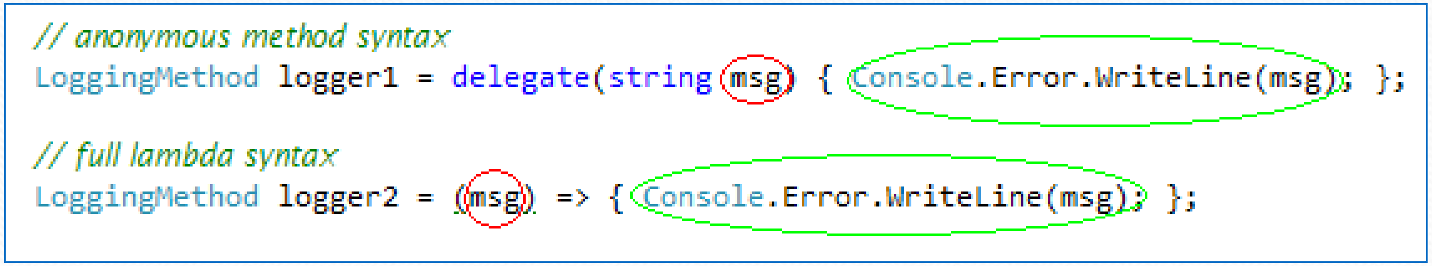
- The only problem with early .NET was that all delegate targets had to be methods.
- This means you’d have to create full methods for even the simplest task.
- The anonymous method syntax introduced in .NET 2.0 allowed writing methods on the fly at the point they would be assigned to a delegate:



```
LoggingMethod logger = delegate(string msg) { Console.Error.WriteLine(msg); };

logger("This goes to standard error.");
```

Lambda expressions

- .NET 3.0 added lambda expression support for writing anonymous methods.
- Lambda expression syntax can be seen as a more concise form of the anonymous method syntax:



```
// anonymous method syntax
LoggingMethod logger1 = delegate(string msg) { Console.Error.WriteLine(msg); };

// full lambda syntax
LoggingMethod logger2 = (msg) => { Console.Error.WriteLine(msg); };
```

- The full lambda expression syntax is:

```
(parameters) => { statement(s) }
```

- The lambda operator “=>” is pronounced “goes to”.

More on lambda parameters

- Specifying type is optional when can be inferred

```
(string s) => { return s.Length; }
(s) => { return s.Length; }
```

- If no parameters, the parenthesis are empty:

```
() => { statement(s) }
```

- If one parameter, the parenthesis are optional:

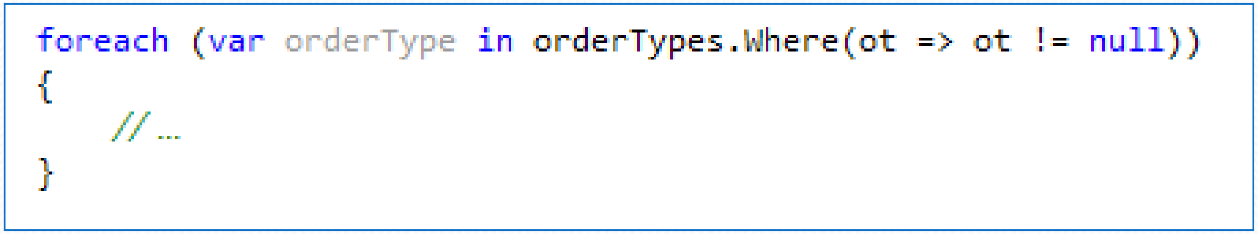
```
(s) => { return s.Length; }
s => { return s.Length; }
```

- If several parameters, use parenthesis and commas:

```
(x,y) => { return x > y; }
```

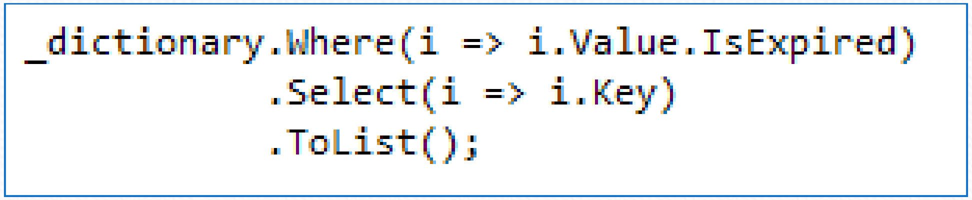
Lambda parameter naming

- The standard convention is a short identifier whose meaning can be inferred from context:



```
foreach (var orderType in orderTypes.Where(ot => ot != null))
{
    //…
}
```

- Names are local to the lambda and can be reused if desired to represent an item flowing down a chain.



```
_dictionary.Where(i => i.Value.IsExpired)
           .Select(i => i.Key)
           .ToList();
```

More on lambda body

- If body more than one statement, must separate with semicolons and enclose in braces:

```
s => {
        Console.WriteLine(s);
        Console.Out.Flush();
     }
```

- If one statement only, can omit semicolon and braces:

```
s => { Console.Error.WriteLine(s); }
s => Console.Error.WriteLine(s)
```

- If only an expression to evaluate, can omit **return**:

```
s => return s.Length
s => s.Length
```

The generic delegates

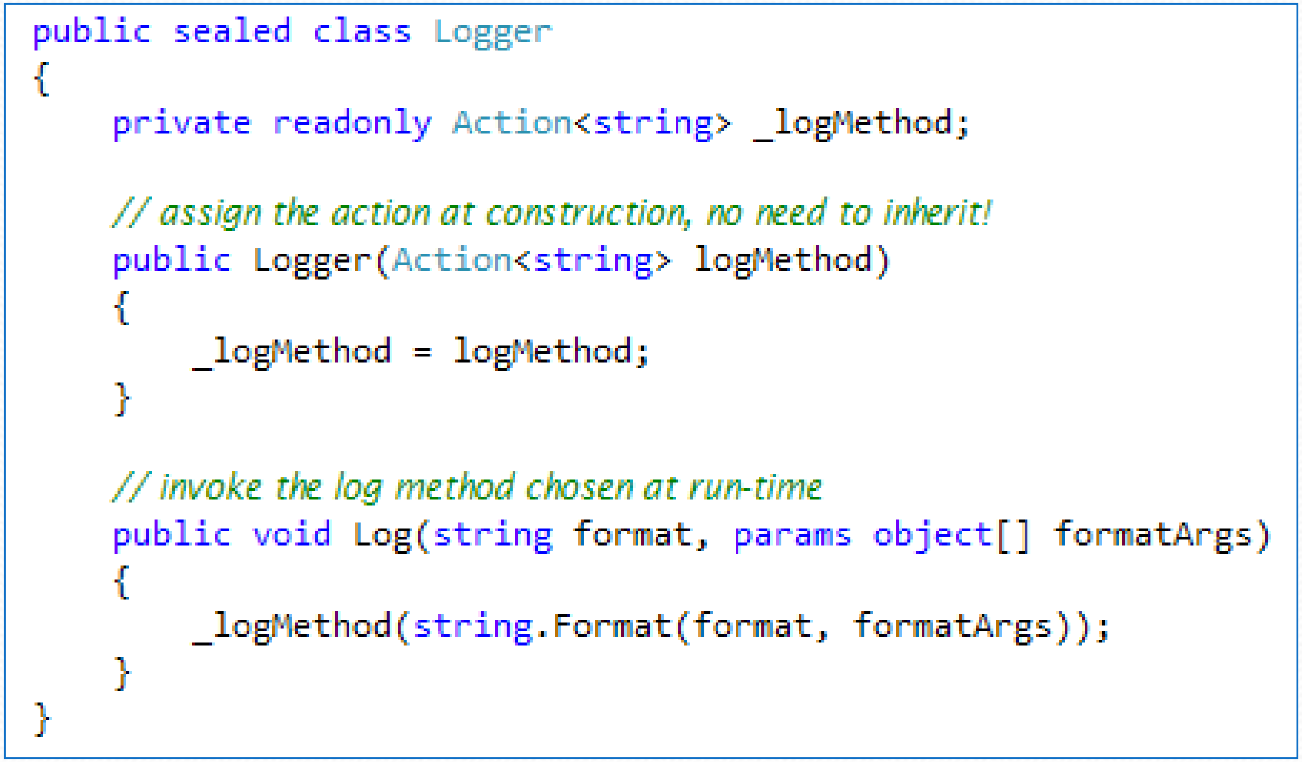
- Delegates can be useful for specifying pluggable behavior at runtime instead of compile time.
- This eliminates much of the need of inheritance in places it was used to specify different behaviors.
- .NET 2.0 added some common generic delegates:
  - **Predicate<T>** - *bool fx(T)* – specifies a condition to be run against an item which returns **true** or **false**.
  - **Action<T>** - *void fx(T)* – specifies an action to be performed on an item, no result.
  - **Action** has other versions as well for varying number of parameters from 0 to 16.

More generic delegates

- .NET 3.5 added a new generic delegate for more general delegate specification:
  - **Func<TResult>** - *TResult fx()* – specifies a delegate that takes no parameters and returns a **TResult**.
  - **Func<T, TResult>** - *TResult fx(T)* – specifies a delegate that takes on parameter and returns a **TResult.**
  - **Func<T1, T2, TResult>** - *TResult fx(T1, T2)* – specifies a delegate that takes 2 parameters and returns **TResult.**
  - **Func<T1…, TResult>** can support up to 16 parameters.
- **Func<T, bool>** is equivalent to **Predicate<T>**.

Pluggable behavior

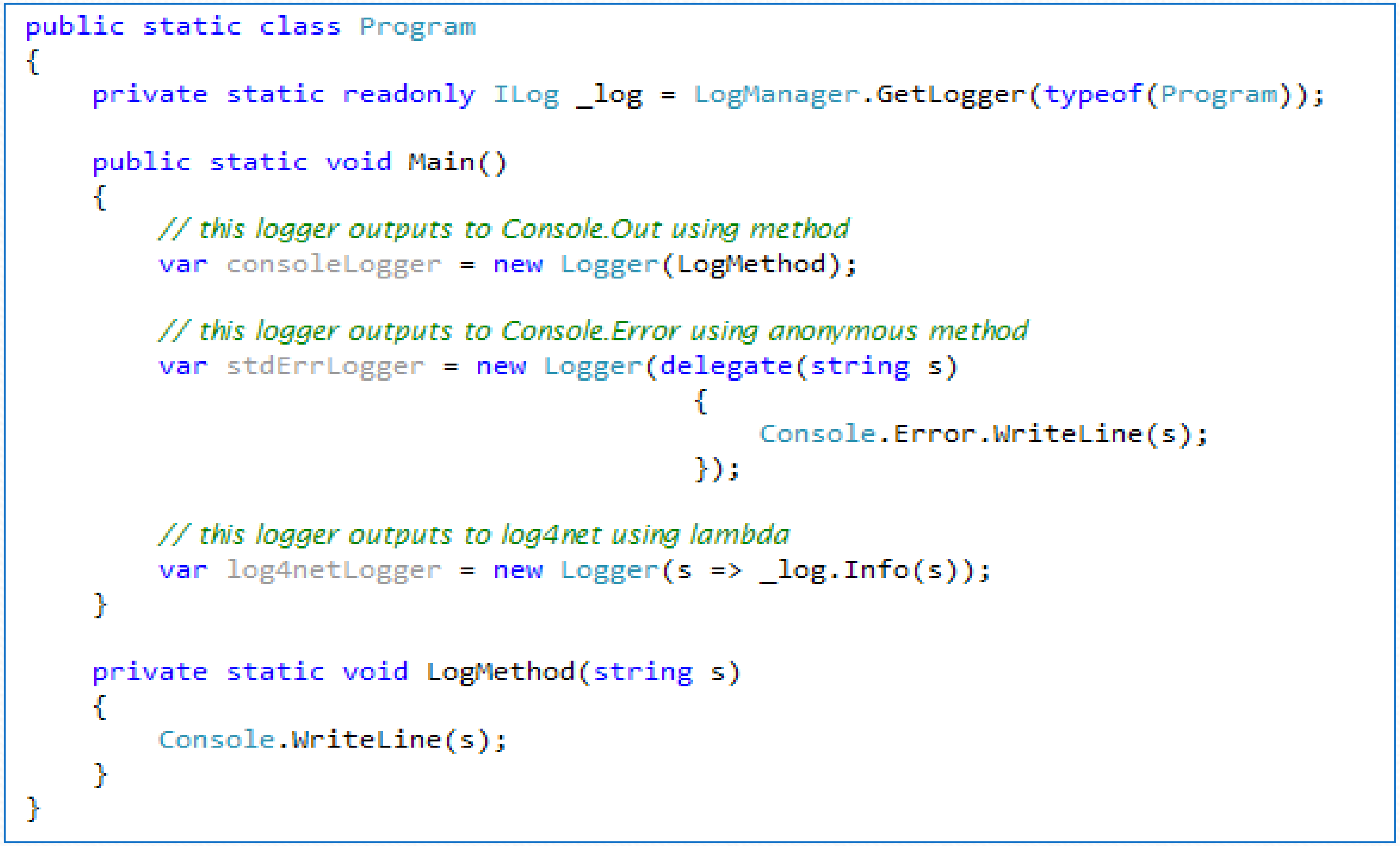
- Delegates allow you to create classes and algorithms with pluggable behavior without inheritance:



```
public sealed class Logger
{
    private readonly Action<string> _logMethod;

    // assign the action at construction, no need to inherit!
    public Logger(Action<string> logMethod)
    {
        _logMethod = logMethod;
    }

    // invoke the log method chosen at run-time
    public void Log(string format, params object[] formatArgs)
    {
        _logMethod(string.Format(format, formatArgs));
    }
}
```

Pluggable behavior

- Behaviors can be changed on the fly:



```
public static class Program
{
    private static readonly ILog _log = LogManager.GetLogger(typeof(Program));

    public static void Main()
    {
        // this logger outputs to Console.Out using method
        var consoleLogger = new Logger(LogMethod);

        // this logger outputs to Console.Error using anonymous method
        var stdErrLogger = new Logger(delegate(string s)
                                        {
                                            Console.Error.WriteLine(s);
                                        });

        // this logger outputs to log4net using lambda
        var log4netLogger = new Logger(s => _log.Info(s));
    }

    private static void LogMethod(string s)
    {
        Console.WriteLine(s);
    }
}
```

LINQ

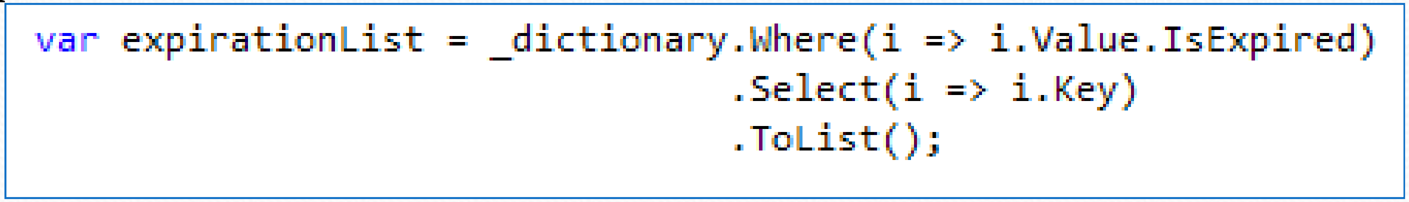
- LINQ = Language INtegrated Query.
- LINQ is a new query language and class libraries.
- LINQ class libraries can be used with or without the query syntax as desired.
- Most LINQ extension methods operate on sequences of data that implement **IEnumerable<T>**.
- Most LINQ extension methods specify behavior with generic delegates (**Action**, **Func**, etc).
- Lambda expressions are a perfect way to supply concise definitions to LINQ.

LINQ: Common behaviors

- Most LINQ extension methods cannot be called on a **null** sequence (throws **ArgumentNullException).**
- You can specify behaviors using any valid means (lambda expressions, anonymous methods, ordinary methods, or method groups).
- You can use the LINQ methods on any sequences that implement **IEnumerable<T>** including **List<T>**, **T[]**, **HashSet<T>**, iterators, etc.
- Many of the LINQ methods use deferred execution (may not compute query until the data is needed).

LINQ: Chaining

- LINQ operations can be chained together.
- Each method call is independent and applies to the previous result in the chain:



```
var expirationList = _dictionary.Where(i => i.Value.IsExpired)
                                .Select(i => i.Key)
                                .ToList();
```

  - ***Where()*** *narrows sequence to only those items whose* ***Value*** *property has an* ***IsExpired*** *property ==* ***true.***
  - ***Select()*** *transforms the expired items from the* ***Where()*** *to return a sequence containing only the* ***Key*** *properties.*
  - ***ToList()*** *takes the sequence of expired* ***Keys*** *from the* ***Select()*** *and returns then in a* ***List<string>.***

LINQ: Selecting and filtering

- **Where()** – Narrows sequence based on condition

```
orders.Where(o => o.Type == OrderType.Buy)
```

  - *Sequence only containing orders with order type of buy.*

- **Select()** – Transforms items in sequence or returns part(s) of items.

```
orders.Select(o => o.Type)
```

  - *Sequence only containing the types of the orders.*

- These two are sometimes confused, remember not to use Select to try to filter or you get a sequence of bool.

```
orders.Select(o => o.Type == OrderType.Buy)
```

LINQ: Consistency checks

- **All()** – **True** if all items satisfy a predicate:

  ```
  requests.All(r => r.IsValid)
  ```

  - *True if **IsValid** returns **true** for all items.*

  ```
  employees.All(e => e.Ssn != null)
  ```

  - *True if **Ssn** is not null for all items.*

- **Any()** – **True** if at least one satisfies predicate:

  ```
  requests.Any(r => !r.IsValid)
  ```

  - *True if any item returns **IsValid** of **false**.*

  ```
  results.Addresses.Any()
  ```

  - *True if Addresses contains at least one item.*

LINQ: Membership and count

- **Contains()** – **True** if sequence contains item.

  ```
  orderTypes.Contains(“Buy”)
  ```

  - *True if contains string “buy” based on default string comparer.*

  ```
  orderTypes.Contains(“buy”, comparer)
  ```

  - *True if contains “buy” based on given string comparer.*

- **Count()** – Number of items (or matches) in sequence.

  ```
  requests.Count(r => !r.IsValid)
  ```

  - *Count of items where **IsValid** returns false*

  ```
  requests.Count()
  ```

  - *Count of all items in sequence*

LINQ: Combine and reduce

- **Distinct()** – Sequence without duplicates.

  ```
  orderIds.Distinct()
  ```

  - *A list of all unique order ids based on default comparer.*

- **Concat()** – Concatenates sequences.

  ```
  defaultValues.Concat(otherValues)
  ```

  - *Sequence containing defaultValues followed by otherValues.*

- **Union()** – Concatenates without duplicates.

  ```
  defaultValues.Union(otherValues)
  ```

  - *Sequence with items from defaultValues followed by items from otherValues without any duplicates.*

LINQ: First item or match

- **First()** – Returns first item or match, throws if none.

```
orders.First()
```

  - *Returns first order, throws if none.*

```
orders.First(o => o.Type == OrderType.Buy)
```

  - *Returns first buy order, throws if no buy orders.*

- **FirstOrDefault()** – Returns first item, default if none.

```
orders.FirstOrDefault()
```

  - *Returns first order, default if no orders.*
  - *Default based on type (null for reference, 0 for numeric, etc)*

```
orders.FirstOrDefault(o => o.Id > 100)
```

  - *Returns first order with id > 100, or default if no match.*

LINQ: Other items and matches

- **Last() / LastOrDefault()**
  - Similar to First except returns last match or item in list.
  - Default version returns default of type if no match.
- **ElementAt() / ElementAtOrDefault()**
  - Returns element at the given position (zero-indexed).
  - Default version returns default of type if position > count.
- **Single() / SingleOrDefault()**
  - Very similar to First except ensures that only one item exists that matches.

LINQ: Set operations

- **Except()** – Set difference, subtracts sequences

  ```
  snackFoods.Except(healthyFoods)
  ```

  - *Returns first sequence minus elements in the second.*
  - *Sequence of snack foods that are not healthy foods.*
- **Intersect()** – Set intersection, common sequence

  ```
  snackFoods.Intersect(healthyFoods)
  ```

  - *Returns first sequence minus elements in the second.*
  - *Sequence of foods that are snack foods and healthy foods.*
- **Union()** – Combines sequences without duplicates.

  ```
  snackFoods.Union(healthyFoods)
  ```

  - *Returns both sequences combined with duplicates removed.*

LINQ: Aggregation operations

- **Sum()** – Adds all in from a sequence

```
orders.Sum(o => o.Quantity)
```

- **Average()** – Agerage of all items in a sequence

```
orders.Average(o => o.Quantity)
```

- **Min()**– Finds minimum item in sequence

```
orders.Min(o => o.Quantity)
```

- **Max()** – Finds maximum item in sequence

```
orders.Max(o => o.Quantity)
```

- **Aggregate()** – Performs custom aggregation

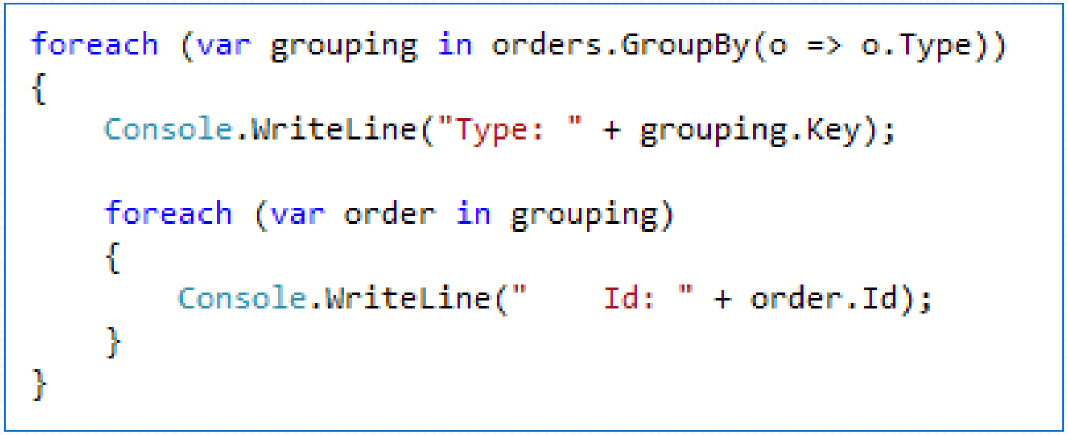
```
orders.Aggregate(0.0, (total, o) =>
    total += o.Quantity * o.Price)
```

LINQ: Grouping

- **GroupBy()** – Groups a sequence by criteria

  `orders.GroupBy(o => o.Type)`

  - *Organizes the sequence into groups of sequences.*
  - *In this case, organizes orders into sequences by order type.*
  - *Each element in resulting sequence is grouping with* ***Key*** *being the group criteria and the grouping being a sequence:*



```
foreach (var grouping in orders.GroupBy(o => o.Type))
{
    Console.WriteLine("Type: " + grouping.Key);

    foreach (var order in grouping)
    {
        Console.WriteLine("    Id: " + order.Id);
    }
}
```

LINQ: Ordering

- **OrderBy()** – Orders in ascending order

```
orders.OrderBy(o => o.Id)
```

  - *Orders in ascending order by order id.*

- **OrderByDescending()** – Orders in descending order

```
Orders.OrderByDescending(o => o.Id)
```

  - *Orders in descending order by order id.*

- **ThenBy()** – Adds additional ascending criteria

```
Orders.OrderBy(o => o.Id).ThenBy(o => o.Type)
```

  - *Orders in ascending order by id and when ids are same ordered by order type as a secondary ordering.*

- **ThenByDescending()** – As above, but descending.

LINQ: Exporting to Collection

- **ToArray()** – Returns sequence as an array.

  ```
  orders.OrderBy(o => o.Id).ToArray()
  ```

  - *Retrieves orders ordered by id into an array.*

- **ToList()** – Returns sequence as a **List**

  ```
  Orders.OrderBy(o => o.Id).ToList()
  ```

  - *Retrieves orders ordered by id into a List<Order>.*

- **ToDictionary()** – Returns sequence as **Dictionary**

  ```
  Orders.ToDictionary(o => o.Id)
  ```

  - *Retrieves orders in a dictionary where the Id is the key.*

- **ToLookup()** – Returns sequence of **IGrouping**

  ```
  Orders.ToLookup(o => o.Type)
  ```

  - *Retrieves orders into groups of orders keyed by order type.*

Query Syntax

- The query syntax is an alternative way to write LINQ expressions.
- Microsoft tends to recommend the query syntax as it tends to be easier to read.
- Ultimately, it is reduced to the same method calls we’ve already seen, so can use either.
- There are some methods which are not directly callable using the query syntax.

Query Syntax

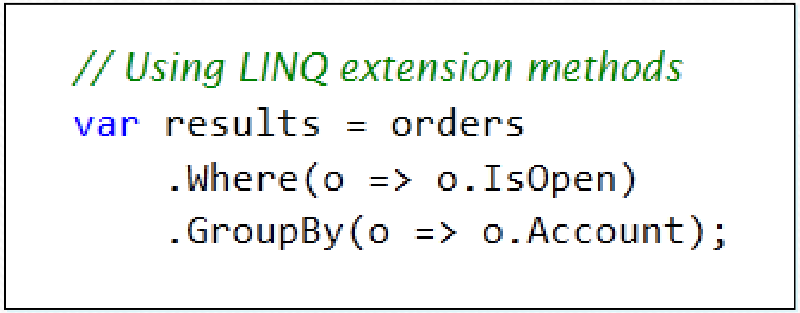
- All queries start with the **from** clause in the form:
  - `from o in orders`
    - *Declares variable representing current and source sequence.*
    - *Similar to **foreach(var o in orders)** except deferred.*
- All queries must end with a **select** or **group** clause:
  - `from o in orders select o.Id`
    - *Projects output same as the **Select()** extension method.*
  - `from o in orders group o by o.Id`
    - *Groups output same as the **GroupBy()** extension method.*

Query Syntax

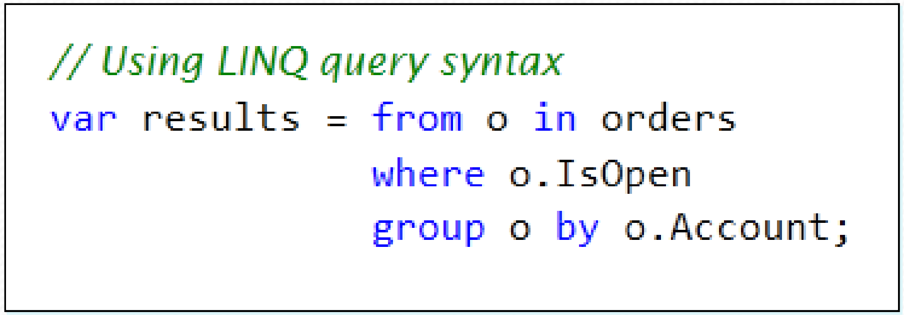
- In between the **from** and the **select/group** clauses, you can filter, order, and join as desired:
  - **where** – *filters to only matching objects, like* ***Where().***
  - **into** – *allows storage of results from a* ***groupby****,* ***join****, or* ***select*** *for use in later clauses.*
  - **order** – *sorts the results, can use* ***ascending*** *or* ***descending*** *modifiers, like the* ***OrderBy()*** *method family.*
  - **join** – *joins two sequences together, like* ***Join().***
  - **let** – *allows storage of result from sub-expression for use in later clauses.*

Same Query, Different Syntax

- These two queries are the same, just different syntax:



```
// Using LINQ extension methods
var results = orders
    .Where(o => o.IsOpen)
    .GroupBy(o => o.Account);
```



```
// Using LINQ query syntax
var results = from o in orders
              where o.IsOpen
              group o by o.Account;
```

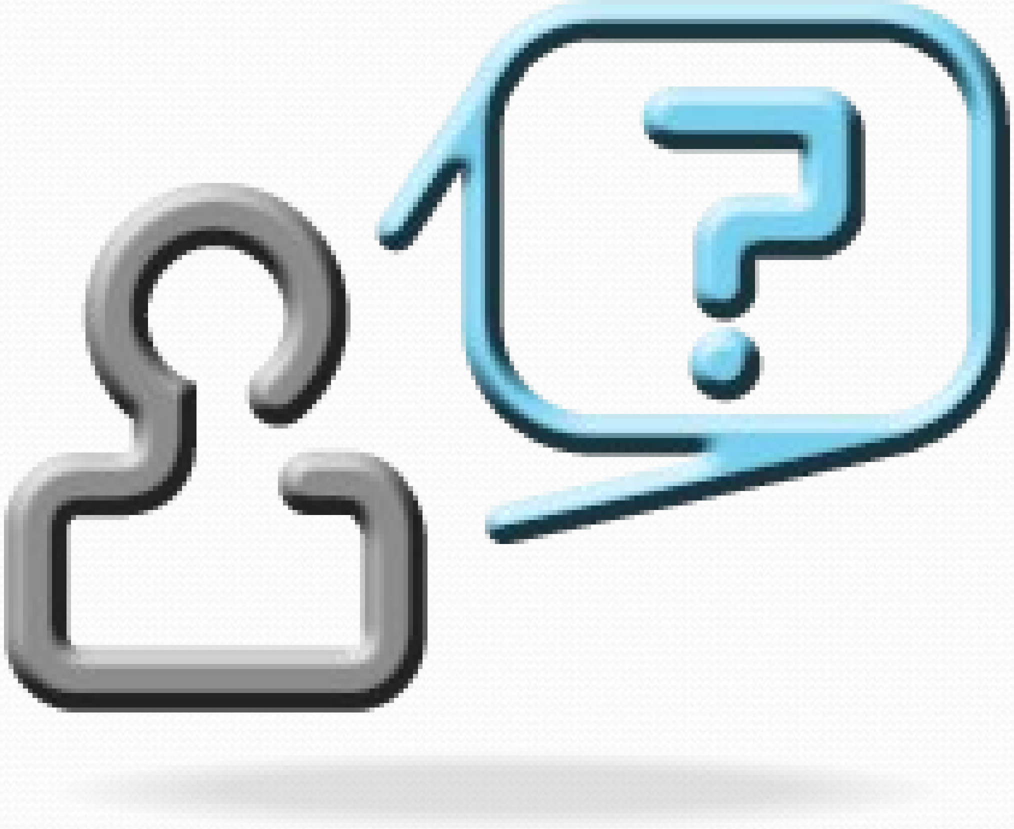
Pros and cons

- Pros:
  - Lambda expressions are much more concise than full methods for simple tasks.
  - LINQ expressions simplifies implementation by using .NET libraries that are optimized and fully tested.
  - Once you learn the lambdas and LINQ, ultimately the code is much more readable and easier to maintain.
- Cons:
  - The lambda syntax and LINQ methods take some getting used to at first *(short ramp-up time)*.

Summary

- Delegates help create more modular code without the need for inheritance.
- Lambdas are just an easy way to assign an anonymous method to a delegate.
- LINQ introduces a great class library for performing common operations on sequences of data.
- Using lambdas and LINQ can help reduce code size and improve code readability and maintainability.
- Care should be taken to make lambda expressions concise and meaningful while still readable.

Questions?



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