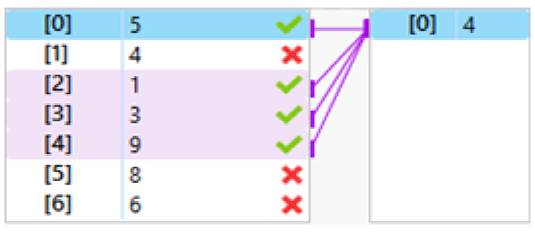
Visual Lexicon of LINQ

LINQ extends the C# language with native data querying capabilities giving you SQL-like expressiveness in C# (and other .NET languages). LINQ can be applied to in-memory data (variables), XML, databases, and more, limited only by the LINQ providers you have on hand. This wallchart is a companion to the Simple Talk article **A Visual Lexicon of LINQ**, which provides a visual example for each LINQ operator to provide a quick understanding of how each one conveys its input to its output. An example is shown immediately below. *Thanks to OzCode (https://oz-code.com/) for the visual pattern renderings.*



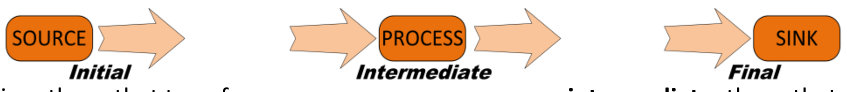
This example visualization of the **Count** operator shows how some of the 7 input elements are included and some excluded, and how the included elements collapse to a single output element (the **"Collapse all to one"** pattern). Purple lines (/) simply indicate an item is *selected* in the editor; other patterns also show grey lines (/) for *unselected* elements.

Characteristics of each LINQ operator

		Position			Syntax		Execution		Laziness			Complexity		Optional Features				
Category	**Operator**	Initial	Intermediate	Final	Lambda	Query	Deferred	Immediate	First element	Some elements	All elements	Time: O(x)	Space: O(x)	Available index	Input Transform	Output projection	Custom Comparer	Conditional Selection
Aggregate	Aggregate			●	●			●			●	n	1			●		
	Average			●	●			●			●	n	1		●			
	Count			●	●			●			●	1 | n	1					●
	LongCount			●	●			●			●	1 | n	1					●
	Max			●	●			●			●	n	1		●			
	Min			●	●			●			●	n	1		●			
	Sum			●	●			●			●	n	1		●			
Conversion	AsEnumerable	●			●		●				●	n	1					
	Cast		●		●	●	●				●	n	1					
	OfType		●		●		●				●	n	1					
	ToArray		●		●			●			●	n	n					
	ToDictionary			●	●			●			●	n	n				●	
	ToList		●		●			●			●	n	n					
	ToLookup			●	●			●			●	n	n				●	
Elements	ElementAt			●	●			●	●	●	●	1 | n	1					
	ElementAtOrDefault			●	●			●	●	●	●	1 | n	1					
	First			●	●			●	●	●	●	1 | n	1					●
	FirstOrDefault			●	●			●	●	●	●	1 | n	1					●
	Last			●	●			●			●	1 | n	1					●
	LastOrDefault			●	●			●			●	1 | n	1					●
	Single			●	●			●	●	●	●	1 | n	1					●
	SingleOrDefault			●	●			●	●	●	●	1 | n	1					●
Generation	DefaultIfEmpty		●		●		●		●	●	●	n	1					
	Empty	●			●							1	1					
	Range	●			●		●					n	1					
	Repeat	●			●							n	1					
Group	GroupBy		●		●	●	●				●	n	n			●	●	
Join	Concat		●		●		●				●	n	n					
	GroupJoin		●		●	●	●				●	n	n				●	
	Join		●		●	●	●				●	n	n				●	
	Zip		●		●		●				●	n	1					
Ordering	OrderBy		●		●	●	●				●	n*logn	n				●	
	OrderByDescending		●		●	●	●				●	n*logn	n				●	
	Reverse		●		●		●				●	n	n					
	ThenBy		●		●	●	●				●	n*logn	n				●	
	ThenByDescending		●		●	●	●				●	n*logn	n				●	
Partitioning	Skip		●		●		●				●	n	1					
	SkipWhile		●		●		●				●	n	1	●				●
	Take		●		●		●		●	●	●	n	1					
	TakeWhile		●		●		●		●	●	●	n	1	●				●
Projection	Select		●		●	●	●				●	n	1	●		●		
	SelectMany		●		●	●	●				●	n*m	1	●		●		
Quantifiers	All			●	●			●	●	●	●	n	1					●
	Any			●	●			●	●	●	●	n	1					●
	Contains			●	●			●	●	●	●	n	1				●	
	SequenceEqual			●	●			●	●	●	●	n	1				●	
Restriction	Where		●		●	●	●				●	n	1	●				●
Sets	Distinct		●		●		●				●	n	n				●	
	Except		●		●		●				●	n	n				●	
	Intersect		●		●		●				●	n	n				●	
	Union		●		●		●				●	n	n				●	

Position

Specifies where this operator may occur in a sequence: those that generate a sequence (a *source*) must be in **initial** position; those that transform or process a sequence are **intermediate**; those that convert the sequence to an object or a value (a *sink*) are **final**. For example, **Select** (intermediate) might appear as op1(...).op2(...).**Select(...)**.op3(...) while **Count** (final) must appear as op1(...).op2(...).**Count(...)**.



Syntax

Every operator exists in **lambda** syntax; only a select few exist in **query** syntax but those are the most commonly used; both styles may be used together. The snippet shows the same result with both styles.

```
var list = new int[] { 1, 2, 3, 4, 5, 6, 7, 8, 9 };
Func<int, bool> isOdd = (n => n % 2 == 1);
var queryResult = from n in list where isOdd(n) select n;
var lambdaResult = list.Where(isOdd);
```

Execution and Laziness

LINQ **defers** execution for many operators; data results are returned **immediately** only for some. Further, when executing a query, only as much of a sequence that is actually needed is evaluated: that might be just the **first** element, **all** elements, or **some** number in between. This could vary for any given operator depending on arguments supplied. Ex: with no arguments **First** evaluates only the first element, but with a condition First might evaluate any number (or all) arguments; thus, **First** shows all 3 possibilities marked.

Complexity

Time complexity specifies how long an operator takes to run. Notes:
>> **Count** & **LongCount** run in **O(1)** if the underlying type implements ICollection; otherwise **O(n)**.
>> **ElementAt(OrDefault)** & **Last(OrDefault)** run in **O(1)** if the type implements IList<T>; otherwise **O(n)**.
>> **First(OrDefault)** & **Single(OrDefault)** run in **O(n)** if a condition is present; otherwise **O(1)**.
Space complexity specifies how much memory is used with respect to the input size.

Optional Features

Available index: When processing a given element, operator may use the element's index in a computation.

`pets.Select((pet, i) => $"{i} {pet.Name}")`

Input Transform: Accepts a transform function for input (rather than invoking **Select** then the operator).

`numbers.Sum(n => n > 5 ? n : 0)`

Output Projection: Accepts a projection function for output (rather than invoking the operator then **Select**).

`pets.GroupBy(p => p.Age, p => p.Name)`

Custom Comparer: Operators that do comparisons can accept a custom comparer rather than the default.

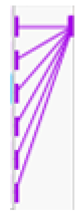
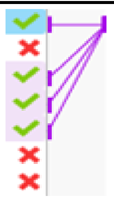
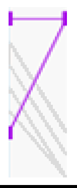
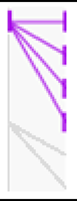
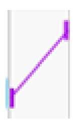
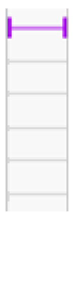
`fruits.Contains(pear, produceComparer)`

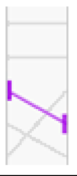
Conditional Selection: Accepts a filtering function for output (rather than invoking **Where** then the operator).

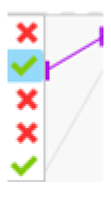
`words.Single(w => w.Length > minLength)`

Visual Patterns of LINQ Operators

LINQ operators can be categorized into these ten patterns. Note that some operators fit more than one pattern. For example, **All** fits **Collapse all to one** when returning true, but **One to one** when returning false. **Count** with conditional selection fits **Collapse some to one** but without it, fits **Collapse all to one**. Refer to the main article for details of each operator.

Category	LINQ Operators	Visual Pattern
Collapse all to one	Aggregate All Any Average Count LongCount Sum	
Collapse some to one	Count LongCount SequenceEqual	
Collapse groups	GroupBy ToLookup	
Expand groups	SelectMany	
One to one	All Any Contains ElementAt(OrDefault) First(OrDefault) Last(OrDefault) Max Min Single(OrDefault)	
None to one	DefaultIfEmpty ElementAtOrDefault FirstOrDefault LastOrDefault SingleOrDefault	
None to some	Range Repeat	
Convey all/ order retained	AsEnumerable Cast Concat DefaultIfEmpty GroupJoin Select Single Skip(While) Take(While) ToArray ToDictionary ToList Union Zip	

Convey all/ order changed	OrderBy(Descending)
	Reverse
	ThenBy(Descending)
		

Convey some	Distinct Except Intersect Join OfType Skip(While) Take(While) Where Zip	

Further Reading

LINQ on MSDN
Enumerable Methods
LINQ Debugging and Visualization
Query Expression Syntax for Standard Query Operators
101 LINQ Samples or LINQ Samples.com