Static and Runtime API Usage Analysis on .NET

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Outline

Introduction

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Overview

Analysis of

- the shape of existing APIs.
- their usage by "projects in the wild."

In terms of

- reusability of APIs.
- OO-specific usage.
- general acceptance and coverage.

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- support research on API migration
- facilitate development of new APIs
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- application of analysis to a corpus of selected open-source software
- composition of metrics that are suitable to measure API related software usage

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Methodology

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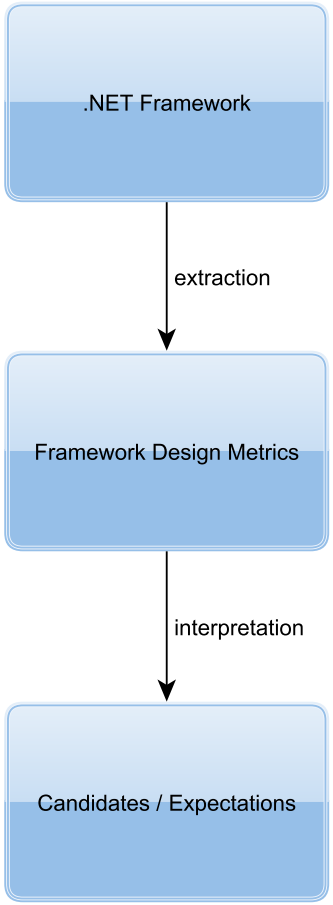
Overview

Explorative analysis approach:

1. framework design analysis



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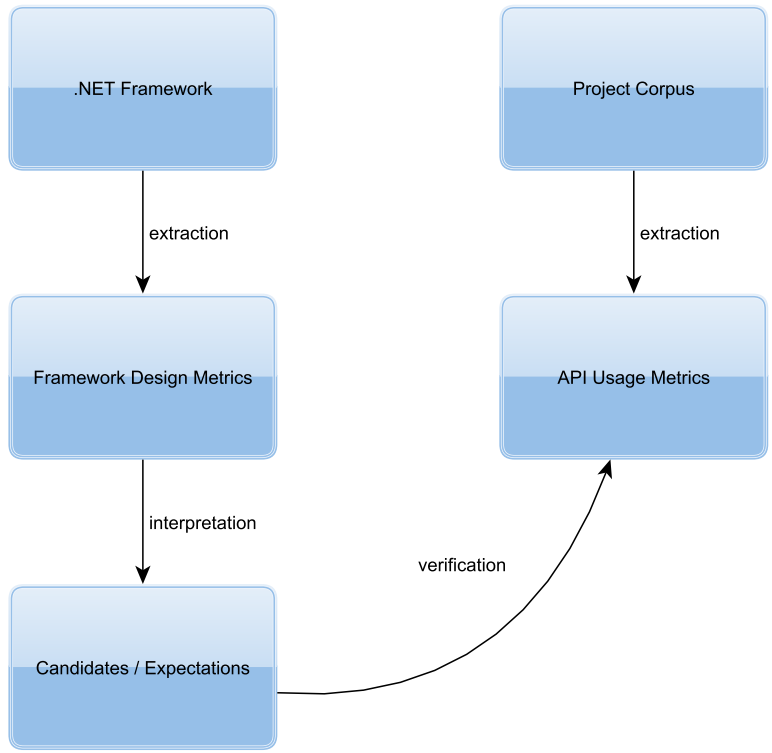
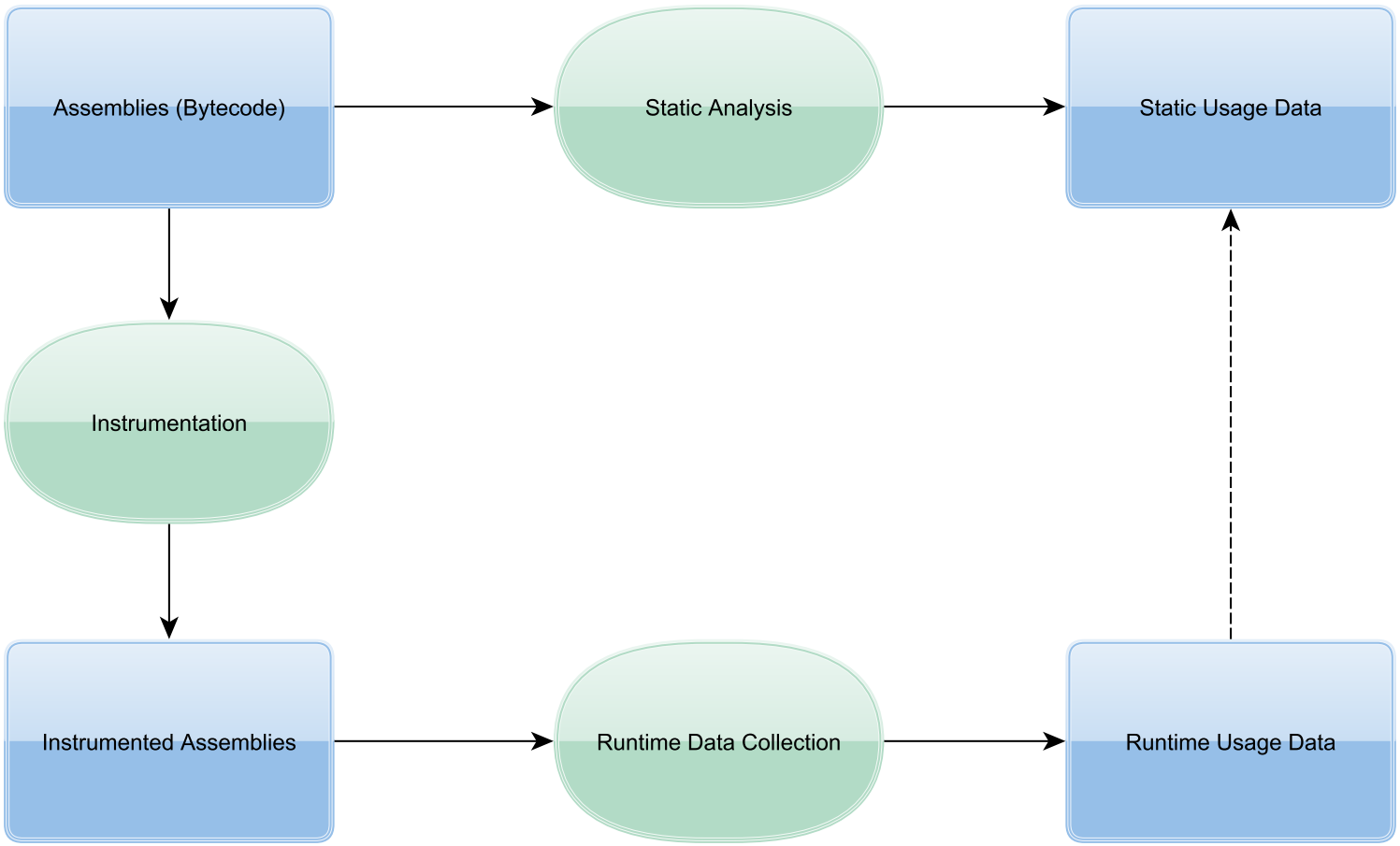


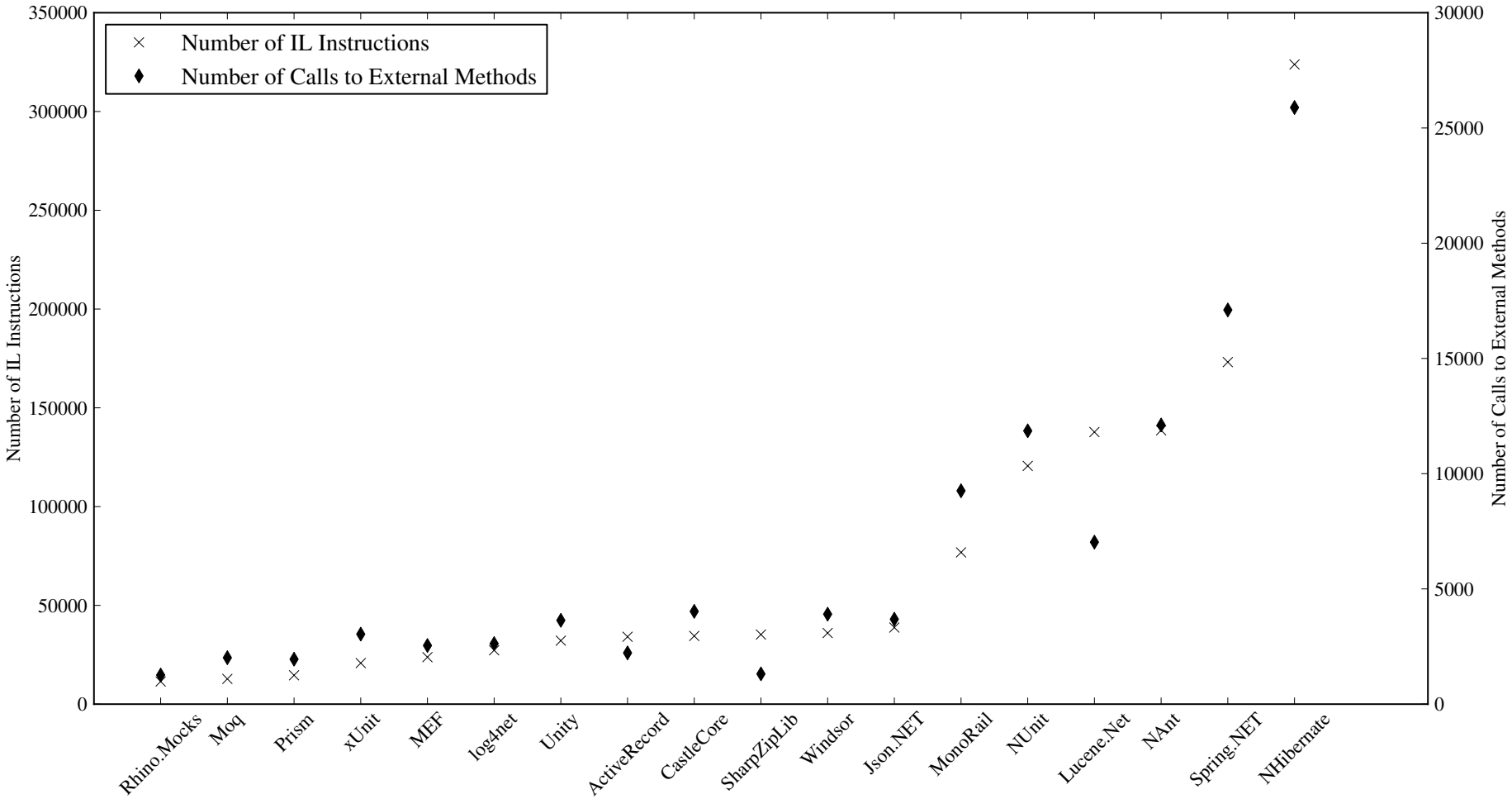
Methodology

Analysis Overview



Methodology

Corpus



Methodology

API

APIs are defined by their namespace.
Namespaces are grouped for easier handling.

Example

The XML API is covered by the namespaces

- `System.Xml`
- `System.Xml.Schema`
- `System.Xml.Serialization`
- ...

All these namespaces are grouped and represented as

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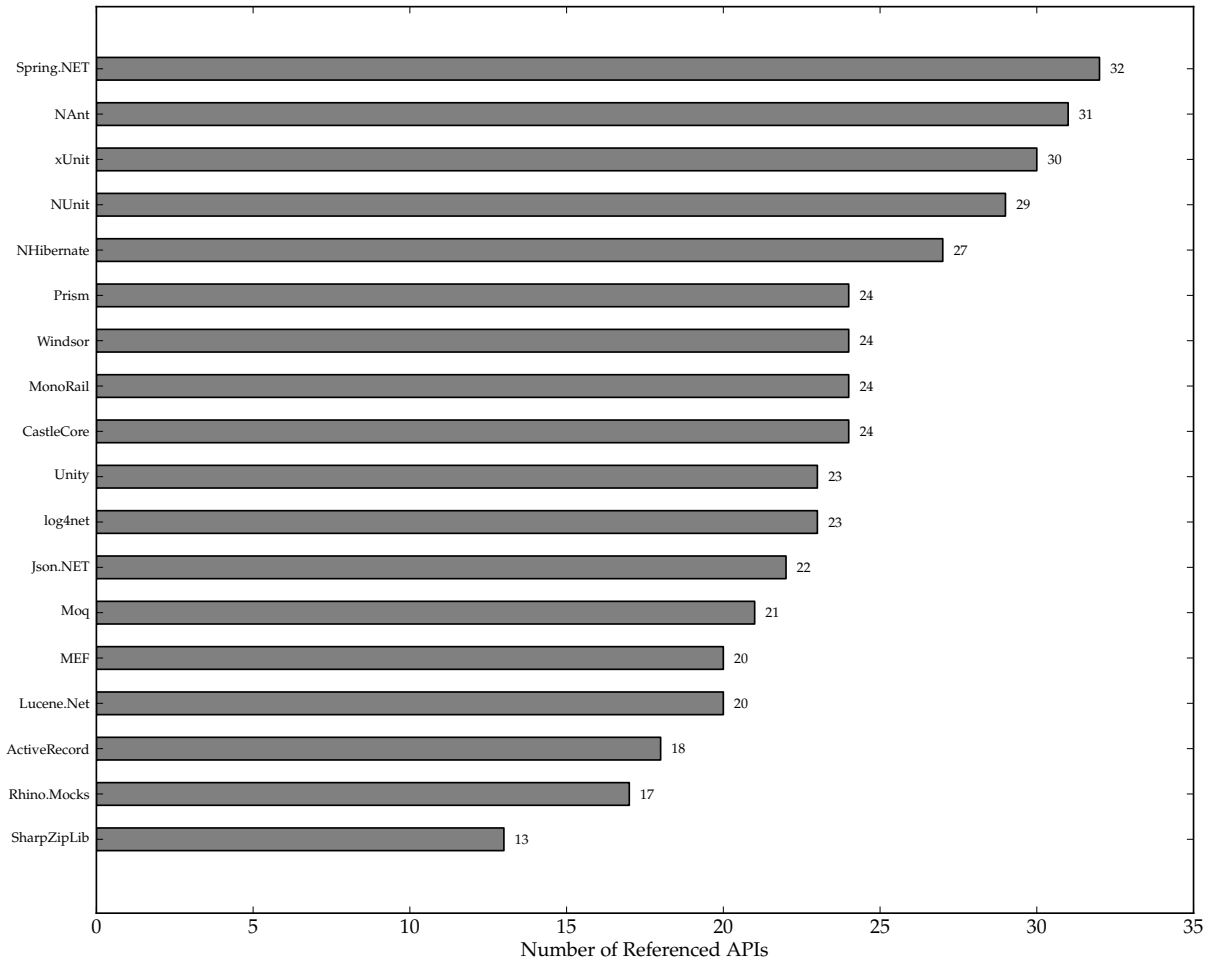

API Usage

The term “API usage” refers to “usage by the developer”.

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```
class SomeClass { public SomeClass() { } }
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Implicitly calls System.Object::.ctor() ⇒ not API usage.

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Results

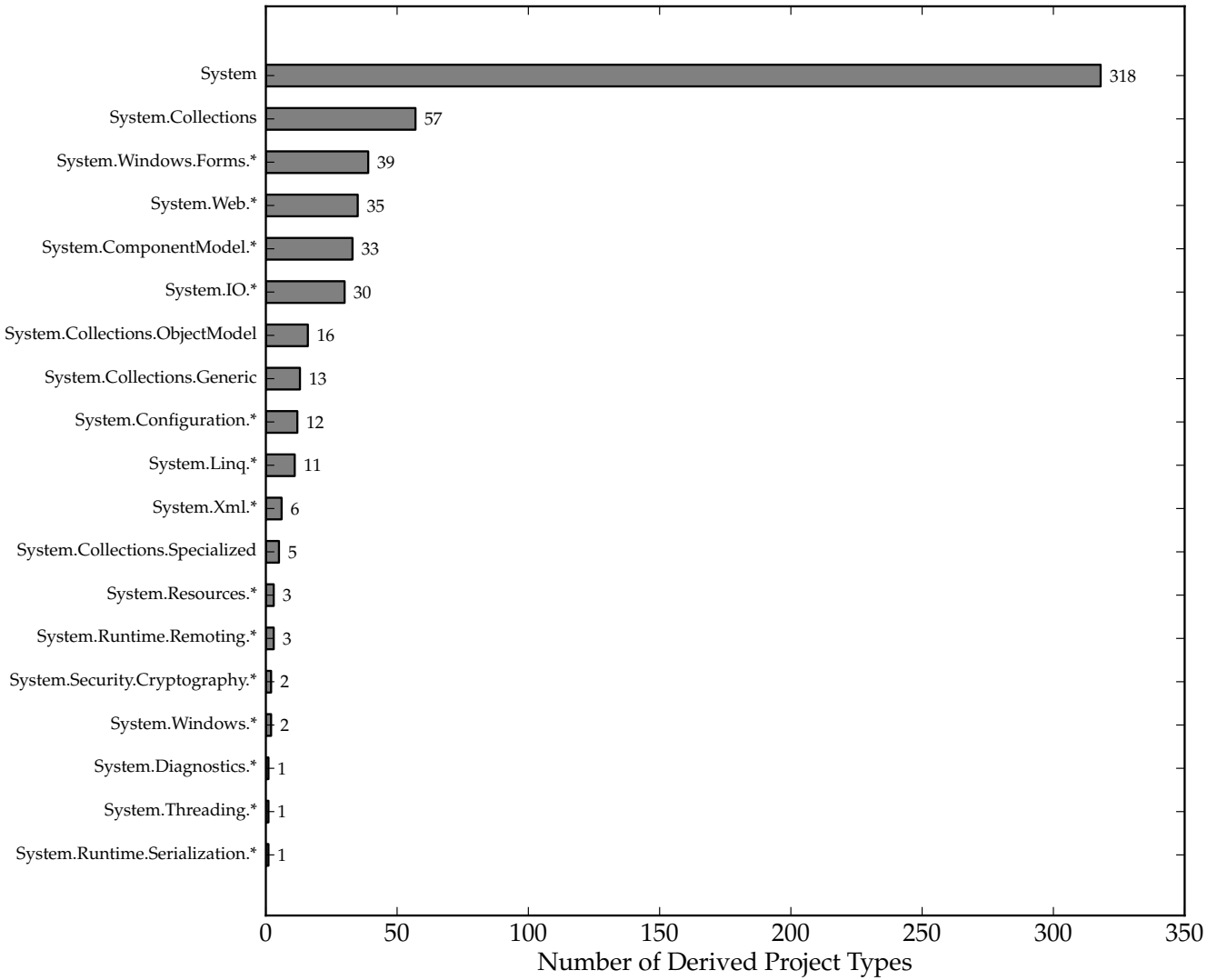
.NET Framework

Design Metrics

General statistics

- namespaces: 74 (3 with only sealed types)
- number of classes: 10457 (4295 sealed classes)
- interfaces: 957

Specialization of types from the .NET APIs



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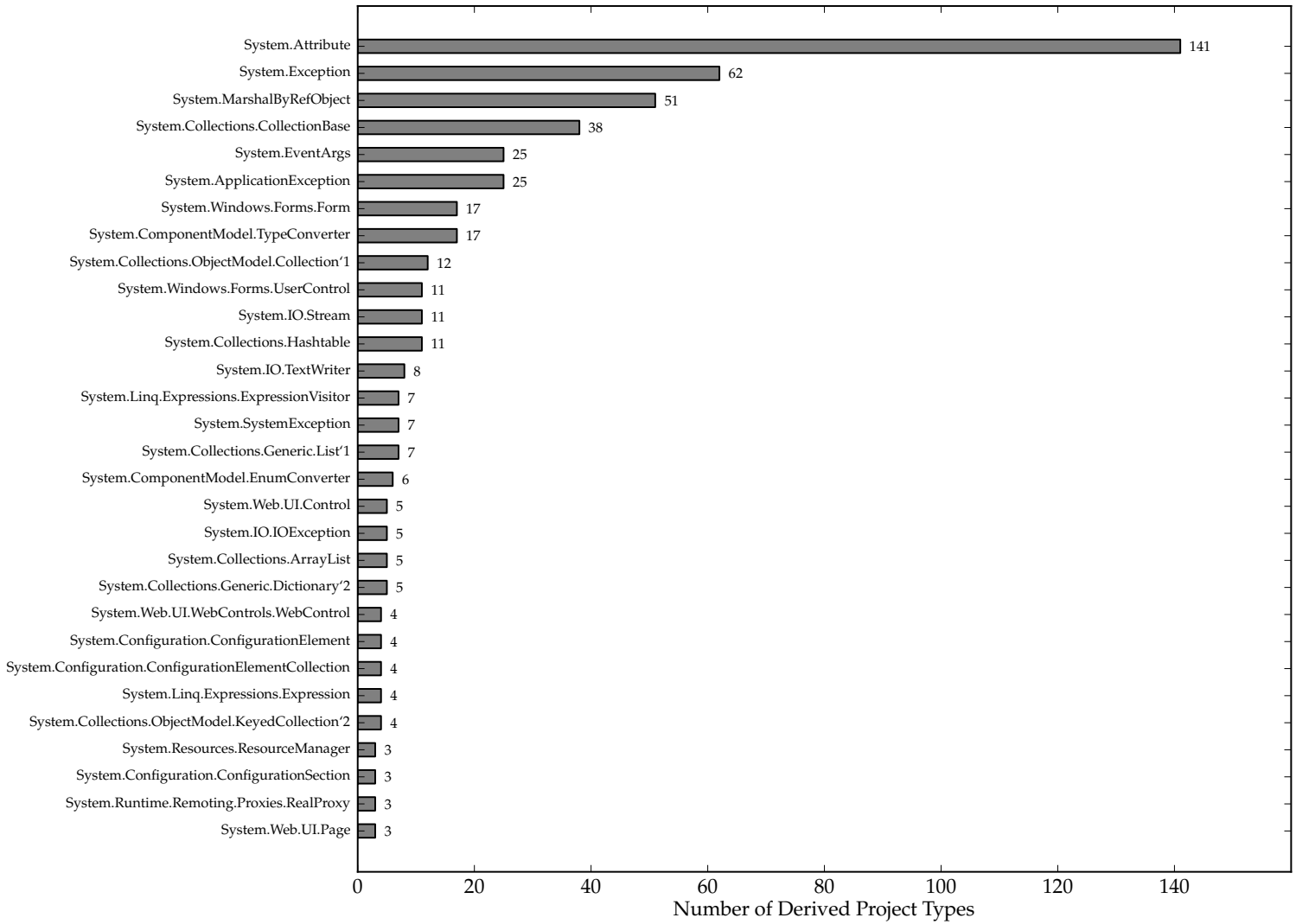
Corpus

Usage Metrics

.NET types specialized by corpus



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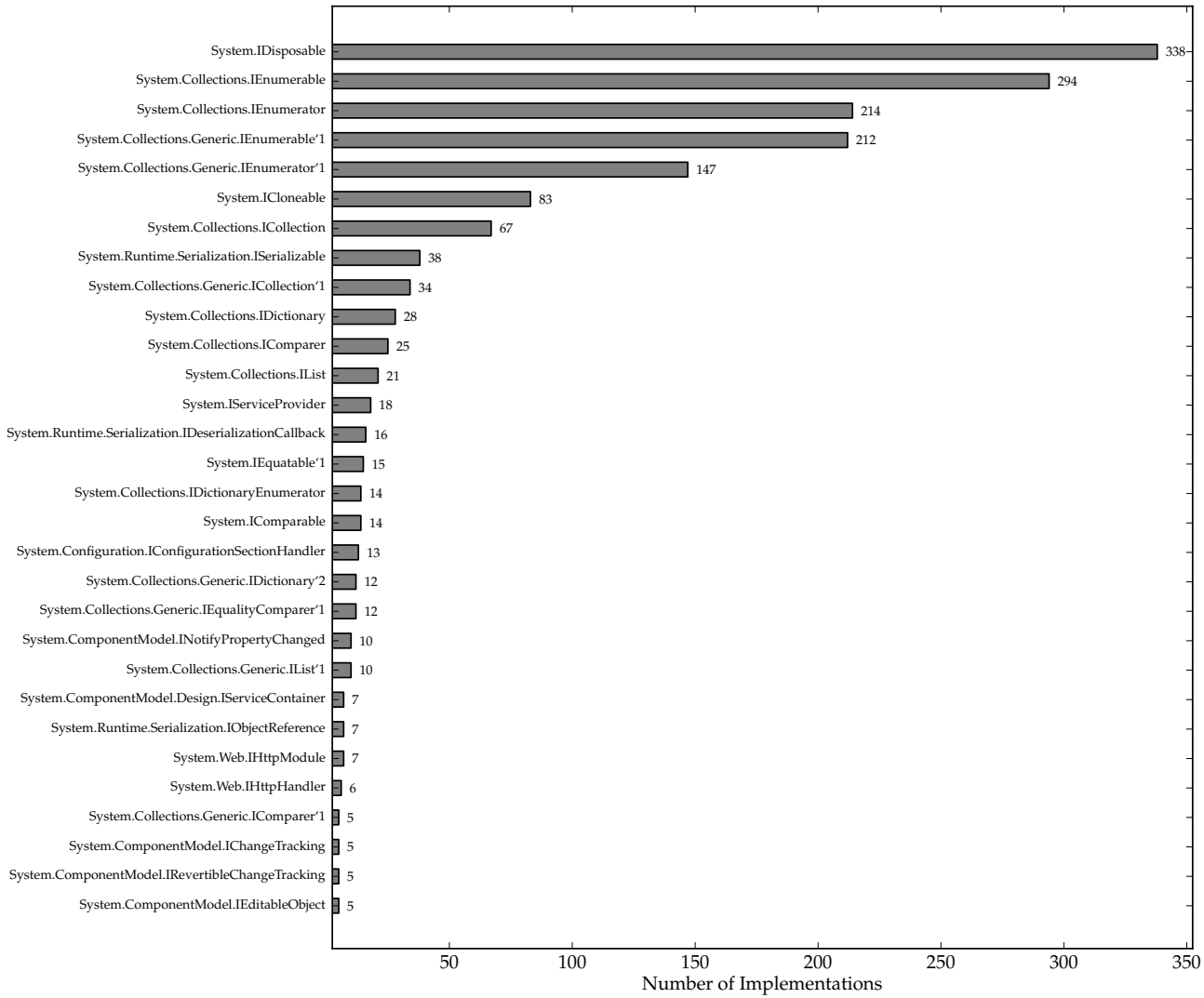
  - 100 types are specialized (1.62%)
- interfaces: 957

Implemented interfaces



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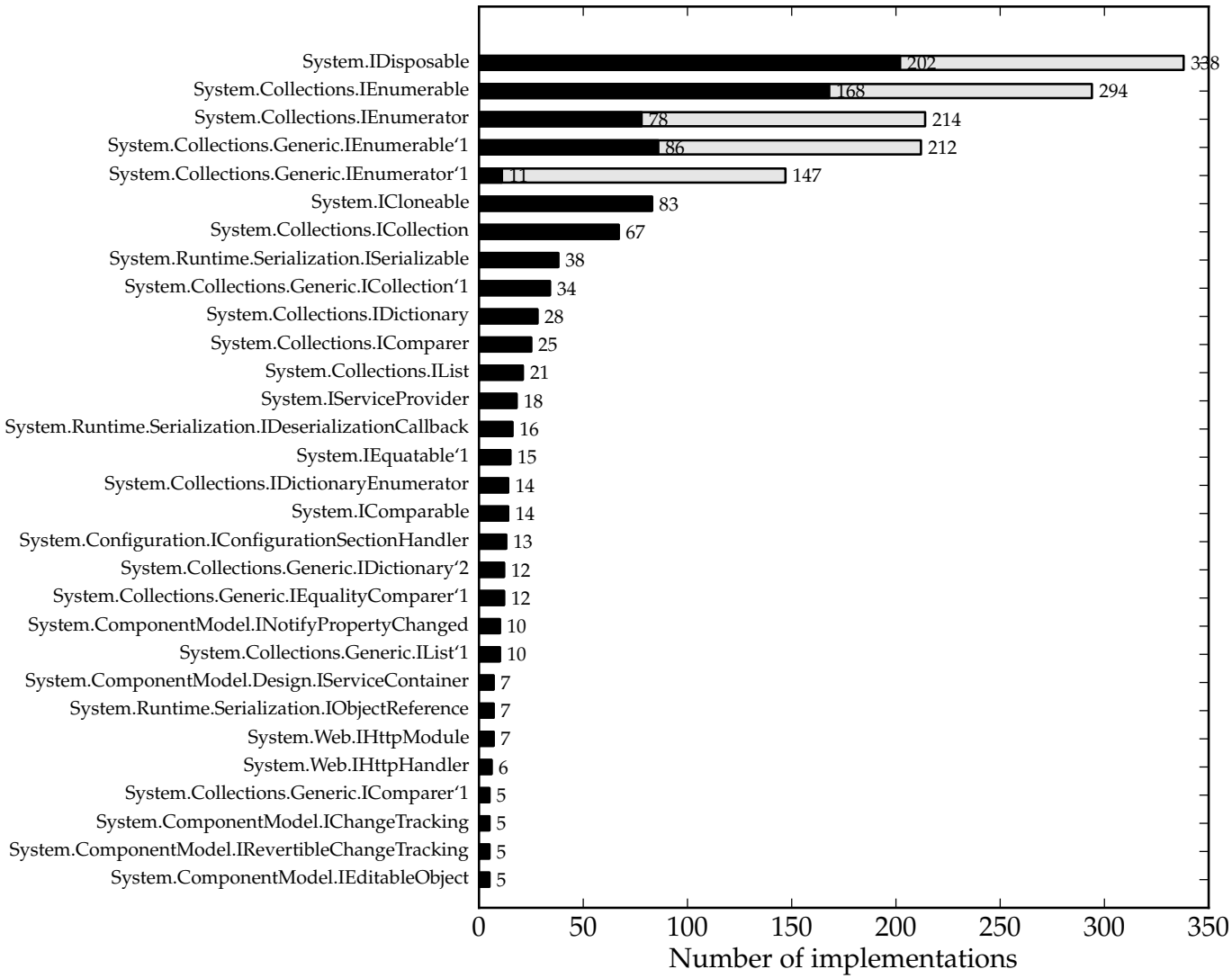
  - 70 interfaces are implemented (7.31%)

Compiler generated interface implementations

A simple number generator in the form of an `IEnumerable`1` can be generated with the following code:

```
IEnumerable<int> GetSomeNumbers(int num)
{
    Random r = new Random();
    for (int i = 0; i < num; i++)
    {
        yield return r.Next();
    }
}
```

Implemented interfaces (without compiler generated)



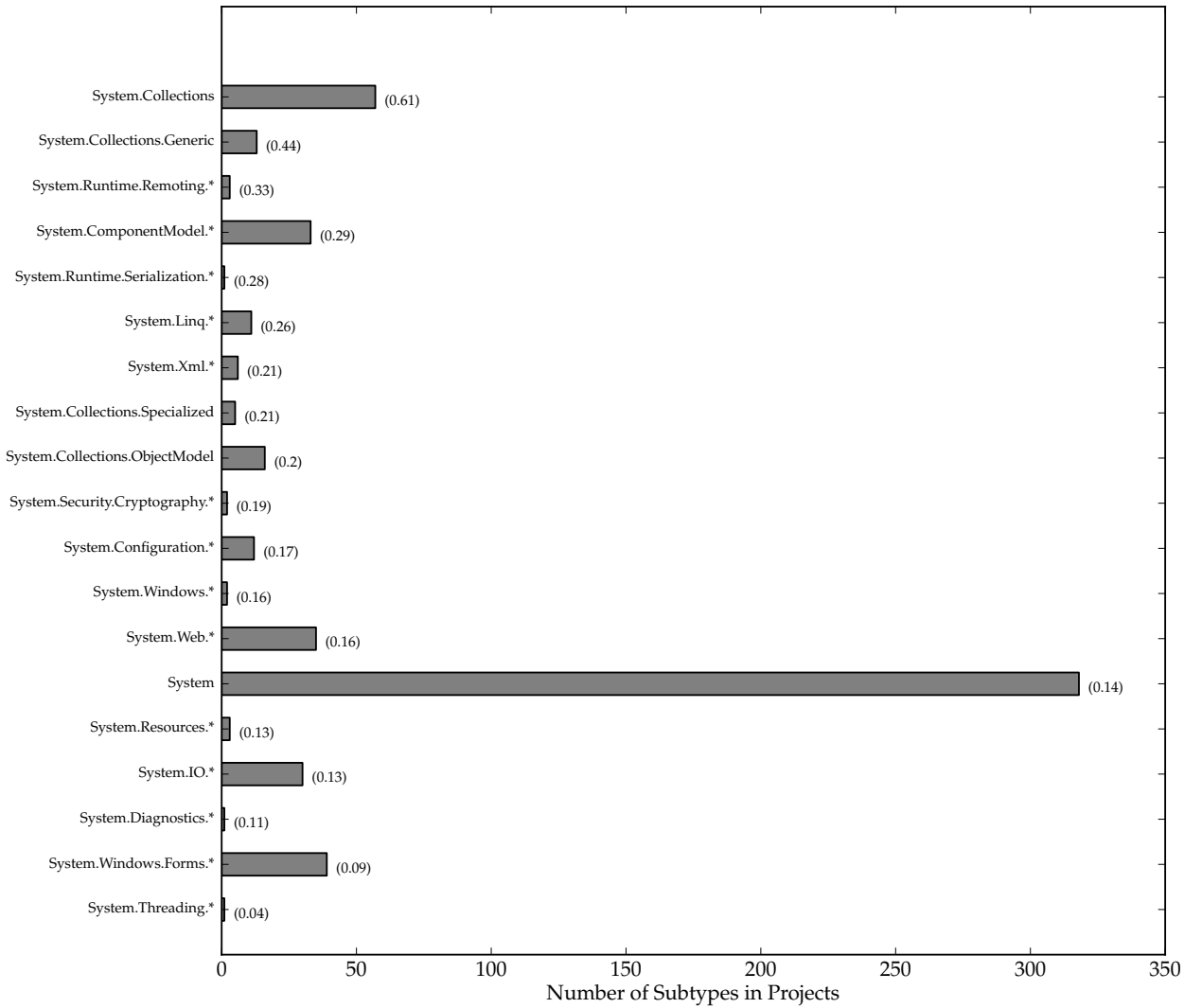
Abstractness of .NET namespaces

Namespace	ConcreteTypes	AbstractTypes	Abstractness
Accessibility	1	6	0.86
System.Dynamic	4	16	0.80
System.AddIn.*	14	27	0.66
System.Collections	9	14	0.61
System.Runtime.InteropServices.*	68	80	0.54
Microsoft.VisualC.*	21	17	0.45
System.Collections.Generic	14	11	0.44
System.Collections.Concurrent	5	3	0.38
System.Security.AccessControl	33	17	0.34
System.Runtime.Remoting.*	108	54	0.33
System.Runtime.Caching.*	14	7	0.33
System.Runtime.ConstrainedExecution	2	1	0.33
System.Xaml.*	37	16	0.30
System.Text	17	7	0.29
System.ComponentModel.*	280	114	0.29
System.Runtime.Serialization.*	46	18	0.28
System.Security	19	7	0.27
Microsoft.JScript.*	140	51	0.27
System.Linq.*	39	14	0.26
System.IdentityModel.*	67	23	0.26

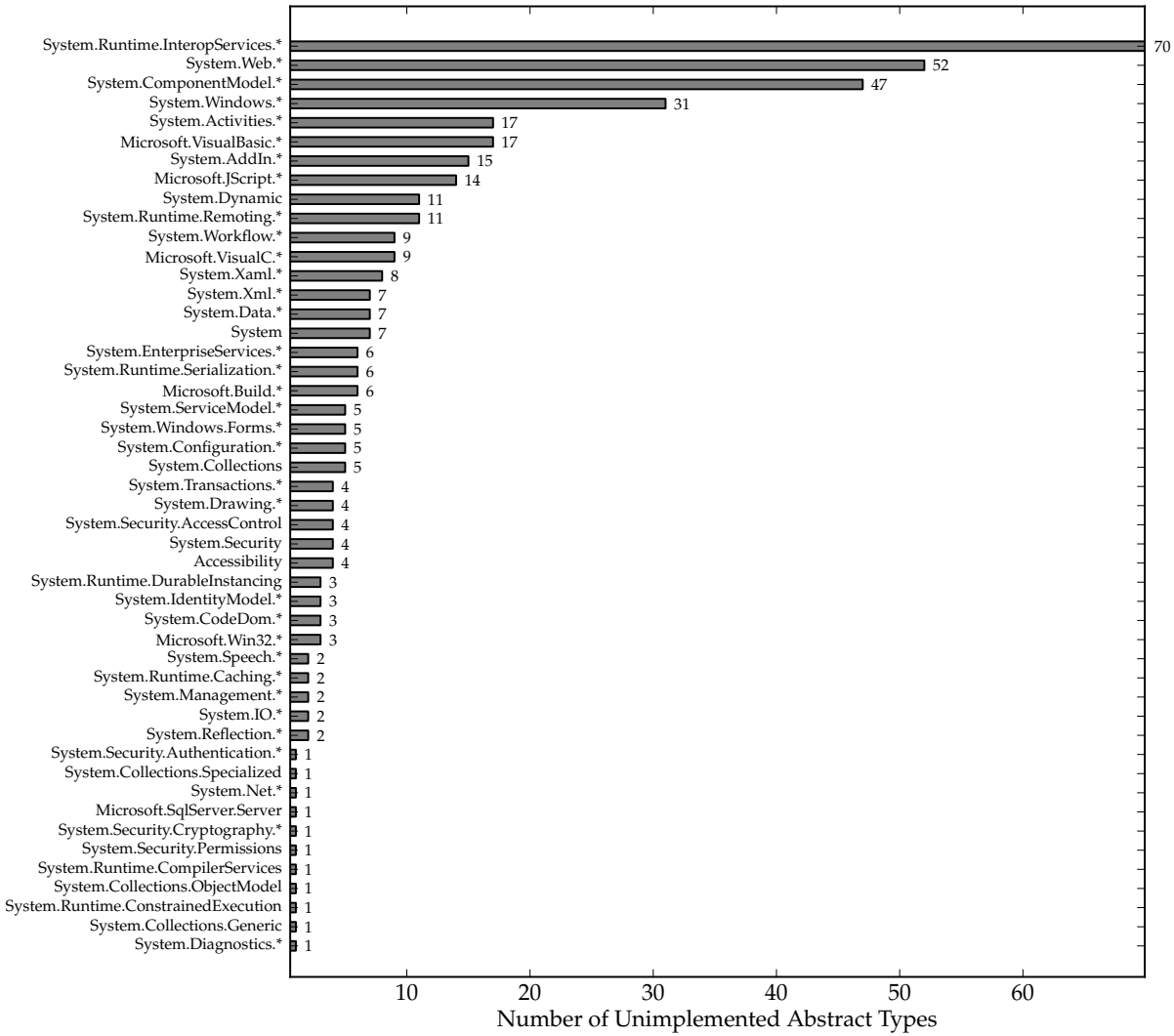
Corpus

Usage Metrics

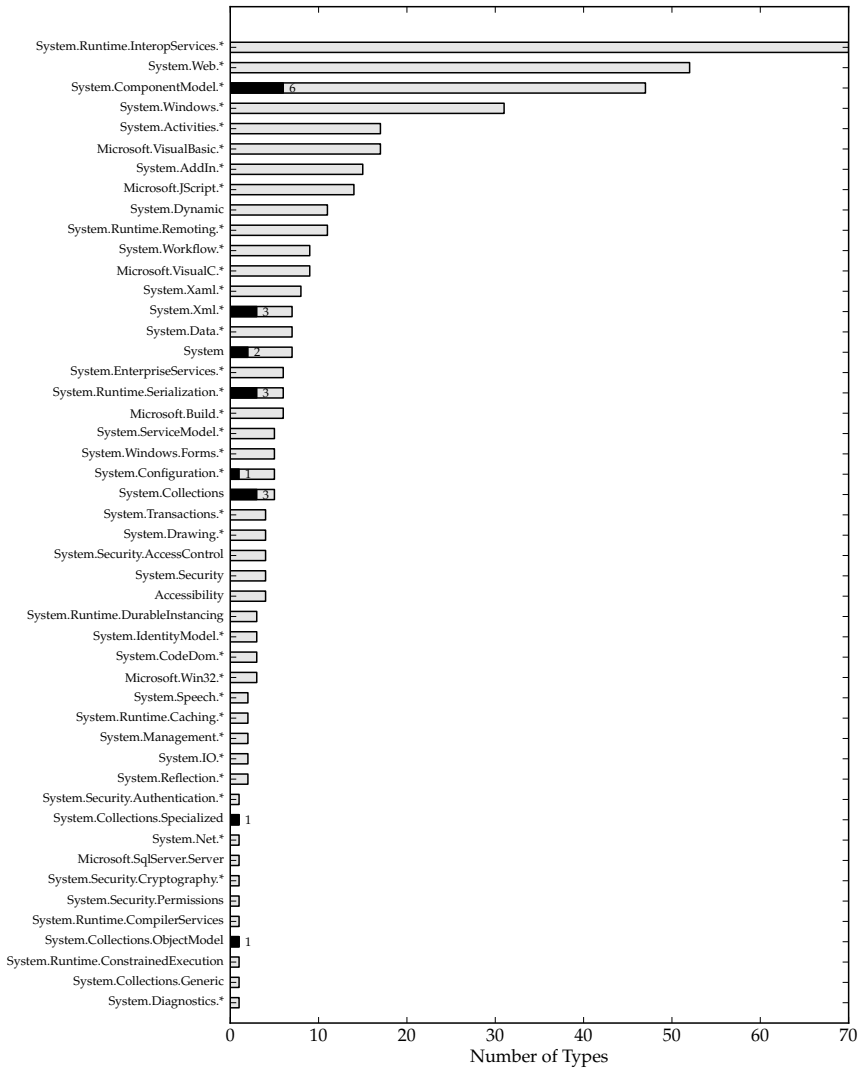
Comparison of API abstractness to number of specializations



Unimplemented abstract types



Previously unimplemented abstract types



Receiver Types

- static receiver type
- runtime receiver type

Example

```
Exception ex = new InvalidOperationException();
string s = ex.ToString();
```

static receiver type: `Exception`
runtime receiver type: `InvalidOperationException`

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Usage Metrics

Late-bound methods

	Static Data	Additional Runtime Data			
Namespace	Methods	Methods	% Public API	% Internal API	% Project
System	493	506	24.90	18.38	56.72
System.Collections	130	488	22.75	32.17	45.08
System.Collections.Generic	105	327	10.70	18.65	70.64
System.Reflection.*	233	111	0.90	99.10	0.00
System.Data.*	123	97	77.32	0.00	22.68
System.Xml.*	354	82	45.12	54.88	0.00
System.IO.*	203	51	45.10	17.65	37.25
System.ComponentModel.*	79	25	8.00	8.00	84.00
System.Linq.*	55	16	37.50	50.00	12.50
System.Runtime.Remoting.*	18	12	0.00	100.00	0.00
System.CodeDom.*	47	9	66.67	33.33	0.00
System.Text	44	9	77.78	22.22	0.00
System.Configuration.*	31	8	25.00	12.50	62.50
System.Net.*	71	7	100.00	0.00	0.00
System.Windows.Forms.*	446	3	0.00	100.00	0.00
System.Web.*	382	3	66.67	33.33	0.00
System.Security.Principal	8	3	100.00	0.00	0.00
System.Windows.*	34	2	0.00	0.00	100.00
System.Runtime.Serialization.*	25	2	50.00	0.00	50.00

Examples for late-bound receiver methods

Public API

```
IDisposable file = new FileStream(...);
file.Close();
```

Internal API

```
// Object.GetType() returns an object
// of type RuntimeType, which is internal.
Type type = file.GetType();
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Examples for late-bound receiver methods

Project

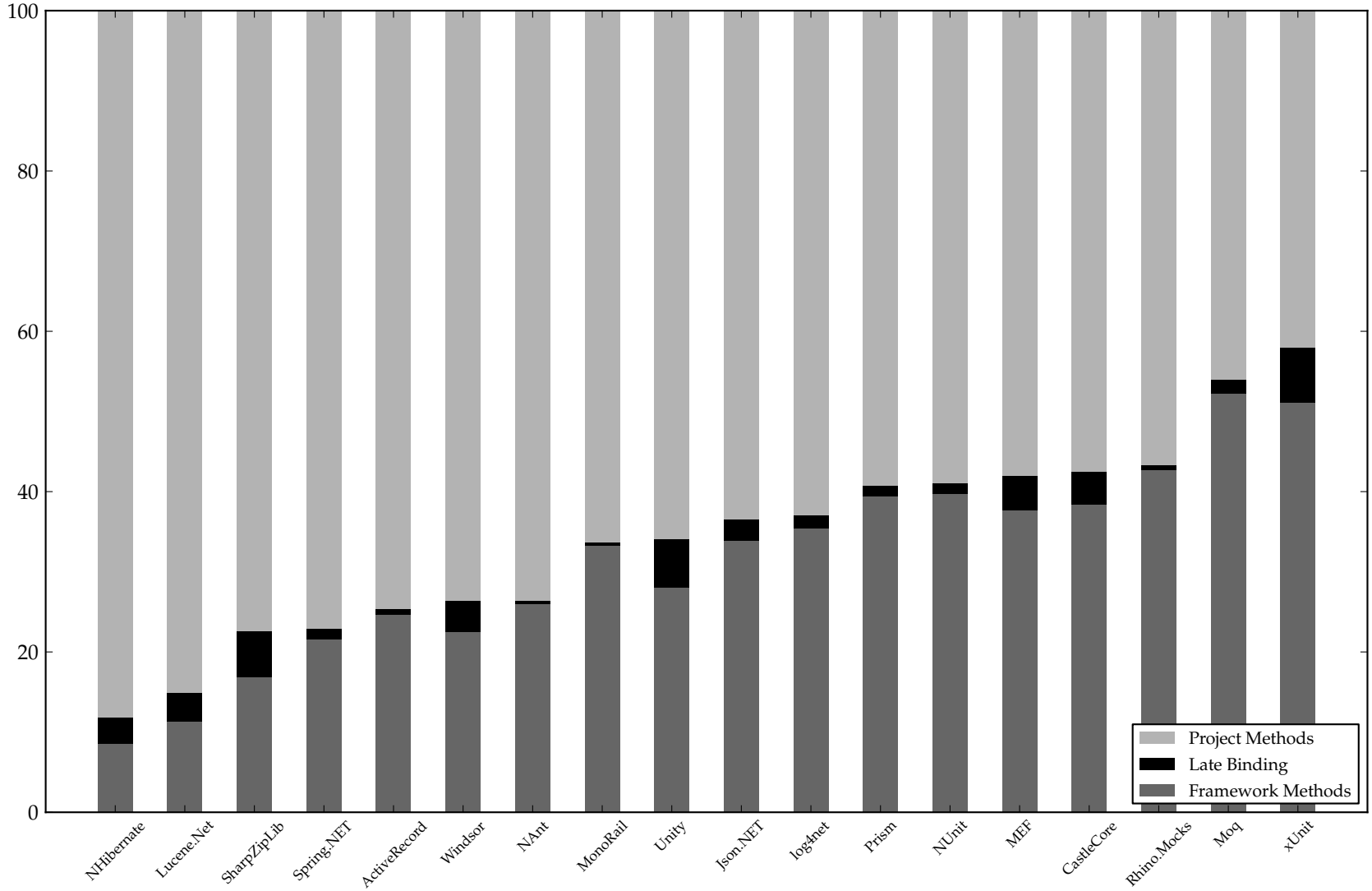
```
class ProjectClass : ICloneable { ... }

ICloneable original = new ProjectClass();
object clone = c.Clone();
```

Corpus

Usage Metrics

Distribution of method calls in the corpus



Conclusion and Further Work

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- not much framework type specialization
  - often limited to special types
- tendency towards interfaces over type specialization
  - late-binding used with interfaces
- corpus mostly does not meet usage expectations from framework design
- many calls into API code, but primarily “library-like” usage

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Further Work

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- specialized analyses for smaller sets of APIs
- measure other API usage forms
- comparison to Java APIs
- acceptance of new framework features

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Thanks for your attention!