Java and C# in depth

Carlo A. Furia, Marco Piccioni, Bertrand Meyer

C#: framework overview and in-the-small features

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C#: framework overview

What’s in a name

Internal name of initial project: Cool (C-like Object Oriented Language)

- Ruled out by the trademark lawyers

Chief C# architect at Microsoft: Anders Hejlsberg

- Previously on Turbo Pascal & Delphi

Grounded in the .NET platform and CLI (Common Language Infrastructure)

“An imitation of Java”

- According to Java’s Bill Gosling

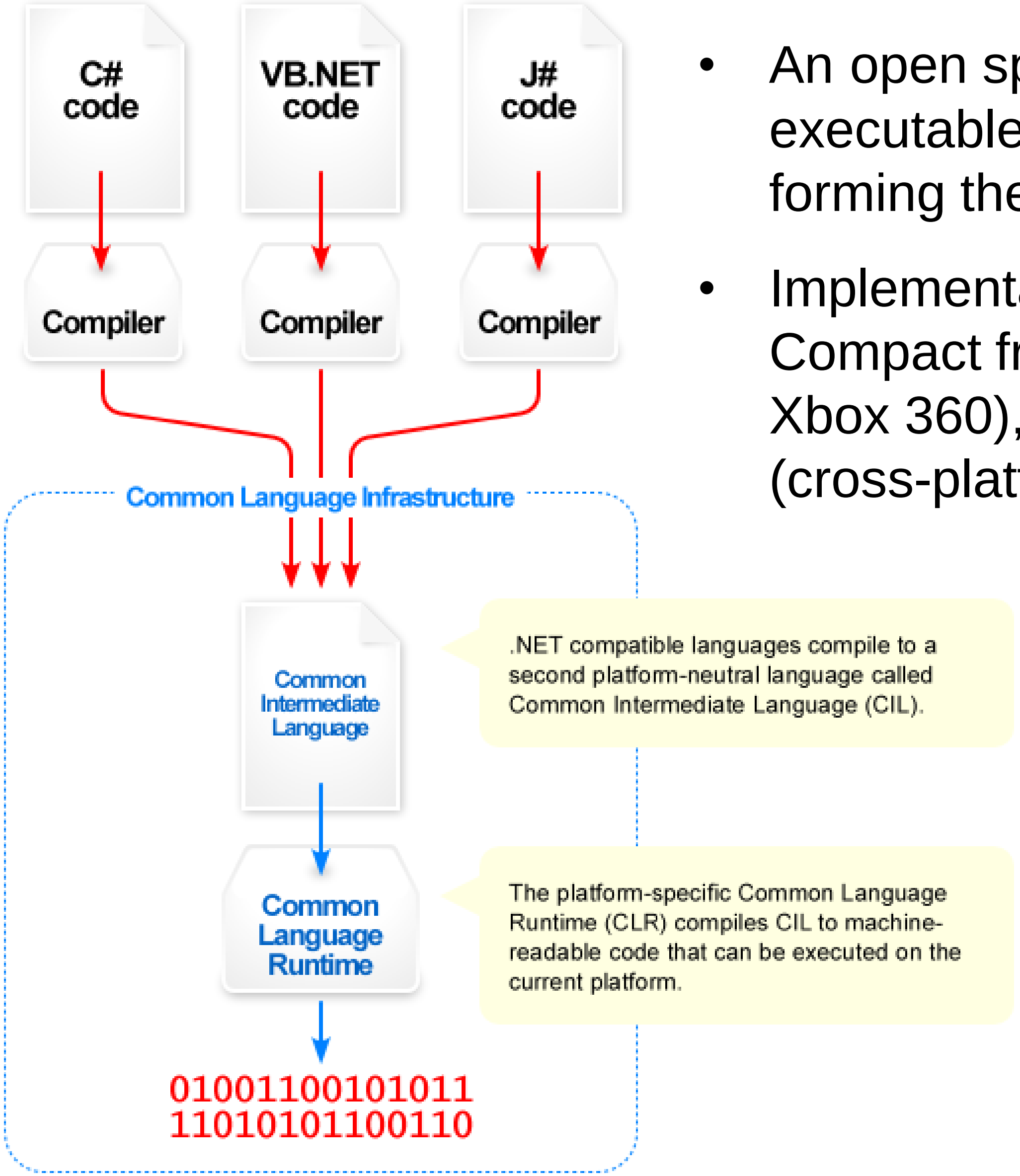
Version 1.0: 2001

Latest version: 5.0 (.NET Framework 4.5) (6.2013)

C# platform goals (from ECMA standard)

- Simple, general-purpose, object-oriented
- Correct and robust
  - strong type checking, array bounds checking, detecting usage of uninitialized variables, automated memory management, ...
- Component- and reusability-oriented
- Programmer-portable
  - easy for developers coming from C/C++ and from other .NET languages
- No direct competition with C in terms of performance
- Introduction of selected functional programming features
  - Main motivation: dealing with data conveniently

CLI: Common Language Infrastructure



.NET compatible languages compile to a second platform-neutral language called Common Intermediate Language (CIL).

The platform-specific Common Language Runtime (CLR) compiles CIL to machine-readable code that can be executed on the current platform.

- An open specification describing the executable code and runtime environment forming the .NET framework
- Implementations: MS .NET/CLR, MS .NET Compact framework (portable devices and Xbox 360), MS Silverlight (browsers), Mono (cross-platform).

CIL and Assemblies

- C# compilation produces CIL (Common Intermediate Language) code
- Instruction set similar to Java bytecode
  - object-oriented stack-based assembly code
  - richer type system, real generics vs. Java’s type erasure
- CIL code is organized in assemblies
  - for Windows platforms: .exe and .dll
- Executed by a Virtual Machine (VM)
  - .NET on Windows platforms
  - Mono for Linux/Unix
- Code generation usually with a JIT compiler
  - AOT (Ahead-Of-Time) option also available

Security

1. Of the language:
   - Restricted: no pointers, no explicit memory de-allocation, checked type casts, enforced array bounds

2. Of the runtime: CAS (Code Access Security)
   - Evidence
     - Any information associated with an assembly
       - E.g., digital signature of publisher, URL, an hash identifying the version, etc.
   - Code group
     - Associate evidences with permission types
     - Associations vary according to environment-dependent policies
3. Verification and validation
   - Series of checks that make sure that the code does not do anything clearly unsafe
     - Checks can be quite conservative: safe code may be rejected

Code generation: CLR

- CLR can denote two things:
  - the runtime component of CLI
  - Microsoft's implementation of it for Windows platforms

- A JIT compiler converts CLI bytecode into native code just before running it
  - classes and methods are compiled dynamically just when they are needed

- Alternatively, a AOT (Ahead-Of-Time) compiler translates the whole application in native code
  - NGEN (Native Image Generator) in Microsoft's CLR
  - not necessarily overall faster than JIT: certain dynamic optimization can be done only with JIT

CLR: more features

- Exception handling
- Memory management (garbage collection)
- Threads and concurrency
- Usually includes set of libraries:
  FCL (Framework Class Libraries)
- Has other languages running on top of it
  - VB.NET
  - J# (transitional language from Java to C#)
  - IronPython, IronRuby, IronScheme
  - ...

Command-line C#

- Compile

```
csc a_file.cs      // Microsoft .NET
mcs a_file.cs      // Mono .NET
```

- Execute

```
a_file.exe
./a_file.exe
```

- Generate XML documentation

```
csc /doc:docu.xml a_file.cs
mcs -doc:docu.xml a_file.cs
```

- Compile all .cs files in the current directory and pack them in a DLL

```
csc /target:library /out:a_library.dll *.cs
mcs -target:library -out:a_library.dll *.cs
```

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C#: in-the-small language features

Encoding and formatting

- Uses unicode as encoding system: www.unicode.org

- Free format
  - Blanks, tabs, new lines, form feeds are only used to keep tokens separate

- Comments
  - Single line: `//Single line comment`
  - Multiple lines:

    ```
    /* non-nested, multi-line
                comment */
    ```

  - Comment for XML documentation system:

    ```
    /** multi                  /// single-line
         line */
    ```

Identifiers

- Maximum length: 255 characters
- Can start with `_` or `@` or a letter
- Cannot start with a digit or a symbol other than `_` or `@`
- Cannot include `/` or `-`
- `@` can appear only in the first position
- Cannot be a keyword

Attributes are something else in C#

The counterparts to Java’s annotations

Meant to provide additional declarative information about program entities, which can be retrieved at run-time.

Typical usages:

- Debugging information
  e.g.: line number in the source where a method is called
  `[CallerLineNumber]`
- Information for code analysis/compilation
  e.g.: to compile certain code only in debugging mode
  `[Conditional (“DEBUG”)]`
- Compiler flags
  e.g.: to generate a warning during compilation
  `[Obsolete (“You should use class X instead”)]`

Keywords

abstract	as	base	bool
break	by	byte	case
catch	char	checked	class
const	continue	decimal	default
delegate	do	double	descending
explicit	event	extern	else
enum	false	finally	fixed
float	for	foreach	from
goto	group	if	implicit
in	int	interface	internal
into	is	lock	long
new	null	namespace	object
operator	out	override	orderby
params	private	protected	public
readonly	ref	return	switch
struct	sbyte	sealed	short
sizeof	stackalloc	static	string
select	this	throw	true
try	typeof	uint	ulong
unchecked	unsafe	ushort	using
var	virtual	volatile	void
while	where	yield	

Operators

- Primary: `.`, `()`, `[]`, `x++`, `x--`, `new`, `typeof`, `checked`, `unchecked`
- Unary: `+`, `-`, `!`, `~`, `++x`, `--x`, `(aType)x`
- Multiplicative: `*`, `/`, `%`
- Additive: `+`, `-`
- Shift: <<, >>
- Relational: `<`, `>`, `<=`, `>=`, `is`, `as`
- Equality: `==`, `!=`
- Logical (precedence left to right): `&`, `^`, `|`, `&&`, `||`
- Conditional: *`condition ? (expr1):(expr2)`*
- Assignment: `=`, `+=`, `-=`, `*=`, `/=`, `%=`, `&=`, `|=`, `^=`, `<<=`, `>>=`
- Precedence: from top to bottom
- Tip: don’t rely too much on precedence rules: use parentheses

Overflow handling

```
int i = 2147483647 + 10; // compiler error
int ten = 10
int j = 2147483647 + ten; /* no compiler error.
Result: -2147483639. Overflow checking can be
enabled by compiler options, environment
configuration or the checked keyword. */
Console.WriteLine(checked(2147483647 + ten));
// OverflowException
Console.WriteLine(unchecked(2147483647 + 10));
// no compiler error. Result: -2147483639
```

Type system: value types

- Basic value types
  - **sbyte, short, int, long, byte, ushort, uint, ulong, decimal, float, double, bool, char**
  - **struct**
  - **enum**

- Nullable types for value types

```
int? n = null; ...
if (n != null){int m = n.Value}

int p = n ?? 7 //null coalescing operator:
//if n != null p = n, otherwise p = 7
```

Type system: reference types

- `[]` (array)
- `class`
- `interface`
- `delegate`
- `event`
- Pointers
  - restricted to blocks marked `unsafe`
  - `unsafe` blocks can be executed only with certain permissions enabled

Widening conversions with precision loss

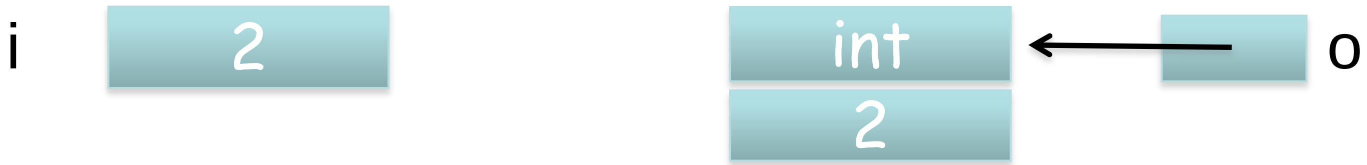
```
float g(int x){
     return x;
}
...
int i = 1234567890;
float f = g(i);
Console.writeline(i - (int)f)
// output: -46
...
```

Boxing and unboxing

- Variables of value types are stored on the stack
- Variables of reference types are stored on the heap

- Boxing transforms a value type into a reference of type `object` and is implicit

```
int i = 2;        object o = i;
```



- Unboxing transforms a reference of type `object` into a value type and requires a cast

```
object o = 3;        int i = (int)o;
```

Control flow: conditional branch

Same syntax as in C/C++/Java

```
if  (booleanExpr)
{
     // do something
}
else // else is optional
{
     // do something else
}
```

Control flow: loops

```
while (booleanExpr)
{
      // execute body
      // until booleanExpr becomes false
}



do
{
      // execute body (at least once)
      // until booleanExpr becomes false
}
while (booleanExpr);
```

Control flow: `for` loop

```
for (int i=0; i < n; i++)
{
     // execute loop body n times
}

// equivalent to the following
int i=0;
while (i < n)
{
      // execute loop body n times
      i++;
}
```

Control flow: **foreach** loop

```
foreach (variable in collection)
{
        // loop body
}
```

- **collection** is an array or an object of a class that implements **IEnumerable**

- Executes the loop body for every element of the **collection**, assigned iteratively to **variable**

Control flow: switch selector

```
switch  (Expr)  {
      case value: instructions;
            break;
      case value: instructions;
             break;
      // ...
      default: instructions;
             break;
}
```

- **Expr** can be an integer or **string** expression
- **break** is required after each non-empty block
  - Including the **default** block
  - Fall through forbidden
    unless an **instructions** block is empty

Breaking the control flow: `break` and `continue`

`break;`

- Within a loop or a switch
- Exit the loop or switch

`continue;`

- Within a loop
- Skip the remainder of the current iteration and continue with the next iteration

Breaking the control flow: `goto`

`Label: instruction`

- Identifies an instruction (possibly compound, such as a loop)

`goto Label;`

- Anywhere
- Transfer control directly to the labeled statement

```
goto case value;
goto default;
```

- Within a `switch` (replacing standard `break` terminator)
- Transfer control to the corresponding `case` or to the `default`