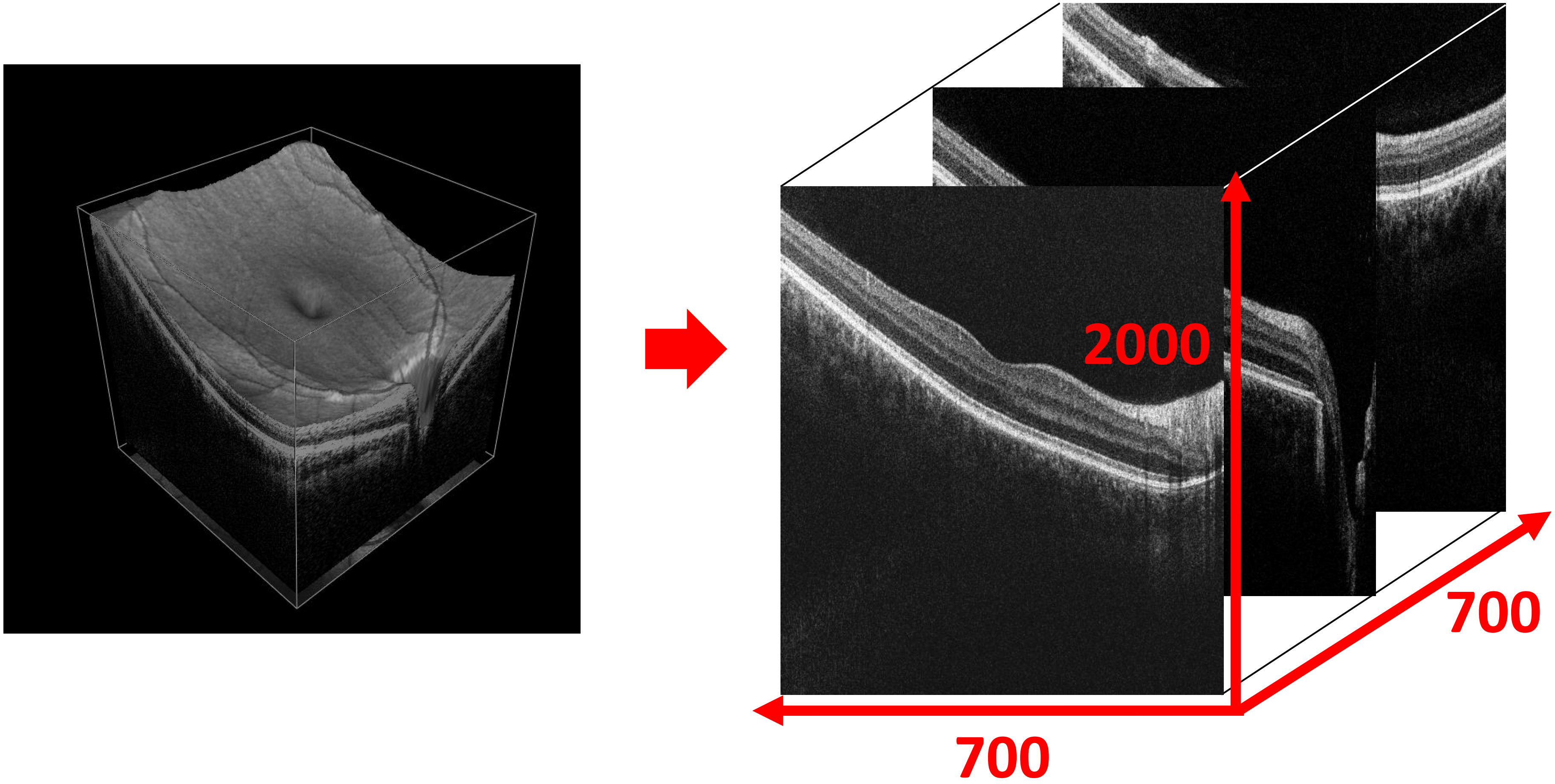
Dwa oblicza szybkości: czyli jak i dlaczego łączyć C++ z C#

Zygfryd Wieszok

O mnie

- Politechnika Śląska
- Cranfield University
- 2 lata doświadczenia z wizją komputerową w Canon OT

Optyczna tomografia oka



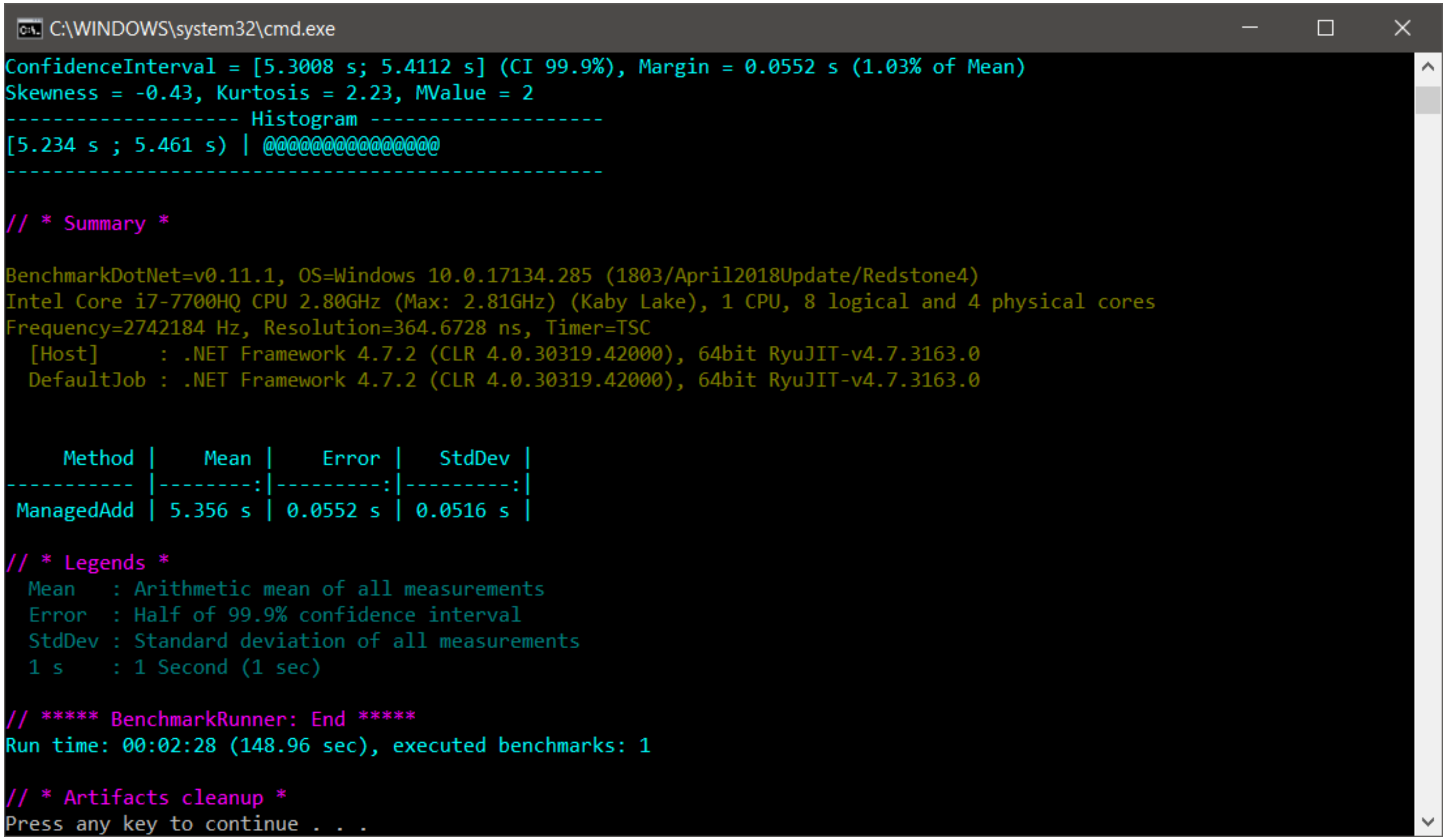
$$700 * 2000 * 700 \approx 1GB\ pikseli$$

Obrazy pochodzą z ***Ophthalmic Software Platform for HS-100,*** Canon

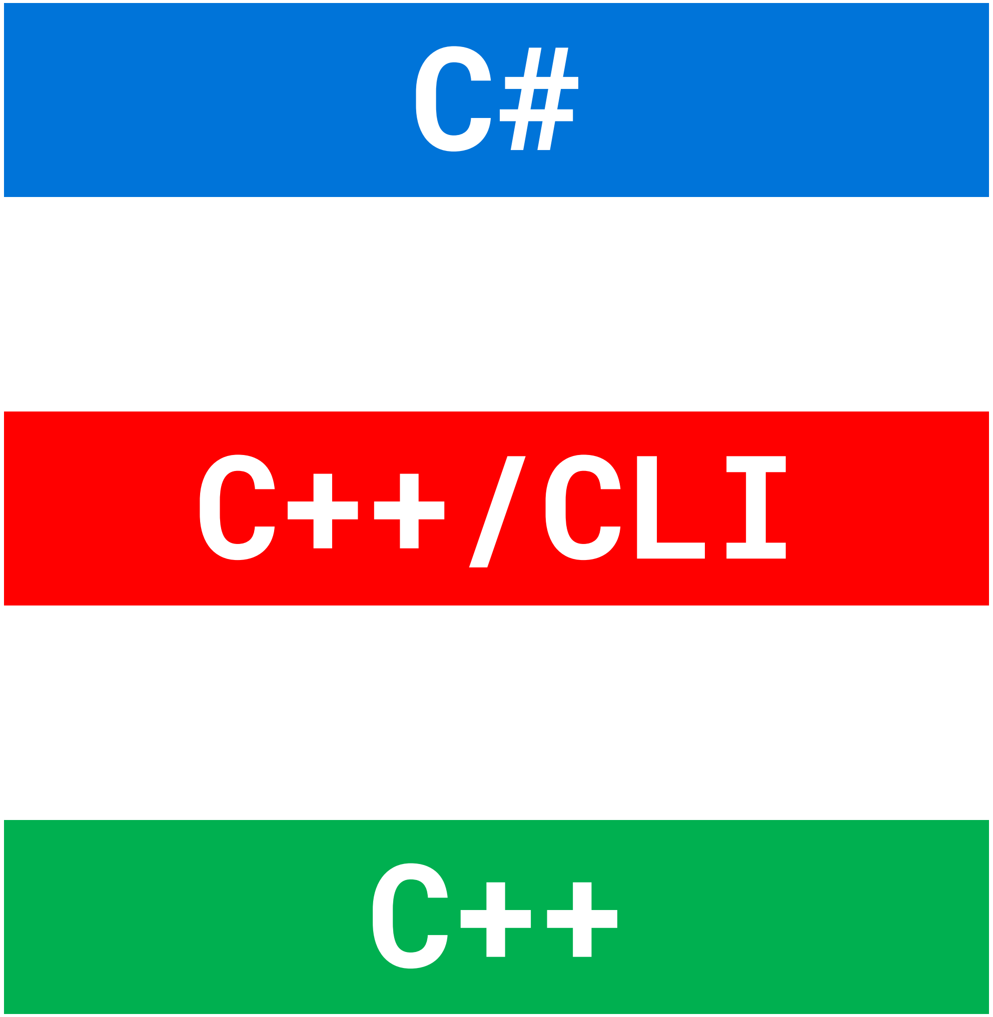
BenchmarkDotNet

```
public class AdditionBenchmark{
  private const int N = 1024 * 1024 * 1024;
  private readonly byte[] argument1;
  private readonly byte[] argument2;
  private readonly byte[] result;

  public AdditionBenchmark(){
    argument1 = new byte[N];
    argument2 = new byte[N];
    result = new byte[N];

    var random = new Random(43);
    random.NextBytes(argument1);
    random.NextBytes(argument2);
  }

  [Benchmark]
  public void ManagedAdd(){
    //  Todo: Add benchmarked code
  }
}
```

```
class Program{
  static void Main(string[] args){
    BenchmarkRunner.Run<AdditionBenchmark>();
  }
}
```



```
ConfidenceInterval = [5.3008 s; 5.4112 s] (CI 99.9%), Margin = 0.0552 s (1.03% of Mean)
Skewness = -0.43, Kurtosis = 2.23, MValue = 2
-------------------- Histogram --------------------
[5.234 s ; 5.461 s) | @@@@@@@@@@@@@@@
---------------------------------------------------

// * Summary *

BenchmarkDotNet=v0.11.1, OS=Windows 10.0.17134.285 (1803/April2018Update/Redstone4)
Intel Core i7-7700HQ CPU 2.80GHz (Max: 2.81GHz) (Kaby Lake), 1 CPU, 8 logical and 4 physical cores
Frequency=2742184 Hz, Resolution=364.6728 ns, Timer=TSC
  [Host]     : .NET Framework 4.7.2 (CLR 4.0.30319.42000), 64bit RyuJIT-v4.7.3163.0
  DefaultJob : .NET Framework 4.7.2 (CLR 4.0.30319.42000), 64bit RyuJIT-v4.7.3163.0


     Method |    Mean |     Error |    StdDev |
----------- |--------:|----------:|----------:|
 ManagedAdd | 5.356 s | 0.0552 s | 0.0516 s |

// * Legends *
  Mean   : Arithmetic mean of all measurements
  Error  : Half of 99.9% confidence interval
  StdDev : Standard deviation of all measurements
  1 s    : 1 Second (1 sec)

// ***** BenchmarkRunner: End *****
Run time: 00:02:28 (148.96 sec), executed benchmarks: 1

// * Artifacts cleanup *
Press any key to continue . . .
```



C#

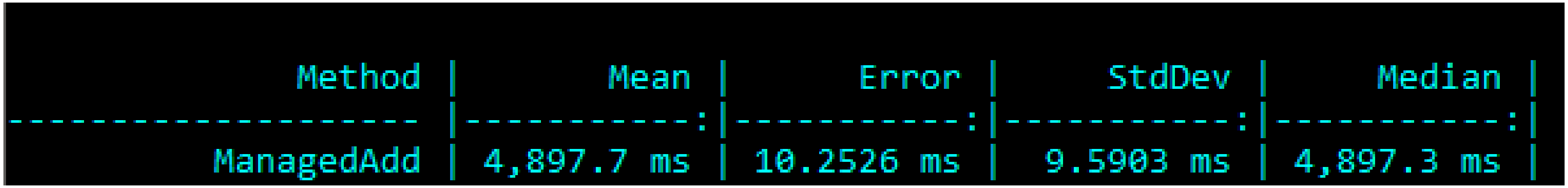
C++/CLI

C++

Prosta implementacja C#

C#

```
[Benchmark]
public void ManagedAdd()
{
   for (int i = 0; i < N; i++)
   {
       var value = argument1[i] + argument2[i];
       result[i] = value <= byte.MaxValue ?
                             (byte) value : byte.MaxValue;
   }
}
```

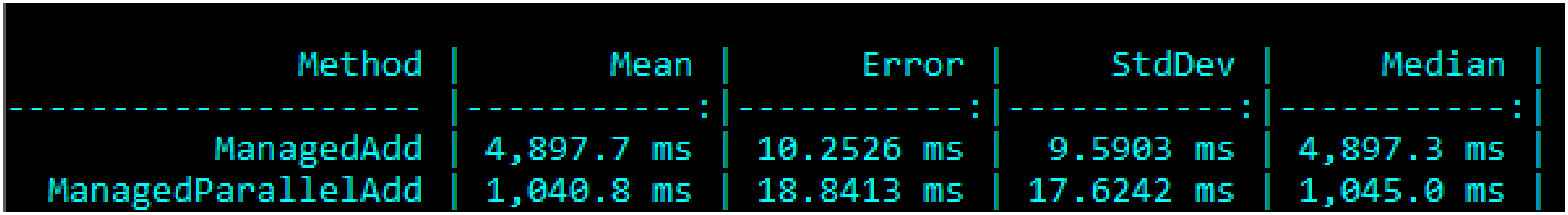


```
              Method |        Mean |       Error |      StdDev |      Median |
-------------------- |-----------:|-----------:|-----------:|-----------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
```

C# wielowątkowo

C#

```
[Benchmark]
public void ManagedParallelAdd()
{
  var partitioner = Partitioner.Create(0, N);
  Parallel.ForEach(partitioner, range =>
  {
    for (int i = range.Item1; i < range.Item2; i++)
    {
      var value = argument1[i] + argument2[i];
      result[i] = value <= byte.MaxValue ?
                                 (byte)value : byte.MaxValue;
    }
  });
}
```



```
              Method |       Mean |      Error |     StdDev |     Median |
-------------------- |-----------:|-----------:|-----------:|-----------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
  ManagedParallelAdd | 1,040.8 ms | 18.8413 ms | 17.6242 ms | 1,045.0 ms |
```

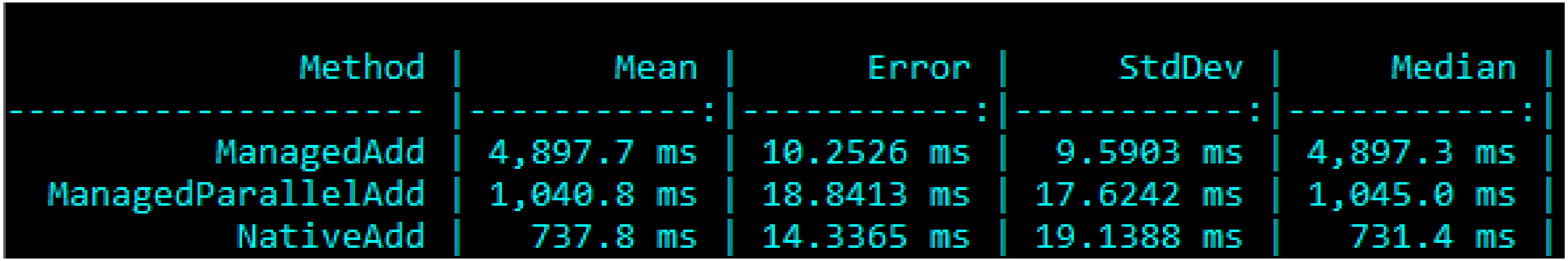
Implementacja C++

C++

```
void NativeAdd(uint8_t * arg1, uint8_t * arg2,
               uint8_t * dst,  int length)
{
   const auto charMax = std::numeric_limits<uint8_t>::max();
   for (int i = 0; i < length; i++)
   {
       int value = arg1[i] + arg2[i];
       dst[i] = value < charMax ? value : charMax;
   }
}
```

C#

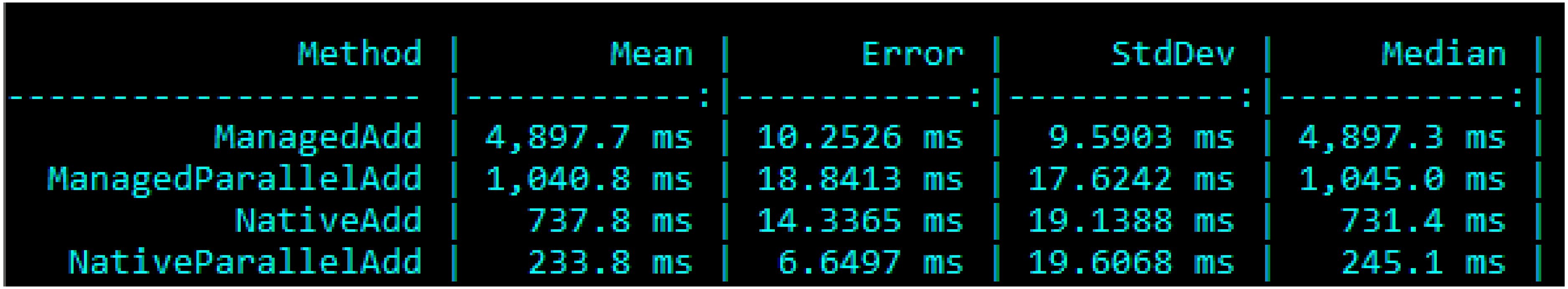
```
[Benchmark]
public void NativeAdd()
{
   NativeLib.NativeAdd(argument1, argument2, result, N);
}
```



```
              Method |        Mean |      Error |     StdDev |      Median |
-------------------- |------------:|-----------:|-----------:|------------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
  ManagedParallelAdd | 1,040.8 ms | 18.8413 ms | 17.6242 ms | 1,045.0 ms |
           NativeAdd |    737.8 ms | 14.3365 ms | 19.1388 ms |    731.4 ms |
```

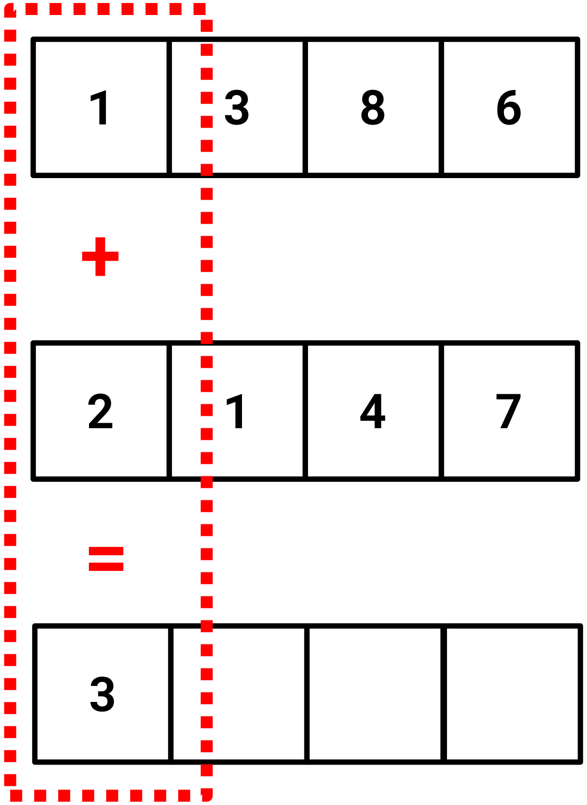
C++ wielowątkowo

```
void NativeParallelAdd(uint8_t * arg1, uint8_t * arg2,    C++
                       uint8_t * dst, int length)
{
  const auto charMax = std::numeric_limits<uint8_t>::max();

  #pragma omp parallel for
  for (int i = 0; i < length; i++)
  {
     int value = arg1[i] + arg2[i];
     dst[i] = value < charMax ? value : charMax;
  }
}
```



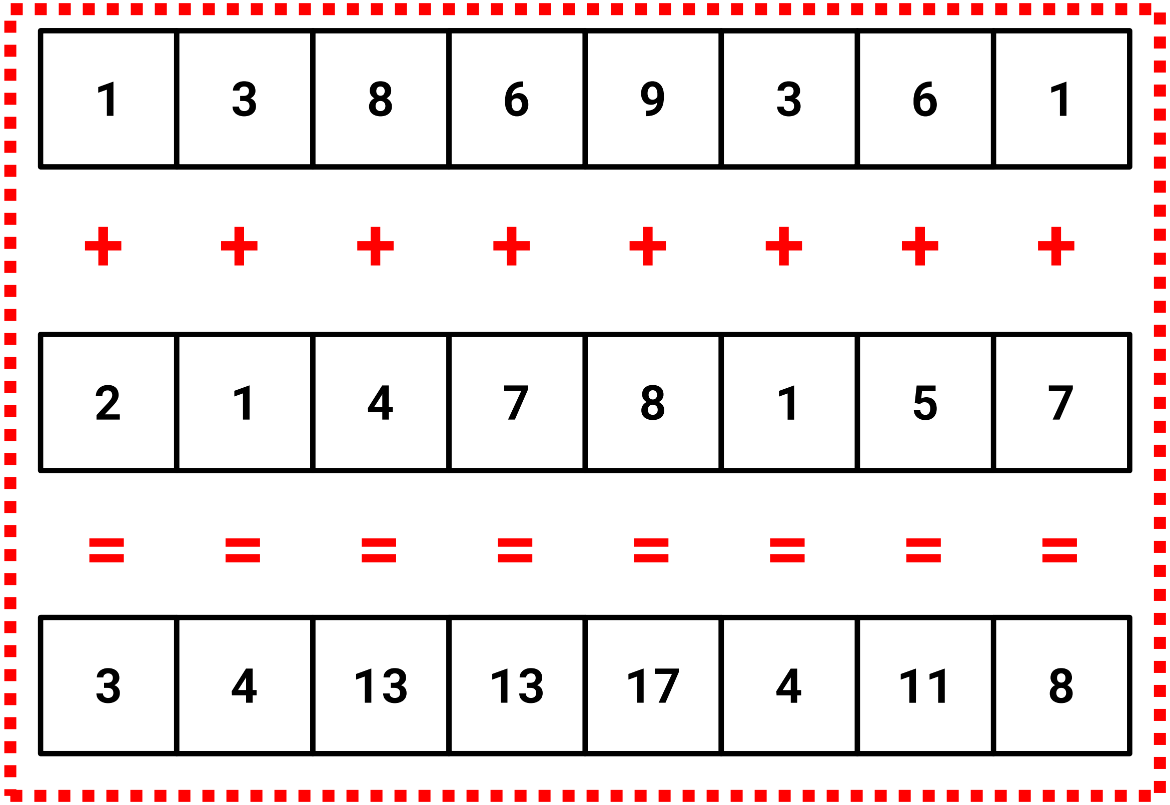
```
              Method |       Mean |      Error |     StdDev |     Median |
-------------------- |-----------:|-----------:|-----------:|-----------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
  ManagedParallelAdd | 1,040.8 ms | 18.8413 ms | 17.6242 ms | 1,045.0 ms |
           NativeAdd |   737.8 ms | 14.3365 ms | 19.1388 ms |   731.4 ms |
   NativeParallelAdd |   233.8 ms |  6.6497 ms | 19.6068 ms |   245.1 ms |
```

Scalar mode



1	3	8	6
+			
2	1	4	7
=			
3			

SIMD mode [MMX 64b]



1	3	8	6	9	3	6	1
+	+	+	+	+	+	+	+
2	1	4	7	8	1	5	7
=	=	=	=	=	=	=	=
3	4	13	13	17	4	11	8

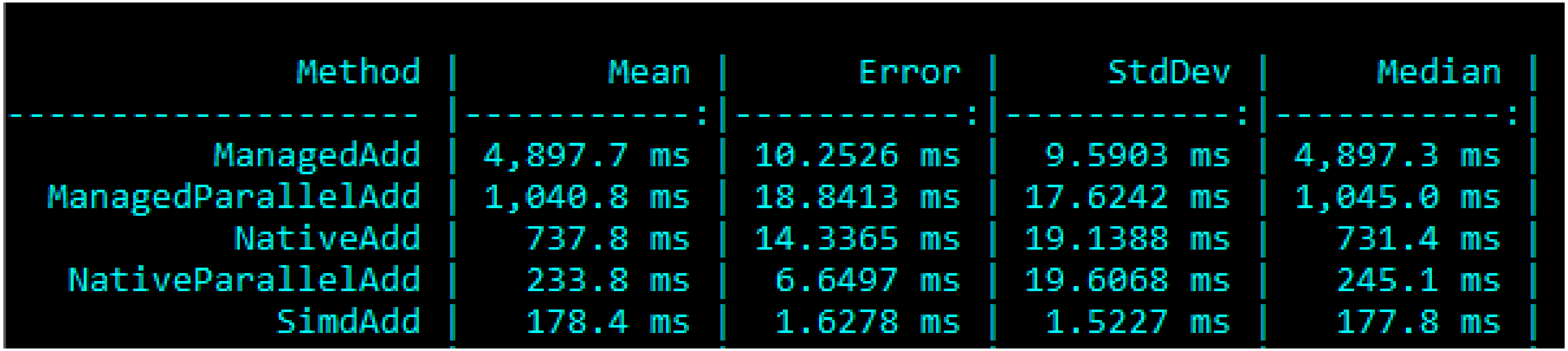
C++

```
void SimdAdd(uint8_t * arg1, uint8_t * arg2,
             uint8_t * dst, int length)
{
    __m128i* arg1Ptr = reinterpret_cast<__m128i*>(arg1);
    __m128i* arg2Ptr = reinterpret_cast<__m128i*>(arg2);
    __m128i* dstPtr  = reinterpret_cast<__m128i*>(dst);

    int i = 0;
    for (; i < length; i += 128 / 8) {
        __m128i a = _mm_loadu_si128(arg1Ptr);
        __m128i b = _mm_loadu_si128(arg2Ptr);
        __m128i c = _mm_adds_epu8(a, b);
        _mm_storeu_si128(dstPtr, c);
        arg1Ptr++;
        arg2Ptr++;
        dstPtr++;
    }

    // Add the remaining part of array indivisible by SIMD size
    auto charMax = std::numeric_limits<uint8_t>::max();
    for (; i < length; i++) {
        int value = arg1[i] + arg2[i];
        dst[i] = value < charMax ? value : charMax;
    }
}
```

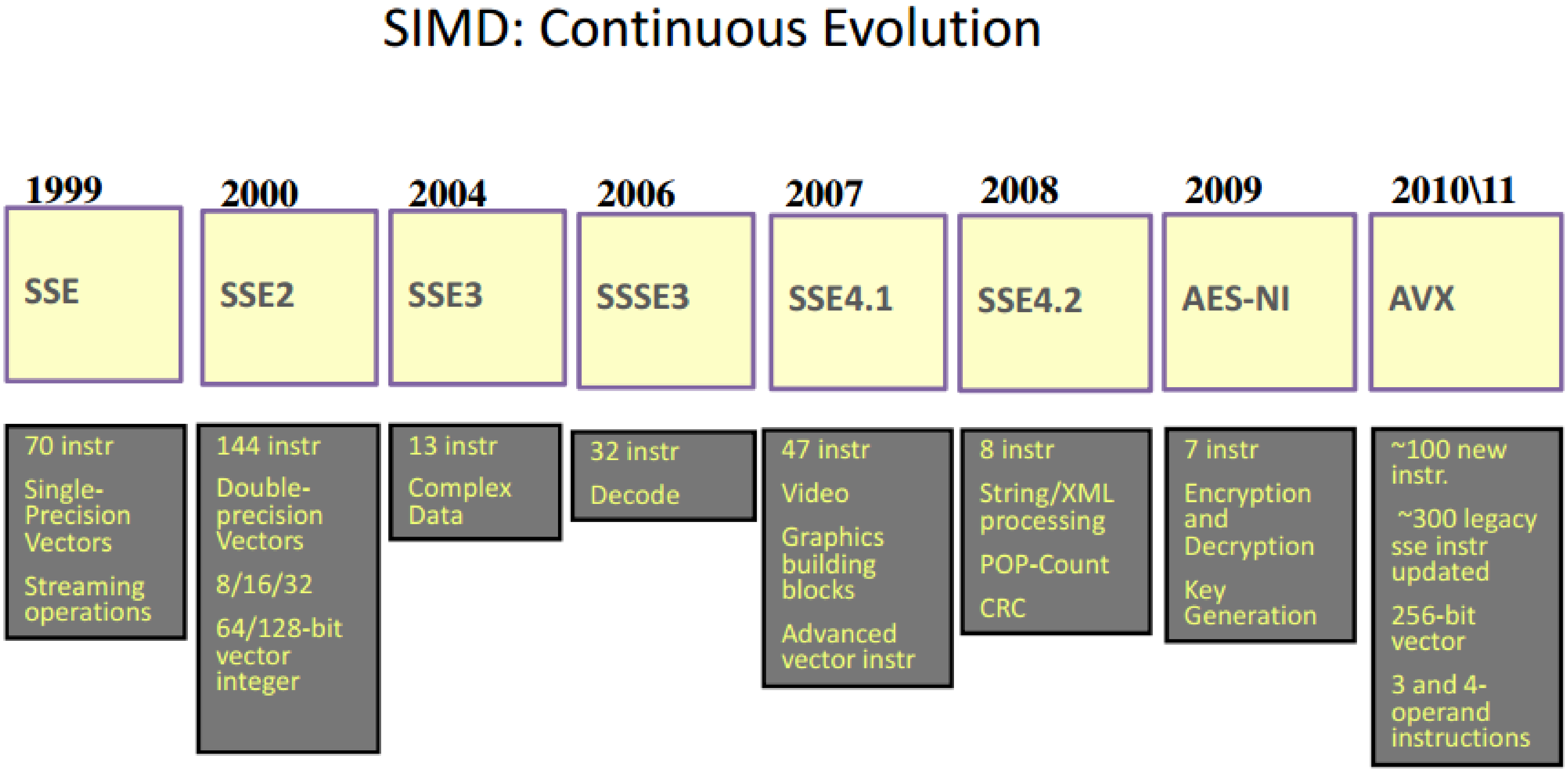
```
int i = 0;
for (; i < length; i += 128 / 8) {
     __m128i a = _mm_loadu_si128(arg1Ptr);
     __m128i b = _mm_loadu_si128(arg2Ptr);
     __m128i c = _mm_adds_epu8(a, b);
     _mm_storeu_si128(dstPtr, c);
     arg1Ptr++;
     arg2Ptr++;
     dstPtr++;
 }
```

C++

```cpp
void SimdAdd(uint8_t * arg1, uint8_t * arg2,
             uint8_t * dst, int length)
{
    __m128i* arg1Ptr = reinterpret_cast<__m128i*>(arg1);
    __m128i* arg2Ptr = reinterpret_cast<__m128i*>(arg2);
    __m128i* dstPtr  = reinterpret_cast<__m128i*>(dst);

    int i = 0;
    for (; i < length; i += 128 / 8) {
        __m128i a = _mm_loadu_si128(arg1Ptr);
        __m128i b = _mm_loadu_si128(arg2Ptr);
        __m128i c = _mm_adds_epu8(a, b);
        _mm_storeu_si128(dstPtr, c);
        arg1Ptr++;
        arg2Ptr++;
        dstPtr++;
    }

    // Add the remaining part of array indivisible by SIMD size
    auto charMax = std::numeric_limits<uint8_t>::max();
    for (; i < length; i++) {
        int value = arg1[i] + arg2[i];
        dst[i] = value < charMax ? value : charMax;
    }
}
```



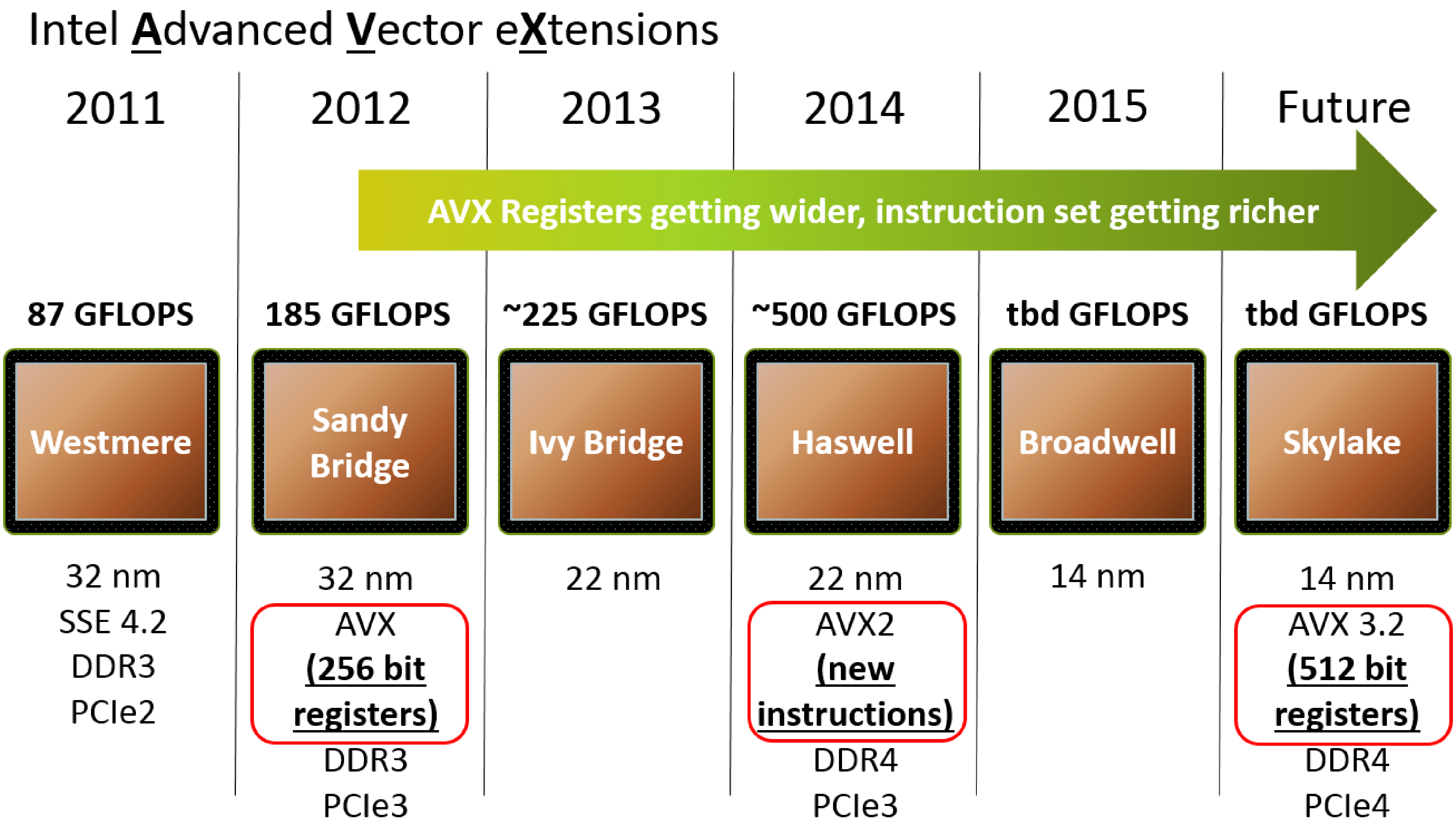
```
              Method |       Mean |      Error |     StdDev |     Median |
-------------------- |-----------:|-----------:|-----------:|-----------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
  ManagedParallelAdd | 1,040.8 ms | 18.8413 ms | 17.6242 ms | 1,045.0 ms |
           NativeAdd |   737.8 ms | 14.3365 ms | 19.1388 ms |   731.4 ms |
   NativeParallelAdd |   233.8 ms |  6.6497 ms | 19.6068 ms |   245.1 ms |
             SimdAdd |   178.4 ms |  1.6278 ms |  1.5227 ms |   177.8 ms |
```



SIMD: Continuous Evolution

1999	2000	2004	2006	2007	2008	2009	2010\11
SSE	SSE2	SSE3	SSSE3	SSE4.1	SSE4.2	AES-NI	AVX
70 instr Single-Precision Vectors Streaming operations	144 instr Double-precision Vectors 8/16/32 64/128-bit vector integer	13 instr Complex Data	32 instr Decode	47 instr Video Graphics building blocks Advanced vector instr	8 instr String/XML processing POP-Count CRC	7 instr Encryption and Decryption Key Generation	~100 new instr. ~300 legacy sse instr updated 256-bit vector 3 and 4-operand instructions

Obraz pochodzi z Intel White Paper: “The Significance of SIMD, SSE and AVX”



Intel Advanced Vector eXtensions

AVX Registers getting wider, instruction set getting richer

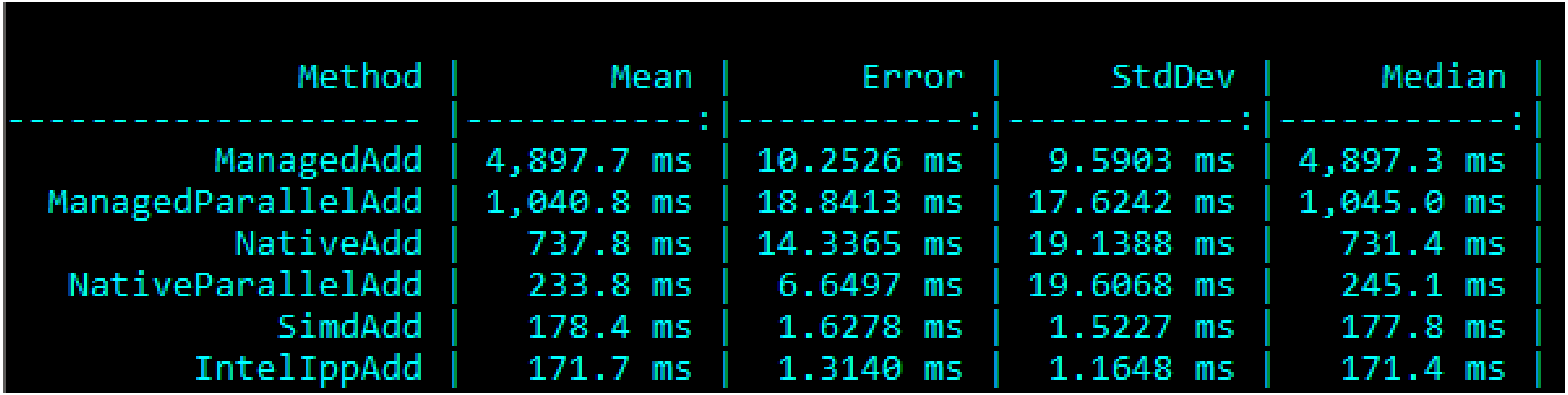
2011	2012	2013	2014	2015	Future
87 GFLOPS	**185 GFLOPS**	**~225 GFLOPS**	**~500 GFLOPS**	**tbd GFLOPS**	**tbd GFLOPS**
Westmere	**Sandy Bridge**	**Ivy Bridge**	**Haswell**	**Broadwell**	**Skylake**
32 nm	32 nm	22 nm	22 nm	14 nm	14 nm
SSE 4.2	AVX **(256 bit registers)**		AVX2 **(new instructions)**		AVX 3.2 **(512 bit registers)**
DDR3	DDR3		DDR4		DDR4
PCIe2	PCIe3		PCIe3		PCIe4

Obraz pochodzi z Intel White Paper: “The Significance of SIMD, SSE and AVX”

Intel IPP

C++

```
void IntelIppAdd(uint8_t * arg1, uint8_t * arg2,
                 uint8_t * dst, int length)
{
    ippsAdd_8u_Sfs(arg1, arg2, dst, length, 0);
}
```

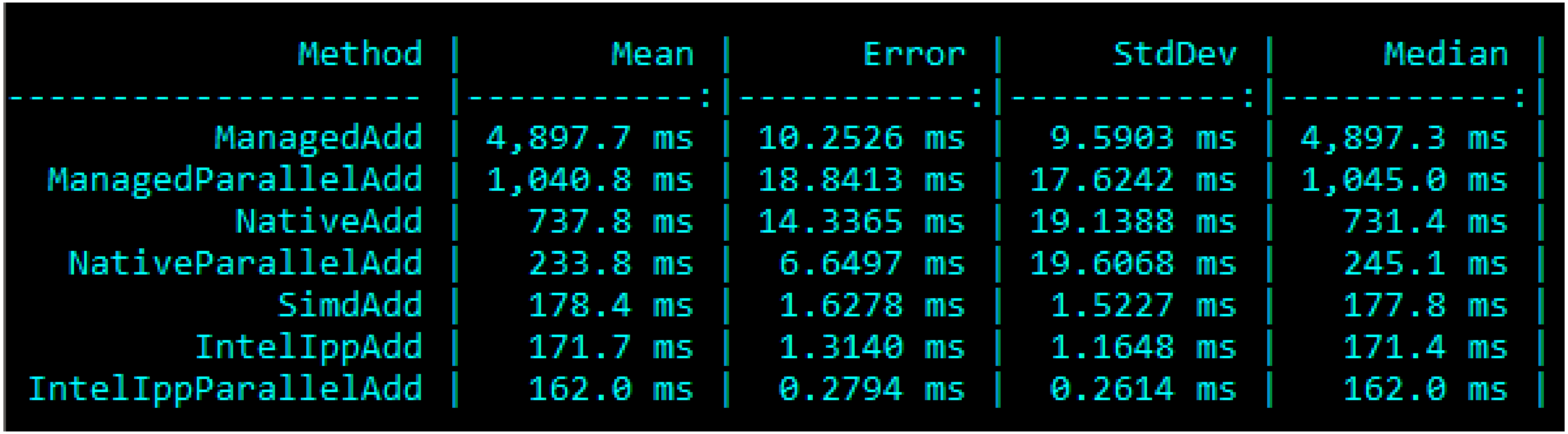


```
              Method |       Mean |      Error |     StdDev |     Median |
-------------------- |-----------:|-----------:|-----------:|-----------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
  ManagedParallelAdd | 1,040.8 ms | 18.8413 ms | 17.6242 ms | 1,045.0 ms |
           NativeAdd |   737.8 ms | 14.3365 ms | 19.1388 ms |   731.4 ms |
   NativeParallelAdd |   233.8 ms |  6.6497 ms | 19.6068 ms |   245.1 ms |
             SimdAdd |   178.4 ms |  1.6278 ms |  1.5227 ms |   177.8 ms |
         IntelIppAdd |   171.7 ms |  1.3140 ms |  1.1648 ms |   171.4 ms |
```

IPP wielowątkowo

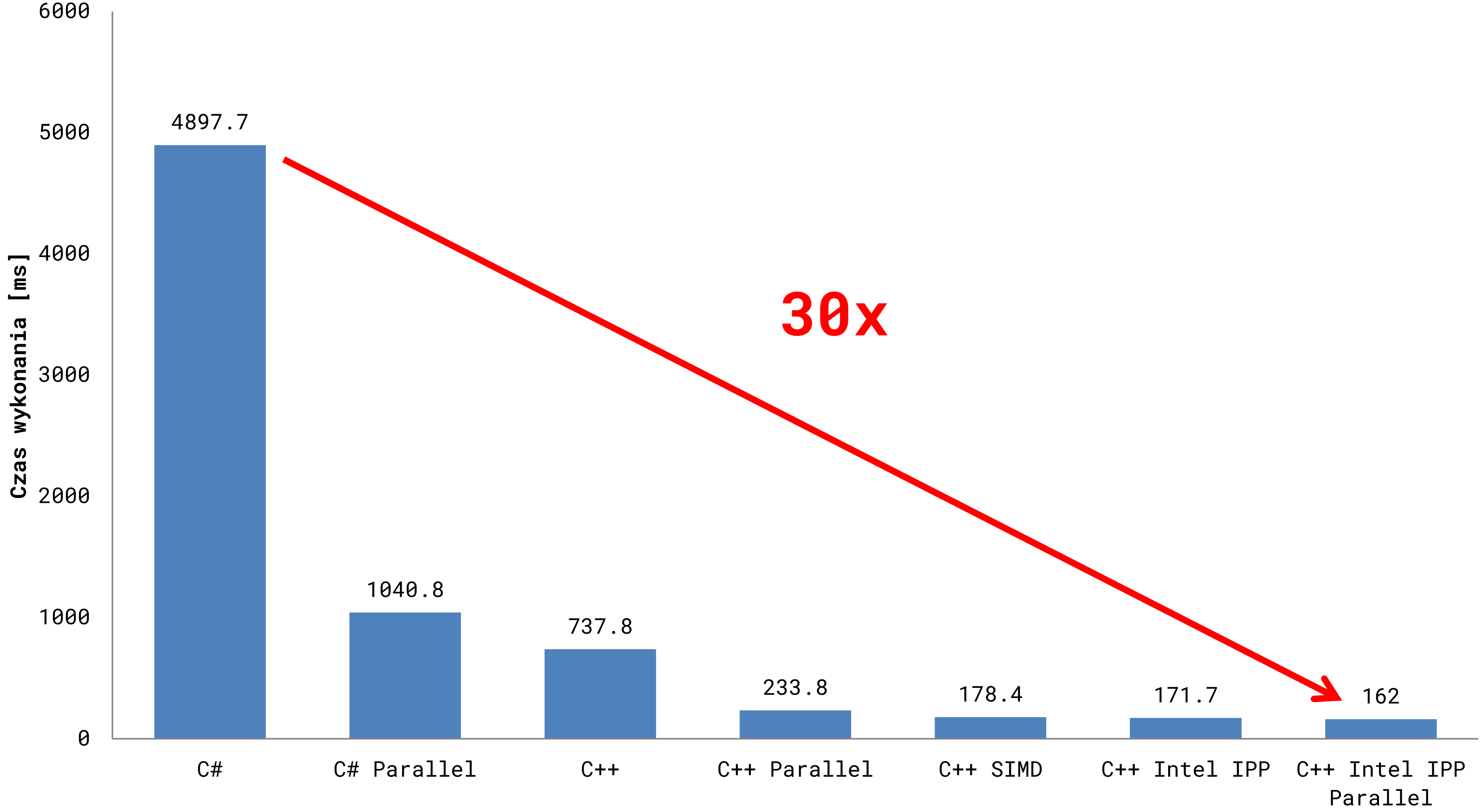
C++

```
void IntelIppParallelAdd(uint8_t * arg1, uint8_t * arg2,
                         uint8_t * dst, int length)
{
    int blockSize = 4096;
    int blockCount = length / blockSize;

    #pragma omp parallel for
    for (int n = 0; n < blockCount; ++n)
        ippsAdd_8u_Sfs(arg1 + n * blockSize, arg2 + n * blockSize,
                       dst + n * blockSize, blockSize, 0);


    // Add the remaining part of array indivisible by block size
    auto remainOffset = blockCount * blockSize;
    int remainLength = length - remainOffset;
    ippsAdd_8u_Sfs(arg1 + remainOffset, arg2 + remainOffset,
                  dst + remainOffset, remainLength, 0);
}
```



```
              Method |       Mean |      Error |     StdDev |     Median |
-------------------- |-----------:|-----------:|-----------:|-----------:|
          ManagedAdd | 4,897.7 ms | 10.2526 ms |  9.5903 ms | 4,897.3 ms |
  ManagedParallelAdd | 1,040.8 ms | 18.8413 ms | 17.6242 ms | 1,045.0 ms |
           NativeAdd |   737.8 ms | 14.3365 ms | 19.1388 ms |   731.4 ms |
   NativeParallelAdd |   233.8 ms |  6.6497 ms | 19.6068 ms |   245.1 ms |
             SimdAdd |   178.4 ms |  1.6278 ms |  1.5227 ms |   177.8 ms |
         IntelIppAdd |   171.7 ms |  1.3140 ms |  1.1648 ms |   171.4 ms |
 IntelIppParallelAdd |   162.0 ms |  0.2794 ms |  0.2614 ms |   162.0 ms |
```

Benchmark


6000
5000
4000
3000
2000
1000
0
Czas wykonania [ms]
4897.7
1040.8
737.8
233.8
178.4
171.7
162
30x
C#
C# Parallel
C++
C++ Parallel
C++ SIMD
C++ Intel IPP
C++ Intel IPP Parallel

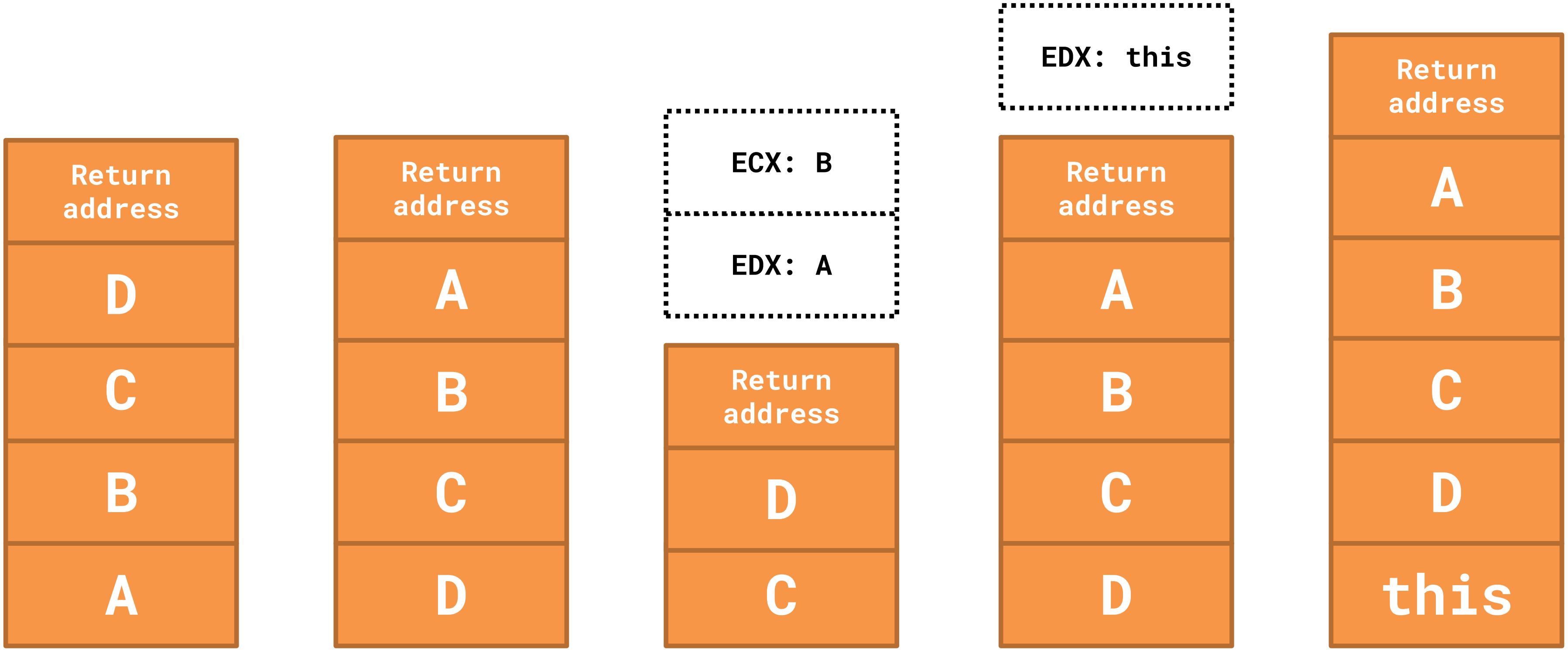
Wywołanie C++ z C#

```
#ifdef NATIVELIB_EXPORTS
#define NATIVELIB_API __declspec(dllexport)
#else
#define NATIVELIB_API __declspec(dllimport)
#endif

void NATIVELIB_API NativeAdd(uint8_t * arg1, uint8_t * arg2,
                             uint8_t * dst, int length);
```

C#

```
using System.Runtime.InteropServices;
public static class NativeLib
{
    [DllImport("NativeLib.dll",
               CallingConvention = CallingConvention.Cdecl)]
     public static extern void NativeAdd(byte[] arg1, byte[] arg2,
                                         byte[] arg3, int length);
}
```

Fun(A,B,C,D)



Return address
D
C
B
A

Return address
A
B
C
D

ECX: B
EDX: A
Return address
D
C

EDX: this
Return address
A
B
C
D

Return address
A
B
C
D
this

	stdcall	cdecl	fastcall	VC++ thiscall	GCC thiscall
Stack cleaning:	callee	caller	callee	callee	caller

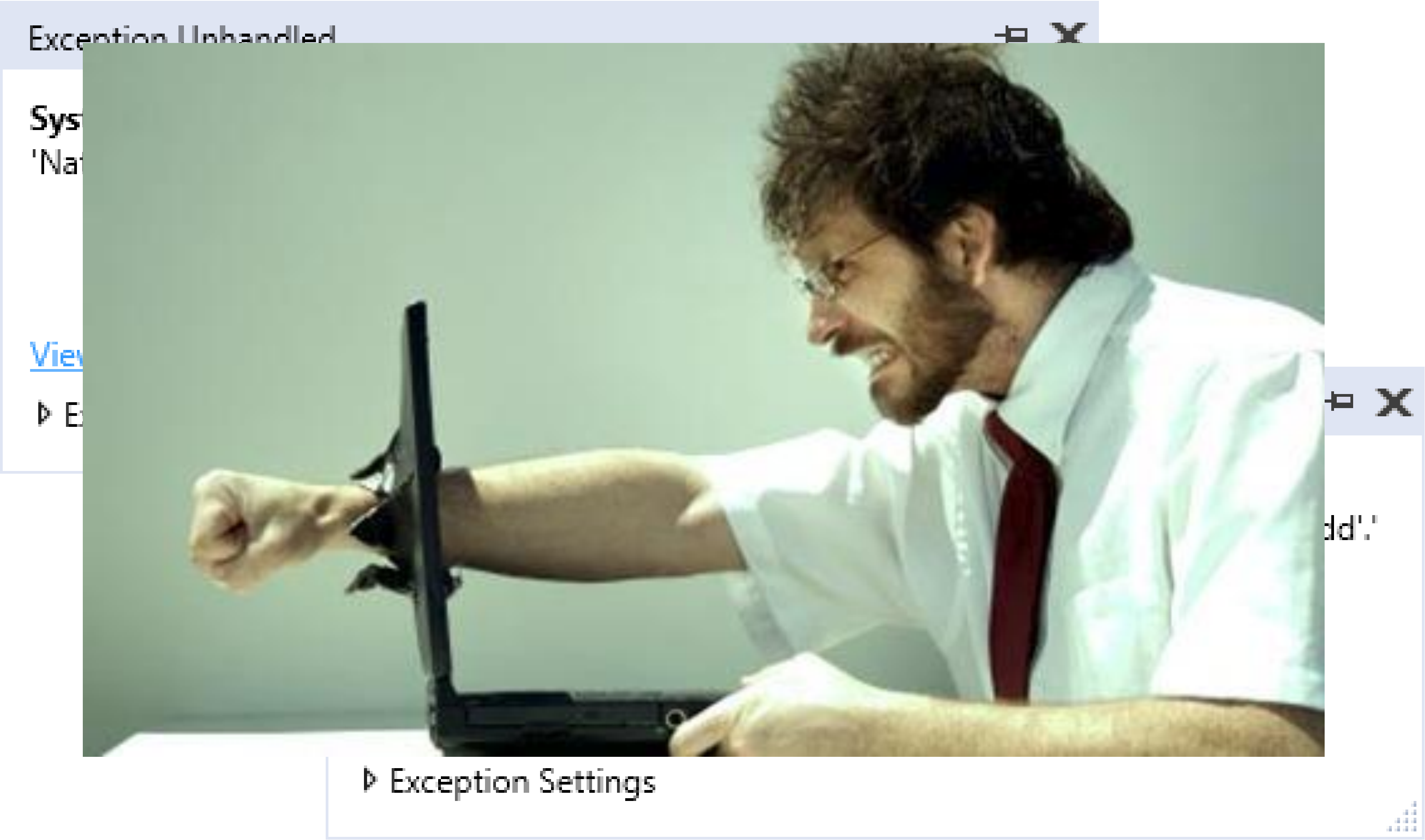
Wywołanie C++ z C#

```
#ifdef NATIVELIB_EXPORTS
#define NATIVELIB_API __declspec(dllexport)
#else
#define NATIVELIB_API __declspec(dllimport)
#endif

void NATIVELIB_API NativeAdd(uint8_t * arg1, uint8_t * arg2,
                             uint8_t * dst, int length);
```

C#

```
using System.Runtime.InteropServices;
public static class NativeLib
{
    [DllImport("NativeLib.dll",
               CallingConvention = CallingConvention.Cdecl)]
     public static extern void NativeAdd(byte[] arg1, byte[] arg2,
                                         byte[] arg3, int length);
}
```

Compile and RUN!



Exception Unhandled

Sys
'Nat

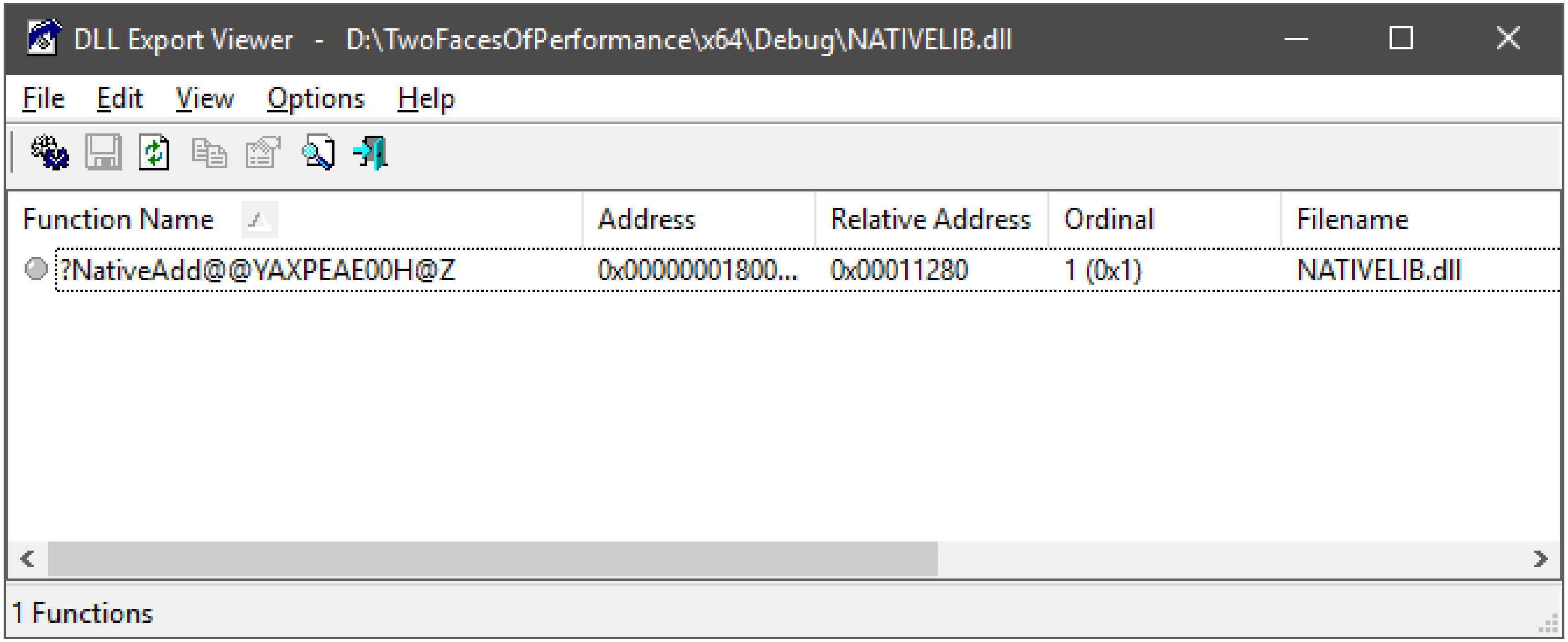
Viev

E

dd'.'

Exception Settings

Dll Export Viewer



DLL Export Viewer - D:\TwoFacesOfPerformance\x64\Debug\NATIVELIB.dll

Function Name	Address	Relative Address	Ordinal	Filename
?NativeAdd@@YAXPEAE00H@Z	0x0000001800...	0x00011280	1 (0x1)	NATIVELIB.dll

1 Functions

NativeAdd -> ?NativeAdd@@YAXPEAE00H@Z

C#

```
using System.Runtime.InteropServices;
public static class NativeLib
{
   [DllImport("NativeLib.dll",
               CallingConvention = CallingConvention.Cdecl
                EntryPoint="?Name@@YAXPEAM00H@Z")]
    public static extern void NativeAdd(byte[] arg1, byte[] arg2,
                                        byte[] arg3, int length);
}
```

LUB

C++

```
#ifdef NATIVELIB_EXPORTS
#define EXPORT_API __declspec(dllexport)
#else
#define EXPORT_API __declspec(dllimport)
#endif

extern “C”{
  void EXPORT_API NativeAdd(unsigned char * arg1, unsigned char * arg2,
                             unsigned char * dst, int length);
}
```

A co z klasami?

C++

```
class NATIVELIB_API NativeCalculator
{
public:
  void Add(
           unsigned char* arg1,
           unsigned char* arg2,
           unsigned char* dst,
           int length);

  void Sum(
           const std::vector<unsigned char*>& arguments,
           unsigned char* dst,
           int length);
};
```

C++

```
extern „C”{
  void* NATIVELIB_API CreateCalculator()
  {
    return new NativeCalculator();
  }


  void AddCalculator(void* object, uint8_t* arg1,
           uint8_t* arg2,uint8_t* dst, int length)
  {
    auto calc = (NativeCalculator*)object;
    calc->Add(arg1, arg2, dst, length);
  }

  […]

  void NATIVELIB_API ReleaseCalculator(void* object)
  {
    delete object;
  }
}
```

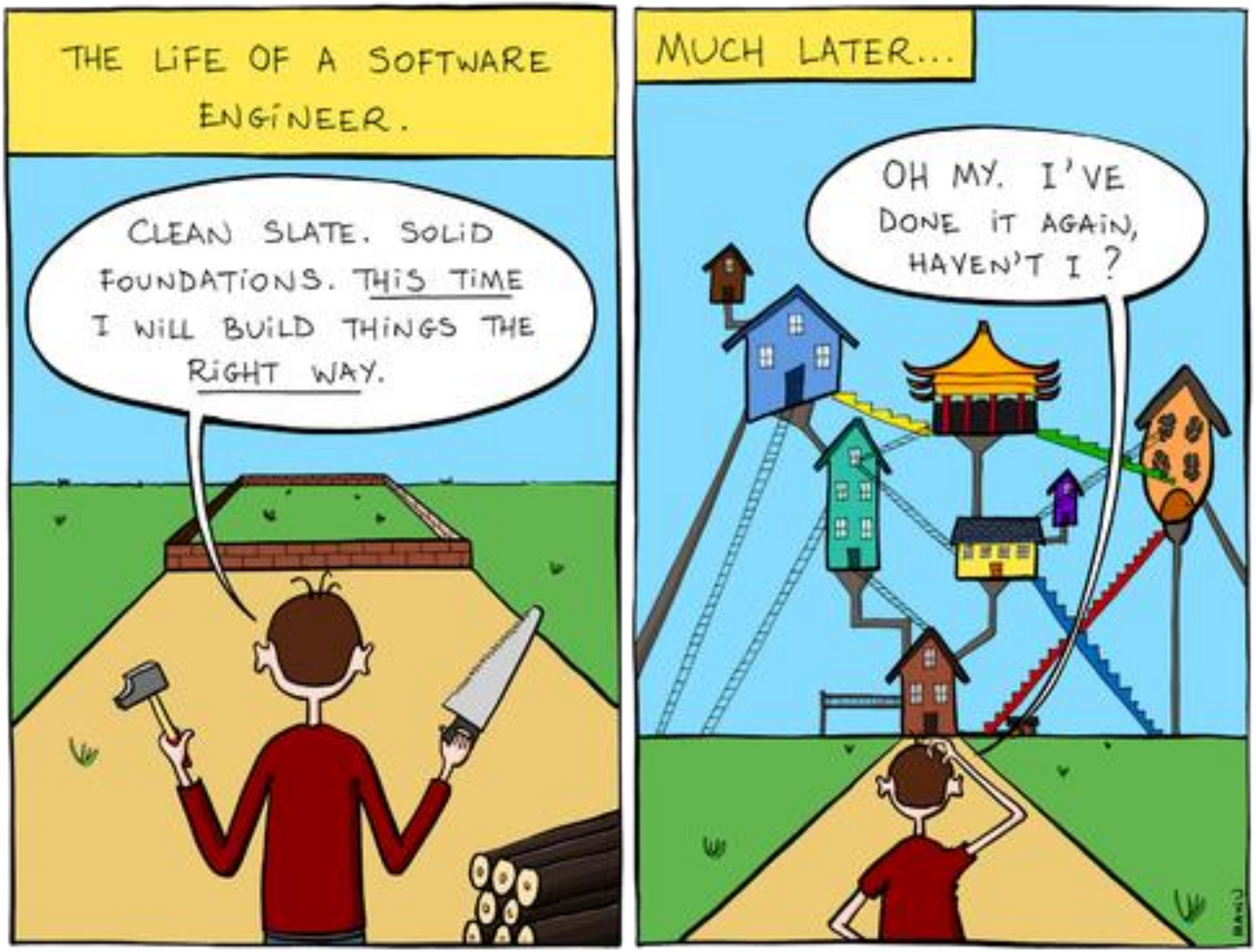
C++/CLI

C++

+

C#

C++/CLI


THE LIFE OF A SOFTWARE ENGINEER.
CLEAN SLATE. SOLID FOUNDATIONS. THIS TIME I WILL BUILD THINGS THE RIGHT WAY.
MUCH LATER...
OH MY. I'VE DONE IT AGAIN, HAVEN'T I ?

C++/CLI

Native code

```
NativeClass * aClass = new NativeClass()

aClass->Function()

delete aClass;
```

Managed code

```
ManagedClass ^ bClass = gcnew ManagedClass()

bClass->Function()
```

C++/CLI

```cpp
public ref class CalculatorWrapper : public System::IDisposable
{
    NativeCalculator *nativeCalculator;
public:
    CalculatorWrapper(){
        nativeCalculator = new NativeCalculator();
    }

    void Add(cli::array<unsigned char>^ arg1,
             cli::array<unsigned char>^ arg2,
             cli::array<unsigned char>^ dst){
        // TODO: Implementation goes here
    }

    ~CalculatorWrapper(){
        this->!CalculatorWrapper();
    }

    !CalculatorWrapper(){
        delete nativeCalculator;
    }
}
```

C++

```
Class NativeCalculator
{
public:
  void Add(
           unsigned char* arg1,
           unsigned char* arg2,
           unsigned char* dst,
           int length);

  void Sum(
           const std::vector<unsigned char*>& arguments,
           unsigned char* dst,
           int length);
};
```

C++/CLI

```
void Add(cli::array<unsigned char>^ arg1,
         cli::array<unsigned char>^ arg2,
         cli::array<unsigned char>^ dst)
{
    pin_ptr<unsigned char> arg1Pin = &arg1[0];
    pin_ptr<unsigned char> arg2Pin = &arg2[0];
    pin_ptr<unsigned char> dstPin  = &dst[0];

    try
    {
        nativeCalculator->Add(arg1Pin, arg2Pin,
                              dstPin,  arg1->Length);
    }
    catch (const std::exception& ex)
    {
        throw gcnew System::Exception(gcnew String(ex.what()));
    }
}
```

C++

```cpp
interface NativeCalculator
{
public:
  void Add(
           unsigned char* arg1,
           unsigned char* arg2,
           unsigned char* dst,
           int length);

  void Sum(
           const std::vector<unsigned char*>& arguments,
           unsigned char* dst,
           int length);
};
```

C++/CLI

```
cli::array<unsigned char>^ Sum(cli::array<cli::array<unsigned char>^>^ arguments)
{
  cli::array<GCHandle>^ memoryHandles = gcnew cli::array<GCHandle>(arguments->Length);

  try
  {
    std::vector<unsigned char*> nativePtrs(arguments->Length);
    for (int i = 0; i < arguments->Length; i++)
    {
      memoryHandles[i] = GCHandle::Alloc(arguments[0], GCHandleType::Pinned);
      nativePtrs[i] =  (unsigned char*) memoryHandles[i].AddrOfPinnedObject().ToPointer();
    }

    pin_ptr<unsigned char> outputPin = &output[0];

    nativeCalculator->Sum(nativePtrs, outputPin, arguments[0]->Length);

  } catch (const std::exception& ex)
  {
    throw gcnew System::Exception(gcnew String(ex.what()));
  } finally
  {
    for (int i = 0; i < arguments->Length; i++)
    {
      memoryHandles[i].Free();
    }
  }
}
```

C++/CLI

```
cli::array<GCHandle>^ memoryHandles =
                        gcnew cli::array<GCHandle>(arguments->Length);

try
{
  std::vector<unsigned char*> nativePtrs(arguments->Length);
  for (int i = 0; i < arguments->Length; i++){
    memoryHandles[i] = GCHandle::Alloc(arguments[0],
                                                 GCHandleType::Pinned);

    nativePtrs[i] =  (unsigned char*)
                     memoryHandles[i].AddrOfPinnedObject().ToPointer();
  }

[…]

} finally
{
  for (int i = 0; i < arguments->Length; i++)
  {
      memoryHandles[i].Free();
  }
}
```

C++/CLI

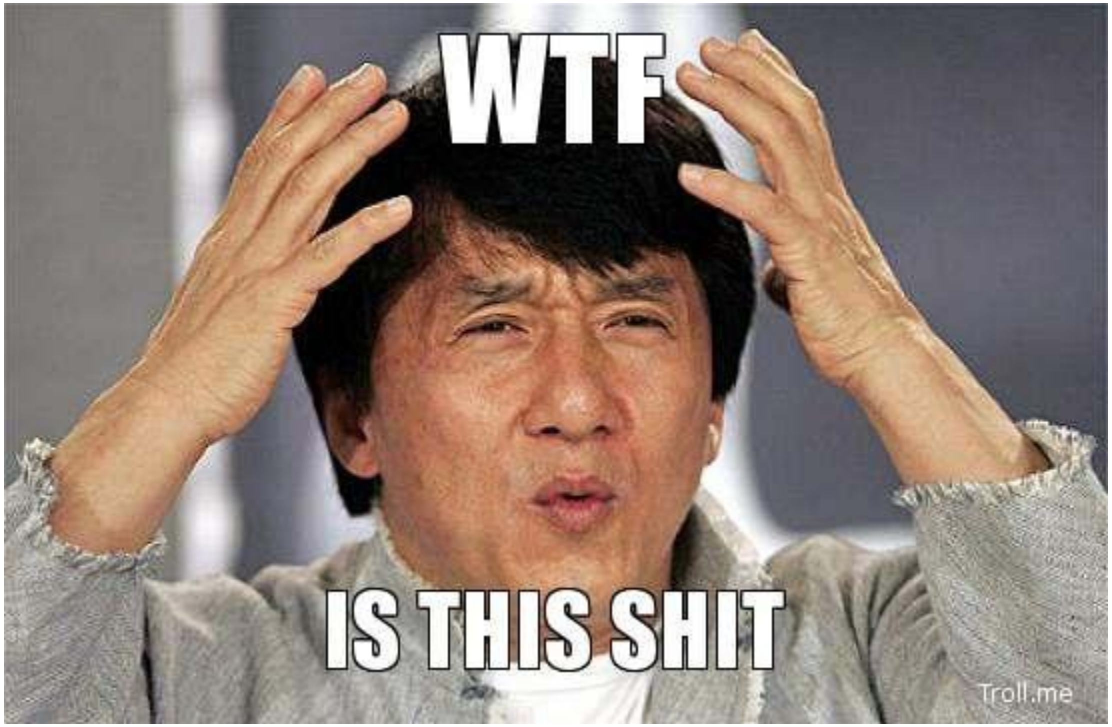
```
cli::array<unsigned char>^ Sum(cli::array<cli::array<unsigned char>^>^ arguments)
{
  cli::array<GCHandle>^ memoryHandles = gcnew cli::array<GCHandle>(arguments->Length);

  try
  {
    std::vector<unsigned char*> nativePtrs(arguments->Length);
    for (int i = 0; i < arguments->Length; i++)
    {
      memoryHandles[i] = GCHandle::Alloc(arguments[0], GCHandleType::Pinned);
      nativePtrs[i] =  (unsigned char*) memoryHandles[i].AddrOfPinnedObject().ToPointer();
    }

    pin_ptr<unsigned char> outputPin = &output[0];

    nativeCalculator->Sum(nativePtrs, outputPin, arguments[0]->Length);

  } catch (const std::exception& ex)
  {
    throw gcnew System::Exception(gcnew String(ex.what()));
  } finally
  {
    for (int i = 0; i < arguments->Length; i++)
    {
      memoryHandles[i].Free();
    }
  }
}
```

C++/CLI

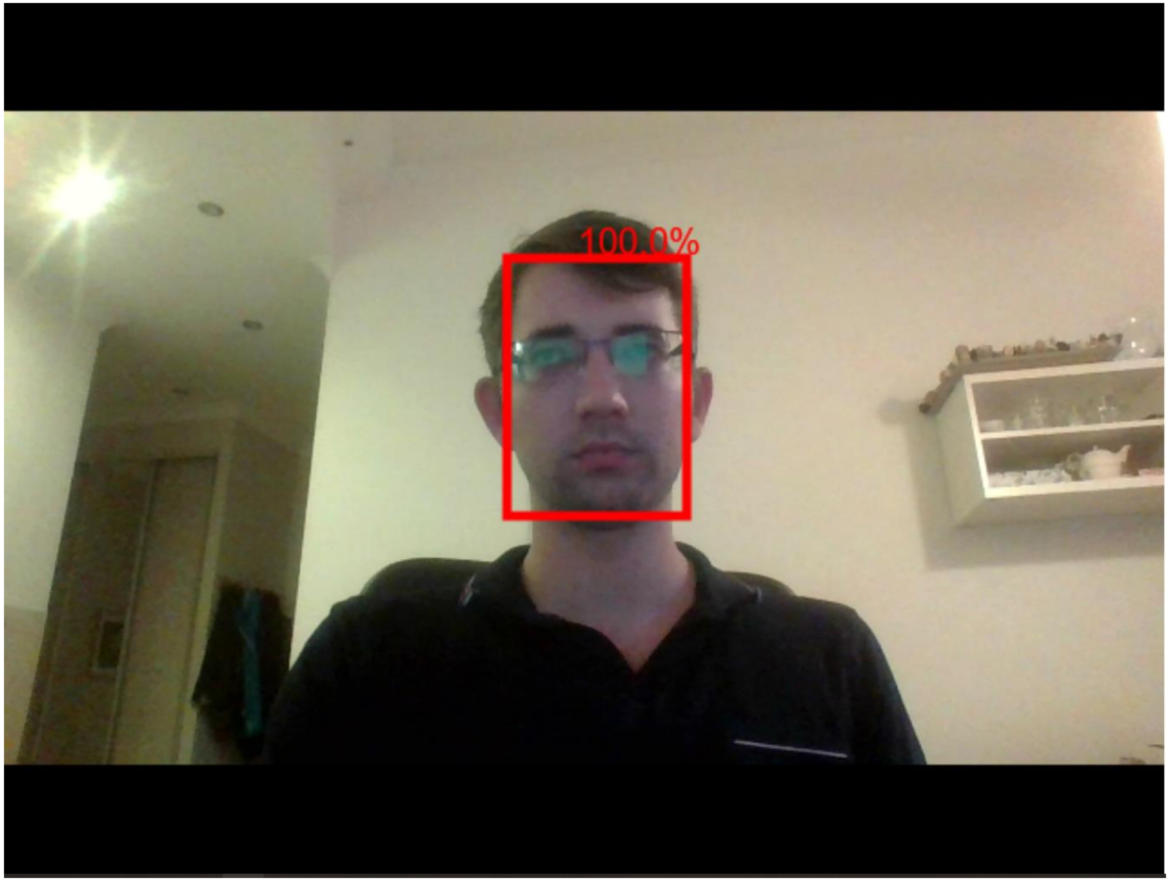
```
public ref class CalculatorWrapper : public System::IDisposable
{
    NativeCalculator *nativeCalculator;
public:
    CalculatorWrapper(){
        nativeCalculator = new NativeCalculator();
    }

    ~CalculatorWrapper(){

       // Dispose managed

       //MANDATORY: Call finallizer
       this->!CalculatorWrapper();
    }

    !CalculatorWrapper(){

       //Dispose unmanaged
       delete nativeCalculator;
    }
}
```

Zwalnianie Zasobów

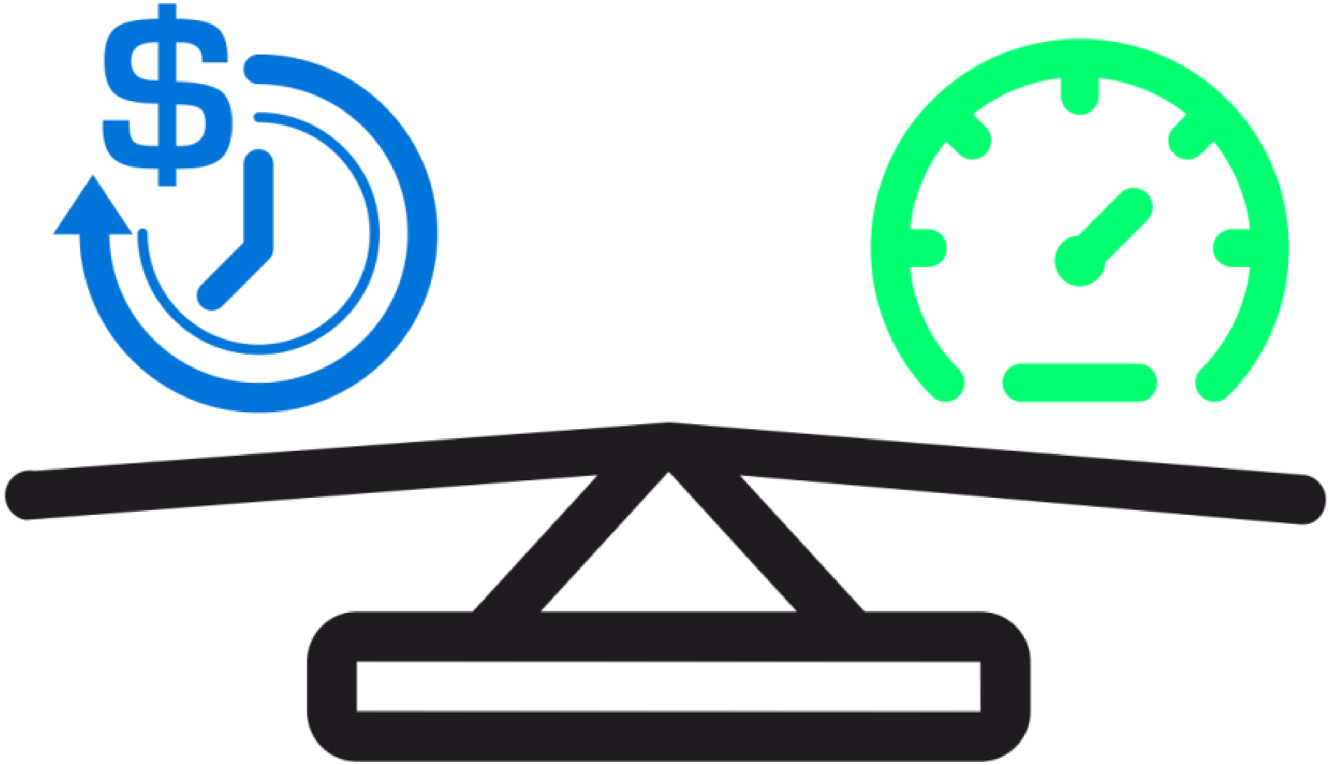
Typ	C#	C++/CLI	C++
Managed	Dispose()	~ClassName()	
Unmanaged	~ClassName()	!ClassName()	~ClassName()



WPF+DNN



Podsumowanie



Zygfryd Wieszok

Dwa oblicza szybkości:
czyli jak i dlaczego łączyć C++ z C#

https://github.com/zygfrydw/TwoFacesOfPerformance

Zygfryd.wieszok@gmail.com

Dispose Pattern

C#

```
using System;
class BaseClass : IDisposable{
   bool disposed = false;

   public void Dispose(){
      Dispose(true);
      GC.SuppressFinalize(this);
   }

   protected virtual void Dispose(bool disposing){
      if (disposed)
         return;
      if (disposing) {
         // Free any other managed objects here.
      }
      // Free any unmanaged objects here.
      disposed = true;
   }

   ~BaseClass(){
      Dispose(false);
   }
}
```

C++/CLI

```
~CalculatorWrapper(){
  this->!CalculatorWrapper();
}

!CalculatorWrapper(){
  delete nativeCalculator;
}
```

```
private void \u007ECalculatorWrapper() {
   this.\u0021CalculatorWrapper();

private unsafe void \u0021CalculatorWrapper() {
  \u003CModule\u003E.delete(
           (void*) this.nativeCalculator, 1UL);
}

[HandleProcessCorruptedStateExceptions]
protected virtual void
Dispose([MarshalAs(UnmanagedType.U1)] bool A_0) {
  if (A_0) {
      this.\u007ECalculatorWrapper();
  } else {
     try {
         this.\u0021CalculatorWrapper();
     } finally {
        // ISSUE: explicit finalizer call
        base.Finalize();
     }
  }
}

public virtual void Dispose()
{
  this.Dispose(true);
  GC.SuppressFinalize((object) this);
}

~CalculatorWrapper()
{
  this.Dispose(false);
}
```

C++/CLI

```
~CalculatorWrapper(){
}

!CalculatorWrapper(){
  delete nativeCalculator;
}
```

Wywołanie metody Dispose spowoduje wywołanie **SuppressFinalizer**. W związku z czym Finalizer nigdy nie będzie wywołany == wyciek pamięci!!!

```
private void \u007ECalculatorWrapper(){
}

private unsafe void \u0021CalculatorWrapper(){
  \u003CModule\u003E.delete(
          (void*) this.nativeCalculator, 1UL);
}

[HandleProcessCorruptedStateExceptions]
protected virtual void
Dispose([MarshalAs(UnmanagedType.U1)] bool A_0){
  if (A_0)
    return;
  try{
    this.\u0021CalculatorWrapper();
  } finally {
    // ISSUE: explicit finalizer call
    base.Finalize();
  }
}

public virtual void Dispose() {
  this.Dispose(true);
  GC.SuppressFinalize((object) this);
}

~CalculatorWrapper() {
  this.Dispose(false);
}
```