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How I put .NET into Firebird database engine

What I mean by .NET into Firebird?

Prerequisites

Not my full-time job

Work in progress

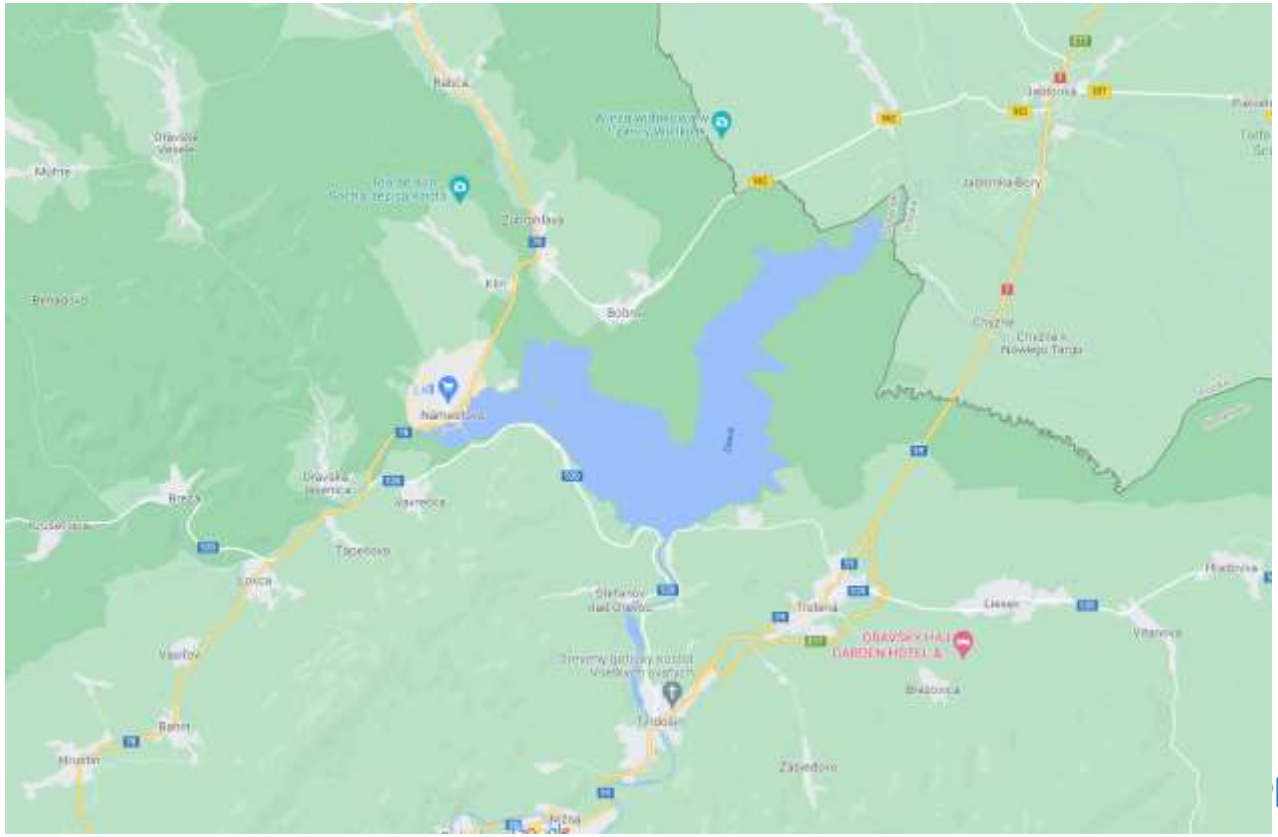
Performance has its (support) cost

Start

Firebird 3 introduced concept of “external engine” plugins

2016 working for a customer ↓ and bored during evenings

“JiriPlugin”



Start

.NET 4.5.2

A lot of reflection “to make it work”

Using Tuple<T, …>

Assembly.LoadFrom

Start


```
public class Argument
{
        readonly IntPtr _valuePtr;
        readonly IntPtr _nullPtr;
        readonly int _type;
        readonly int _length;

        public Argument(IntPtr valuePtr, IntPtr nullPtr, int type, int length)
        {
                _valuePtr = valuePtr;
                _nullPtr = nullPtr;
                _type = type;
                _length = length;
        }
```

ValueTuple<T, …>

C# 7 syntax sugar

Size, indexer access

Reflection

No ITuple yet ☹ (4.7.1)

Hot-reload

Idea to hot-swap assemblies while server is running ☺

AppDomains, MarshalByRefObject, …

```
public class AppDomainExecutor : MarshalByRefObject, IDisposable
var appDomainSetup = new AppDomainSetup()
{
        ApplicationBase = LocationHelper.BaseDirectory,
        LoaderOptimization = LoaderOptimization.MultiDomainHost,
};
```

Marshaling between AppDomains is very slow

Hack: Not loading from filename, but from byte array

- Dependencies

No unloading

Lucky it didn’t work out, because .NET Core dropped AppDomains

DelegateBuilder

Calling methods dynamically is slow

Need to build delegates

- Expressions or Reflection.Emit

Expressions more straightforward

- But also somewhat limited

Caching Type for comparison

Some Type == typeof(…) comparisons in plugin Caching

```
protected static Type TypeInt = typeof(int?);
protected static Type TypeString = typeof(string);
protected static Type TypeShort = typeof(short?);
protected static Type TypeLong = typeof(long?);
protected static Type TypeDateTime = typeof(DateTime?);
protected static Type TypeTimeSpan = typeof(TimeSpan?);
protected static Type TypeBool = typeof(bool?);
protected static Type TypeFloat = typeof(float?);
protected static Type TypeDouble = typeof(double?);
protected static Type TypeDecimal = typeof(decimal?);
```

Enum for Type

Caching was not enough

```
public enum ArgumentType : byte
{
          Int = 1,
          String = 2,
          Short = 3,
          Long = 4,
          DateTime = 5,
          TimeSpan = 6,
          Bool = 7,
          Float = 8,
          Double = 9,
          Decimal = 10,
          Binary = 11,
}
```

Comparing Type instances sucks

Dictionary with delegates

Originally used two ConcurrentDictionary<K, V>

My usage is mostly reads, bit writes

Eventually switched to RWLockSlim and Dictionary<K, V>

- Pre .NET Core 3.1

.NET Core migration

2019/2020

C++/CLI

AssemblyLoadContext

IJW

runtimeconfig

Local .NET Core loading

Distribute .NET Core together with plugin

Shim

DOTNET_ROOT

DOTNET_ROOT(x86)

DOTNET_MULTILEVEL_LOOKUP

Specific code

```
public class MessageMeta
{
        public uint Count { get; }
        public uint[] ValueOffsets { get; }
        public uint[] NullOffsets { get; }
        public uint[] Types { get; }
        public uint[] SubTypes { get; }
        public uint[] Lengths { get; }
        public int[] Scales { get; }
        public uint[] Charsets { get; }
```

Specific code

```
+         Marshal.WriteInt16(GetNullLocation(index), value ? (short)-1 : (short)0);
-         Marshal.WriteInt16(GetNullLocation(index), Convert.ToInt16(value));

+         T? GetValueVal<T>(int index, Func<int, T> getter) where T : struct
+         T GetValueRef<T>(int index, Func<int, T> getter) where T : class
-         object GetValue<T>(int index, Func<int, T> getter)

+         return Marshal.ReadInt16(GetNullLocation(index)) != 0;
-         return Convert.ToBoolean(Marshal.ReadInt16(GetNullLocation(index)));
```

Specific code

```
static (Expression, ParameterExpression, ParameterExpression) CreateMethodCall(MethodInfo method)
{
            var methodParameters = method.GetParameters();
            var argumentsParameter = Expression.Parameter(typeof(Arguments));
            var statementExecutorParameter = Expression.Parameter(typeof(IStatementExecutor));

            var arguments = new Expression[methodParameters.Length];
            var length = arguments.Length;
            if (methodParameters.Length > 0 && methodParameters[^1].ParameterType == typeof(IExecutionContext))
            {
                        length -= 1;
                        var t = typeof(Integration.ExecutionContext);
                        arguments[^1] = Expression.New(t.GetConstructor(new[] { typeof(IStatementExecutor) }),
statementExecutorParameter);
            }
            var getValueMethod = typeof(Arguments).GetMethod(nameof(Arguments.GetValue));
            for (var i = 0; i < length; i++)
            {
                        var a = Expression.Call(argumentsParameter, getValueMethod, Expression.Constant(i),
Expression.Constant(methodParameters[i].ParameterType.ToArgumentType()));
                        arguments[i] = Expression.Convert(a, methodParameters[i].ParameterType);
            }
```

Unsafe and void*

Hope for faster and more tight code compared to Marshal and IntPtr

```
[MethodImpl(MethodImplOptions.AggressiveInlining)]
static T Read<T>(void* source, int offset)
{
	return Unsafe.ReadUnaligned<T>(Unsafe.Add<byte>(source, offset));
}
[MethodImpl(MethodImplOptions.AggressiveInlining)]
static void Write<T>(void* source, int offset, T value)
{
	Unsafe.WriteUnaligned<T>(Unsafe.Add<byte>(source, offset), value);
}
```

Unsafe and void*

Strings, etc. are composed from smaller pieces, enforce struct

```
[MethodImpl(MethodImplOptions.AggressiveInlining)]
static T Read<T>(void* source, int offset) where T : struct
{
	return Unsafe.ReadUnaligned<T>(Unsafe.Add<byte>(source, offset));
}
[MethodImpl(MethodImplOptions.AggressiveInlining)]
static void Write<T>(void* source, int offset, T value) where T : struct
{
	Unsafe.WriteUnaligned(Unsafe.Add<byte>(source, offset), value);
}
```

Less indexing, RO structs, ref, in


```
public sealed class MessageMeta
{
        const int SQL_BLOB = 520;

        public readonly struct Value
        {
                public readonly int ValueOffset;
                public readonly int NullOffset;
                public readonly int Type;
                public readonly int SubType;
                public readonly int Length;
                public readonly int Scale;
                public bool IsBlob => Type == SQL_BLOB;

                public Value(int valueOffset, int nullOffset, int type, int subType, int length, int scale)
                {
                        ValueOffset = valueOffset;
                        NullOffset = nullOffset;
                        Type = type;
                        SubType = subType;
                        Length = length;
                        Scale = scale;
                }
        }

        readonly Value[] _items;
        public ref Value this[int index] => ref _items[index];
        public int Count => _items.Length;
```

Less indexing, RO structs, ref, in

```
bool ReadIsNull(in MessageMeta.Value meta)
```

C++/CLI pieces without managed


```
#pragma managed(push, off)
void Function::getCharSet(ThrowStatusWrapper* status, IExternalContext* context, char* name, unsigned
nameSize)
{
        strncpy(name, "UTF8", nameSize);
}
#pragma managed(pop)
```

Split “generation” from “invocation”

Dictionary lookups are expensive ☺

Split “generation” from “invocation”

- Access reference

Reuse generated pieces across invocations

```
public abstract class InvokerBase<TResult>
{
        readonly Func<Arguments, Arguments, IStatementExecutor, TResult> _invoker;
        readonly MessageMeta _inputsMeta;
        readonly MessageMeta _outputsMeta;
```

Less Arguments instances


```
public sealed unsafe class Arguments
{
        public Arguments(MessageMeta messageMeta)
        {
                _messageMeta = messageMeta;
        }

        public void Use(void* msg, IBlobHandler blobHandler)
        {
                _msg = msg;
                _blobHandler = blobHandler;
        }
```

Switch to Reflection.Emit

Control IL generation exactly

Expressions are great, but I’m hunting 1% of performance

Switch to Reflection.Emit


```
public static Func<Arguments, IStatementExecutor, object> BuildFunctionMethodDelegate(MethodInfo method)
{
                var (dynamicMethod, il) = Start<IEnumerator>("JiriFunction");
                var (methodParameters, hasExecutionContext) = PrepareMethod(method);
                EmitArgumentsValues(methodParameters.Length - (hasExecutionContext ? 1 : 0), methodParameters, il);
                if (hasExecutionContext)
                {
                                EmitExecutionContext(il);
                }
                EmitCall(method, il);
                if (method.ReturnType.IsValueType)
                {
                                il.Emit(OpCodes.Box, method.ReturnType); // type (i.e. int?) -> object
                }
                return Finish<object>(dynamicMethod, il);
}

static readonly MethodInfo GetValueMethod = typeof(Arguments).GetMethod(nameof(Arguments.GetValue));
static void EmitArgumentsValues(int count, ParameterInfo[] methodParameters, ILGenerator il)
{
                for (var i = 0; i < count; i++)
                {
                                var parameterType = methodParameters[i].ParameterType;
                                il.Emit(OpCodes.Ldarg_0); // Arguments
                                il.Emit(OpCodes.Ldc_I4, i); // index
                                il.Emit(OpCodes.Ldc_I4_S, (byte)parameterType.ToArgumentType()); // ArgumentType
                                il.Emit(OpCodes.Callvirt, GetValueMethod);
                                if (parameterType.IsValueType)
                                {
                                                il.Emit(OpCodes.Unbox_Any, parameterType); // object -> type (i.e. int?)
                                }
                }
}
```

Hot-reload revisited

Unloading difficult

Dependencies

Difficult to manage from developer POV

- Are restart really that problematic?

Static values

- Caches

https://www.tabsoverspaces.com/233870-csharp-static-constructor-called-multiple-times

https://www.tabsoverspaces.com/233871-going-deeper-into-static-constructors-hole

What’s next?

More performance (.NET 6) ☺

Unsafe casting

Fully generic pipeline from Reflection.Emit pieces

Manual .NET hosting/loading (and marshaling calls/data)

Building functions/procedures from source in DB

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