

# Interoperability in Programming Languages

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# What is interop?

- Interoperability: The ability for two systems to interact.
- Often shortened to interop.
- In programming languages: The ability of a language to call on code from another language.

# Why is interop important?

## Developer time and effort:

- Existing and working code is easier to use as-is.
- Legacy systems: extensive or little-understood code base.
- Third-party systems: source code is unavailable

## Language Strength:

- Explicit memory access (C)
- Parallel or distributed systems (Clojure, Erlang)
- Statistics (R)

# Outline

- 1 Common difficulties in interop
- 2 Concepts in interoperability
- 3 Tools used in achieving interoperability
- 4 Conclusions

# Outline

- 1 Common difficulties in interop
  - Type systems
  - Data structures
  - Data processing
- 2 Concepts in interoperability
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# Differences in type systems

- Languages represent data in different ways
- Statically-typed languages assign types as soon as data is collected.
- Dynamically-typed languages only deal with types when evaluating data.

```
Class Person
  string name = "Cliff"
  date dateOfBirth = 4/16/1978
  int height = 74
  double weight = 212
end
statically-typed person
```

```
Class Person
  var name = "Cliff"
  var dateOfBirth = 4/16/1978
  var height = 74
  var weight = 212
end
dynamically-typed person
```

# Types in data structures

- Untyped lists can contain different types,
- Strongly typed lists can only contain the type given by the list.

```
[23, v, "hello", True]
```

An untyped list

```
[1, 53, 13, 100]
```

a typed list

```
Object[] = [?, ?, ?, ?]
```

A Java list of Objects

# Missing data structures

- A data structure in one language may be absent in another.
- Any language can build any data structure, but it may be more difficult in certain languages.
- Building a non-native data structure takes time and effort.

```
{:name "Cliff", :age 32}
```

Maps are common data structures, but absent in C.

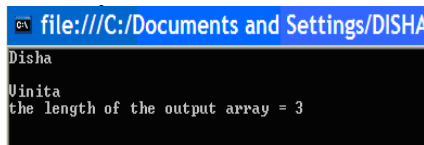


# Handling data

- Languages act on data in different ways.
- Handling NULL or NIL objects.



Result = [Disha, null, Vinita]



images based on Shetty and Vadivel[2]

# Outline

- 1 Common difficulties in interop
- 2 Concepts in interoperability**
  - Metadata
  - Standards
- 3 Tools used in achieving interoperability
- 4 Conclusions

# Metadata and type conversion

Metadata: Data about data

or: Information beyond what the data itself can convey

```
(def mylist [1, 2, 3, 4])  
(with-meta mylist {:length 4, :type Integer}))
```

In Clojure:

- lists are untyped; can contain entries of different types.
- metadata use and checking is up to the programmer.

# Metadata and type conversion

no metadata

[1, 2, 3, 4]       $\longrightarrow$       [?, ?, ?, ?]

{:type Integer}

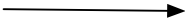
[1, 2, 3, 4]       $\longrightarrow$       [1, 2, 3, 4]

# Metadata and standards

`{:type number}`                      `{:type Integer}`  
`[1, 2, 3, 4]`                      `[?, ?, ?, ?]`

A horizontal arrow points from the list `[1, 2, 3, 4]` to the list `[?, ?, ?, ?]`.

`{:type number}`                      `{:type number}`  
`[1, 2, 3, 4]`                      `[1, 2, 3, 4]`

A horizontal arrow points from the list `[1, 2, 3, 4]` to the list `[1, 2, 3, 4]`.

# The importance of standards

Standards are meant to ensure:

- Agreement on what metadata is being used, and how.
- All involved parties know how data will be represented.
- Future parties will know how data is represented.
- In general, that correct communication happens.

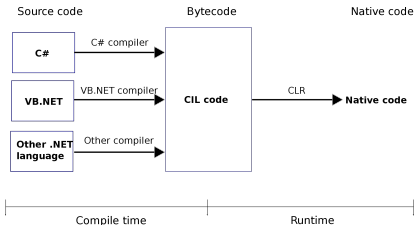
```
{  
  "name": "Person",  
  "properties": {  
    "name": {  
      "type": "string"  
    },  
    "birthdate": {  
      "type": "date"  
    },  
    "height": {  
      "type": "number"  
    },  
    "weight": {  
      "type": "number"  
    }  
  }  
}
```

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- 3 Tools used in achieving interoperability**
  - Virtual Machines
  - Markup Languages
- 4 Conclusions

# Virtual machines

- Virtual Machines (VMs) are a runtime environment for a program
- High-level languages compile to an intermediate language
- Intermediate language: Java bytecode or Common Intermediate Language



Wikipedia

[https://en.wikipedia.org/wiki/Common\\_Language\\_Runtime](https://en.wikipedia.org/wiki/Common_Language_Runtime)



# High-level vs Bytecode

```
public class Fib{  
  
    public int fibonacci(int n) {  
        if(n == 0){  
            return 0;  
        }else if(n == 1){  
            return 1;  
        }else{  
            return fibonacci(n - 1) + fibonacci(n - 2);  
        }  
    }  
}
```

```
public class Fib{  
    public Fib();  
        Code:  
            0: aload_0  
            1: invokespecial #1  
            4: return
```

```
    public int fibonacci(int);  
        Code:  
            0: iload_1  
            1: ifne          6  
            4: iconst_0  
            5: ireturn  
            6: iload_1  
            7: iconst_1  
            8: if_icmpne     13  
           11: iconst_1  
           12: ireturn  
           13: aload_0  
           14: iload_1  
           15: iconst_1  
           16: isub  
           17: invokevirtual #2  
           20: aload_0  
           21: iload_1
```

# Interoperability with virtual machines

- Usually some overhead associated with calling other languages.
- Overhead can be lessened when all languages are on one VM.
- High-level languages can have conventions to call other high-level languages on the same VM.
- Common language ensures common syntax and behavior.

A Java method of object cliff:

```
cliff.getAge();
```

Clojure calling Java:

```
(. getAge cliff)
```

JRuby calling Java:

```
require 'java'  
cliff.getAge()
```

# Markup languages

- Markup languages are a way of modeling data, and act as metadata
- XML and JSON can model data like objects.
- Markup languages are independent of programming languages.

```
<Person>
  <name> Cliff </name>
  <birthdate> 4/16/1978 </birthdate>
  <height> 74 </height>
  <weight> 212 </weight>
</Person>
```

XML model of a person

```
{
  "name": "Cliff",
  "birthdate": "4/16/1978",
  "height": "74",
  "weight": "212";
}
```

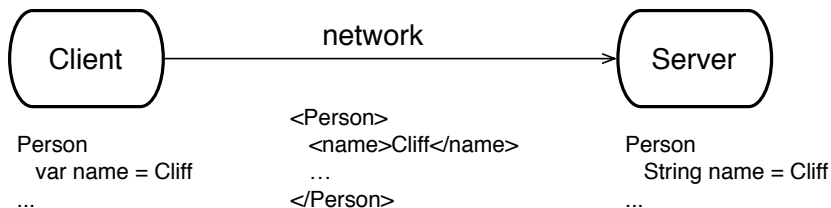
JSON model of a person

# Schema and standardization

- Schema provide both standardization and additional metadata.
- Libraries exist to check incoming data against a schema.

```
<?xml version="1.0" encoding="utf-8"?>
<xs:schema elementFormDefault="qualified"
  xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="Person">
    <xs:complexType>
      <xs:sequence>
        <xs:element name="name" type="xs:string" />
        <xs:element name="birthdate" type="xs:date" />
        <xs:element name="height" type="xs:double" />
        <xs:element name="weight" type="xs:double" />
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

# Client/server interop with markup languages



Communication across a network using XML

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# Conclusions

- Interop allows programmers to extend existing systems without requiring them to know the original language.
- Also allows programmers access to the strengths of languages other than the main system language.
- Metadata and standards allow programmers to reason about interoperability, and to communicate how their system handles interop.
- Virtual machines and markup languages make use of these concepts to enable interop.

Thank you for listening!

Questions?

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# References



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