Fuzion — A New Language for the OpenJDK

Unifying Java’s concepts

TOKIWA software

Who is this guy?

Fridtjof Siebert

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github: fridis
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‘90-‘94	AmigaOberon, AMOK PD
‘97	FEC Eiffel Compiler Sparc / Solaris
‘98-‘99	OSF: TurboJ Java Compiler
‘00-‘01	PhD on real-time GC
‘02-‘19	JamaicaVM real-time JVM based on CLASSSPATH / OpenJDK, VeriFlux static analysis tool
‘20-…	Fuzion
‘21-…	Tokiwa Software

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Motivation

Many languages overloaded with concepts like classes, methods, interfaces, constructors, traits, records, structs, packages, values, …

➡ Fuzion has one concept: a feature

Today's compilers and tools are more powerful

➡ Tools make better decisions

Systems are safety-critical

➡ we need to ensure correctness

Fuzion Summary

Fuzion

- ➡ uses the **feature** as its main concept
- ➡ is **statically typed**
- ➡ has **inheritance** and **redefinition**
- ➡ uses **value types** and **dynamic (ref) types**
- ➡ encourages **immutability**
- ➡ offloads tasks and decisions from developers to **tools**

Backing Company

- supports development of Fuzion
- currently three employees
- hiring
- searching for funding

Fuzion Language Tutorial

Not part of this talk

➡ online at **flang.dev**

This talk will show how

➡ Java maps to Fuzion

Fuzion vs. Java Constructs

Java class

```
class Complex {
  int re, im;
  Complex(int re, int im) {
    this.re = re;
    this.im = im;
  }
}
```

Fuzion vs. Java Constructs

Java class

```
class Complex {
  int re, im;
  Complex(int re, int im) {
    this.re = re;
    this.im = im;
  }
}
```

Fuzion feature

```
complex(re, im i32) {


}
```

Fuzion vs. Java Constructs

Java class

```
class Complex {
  [..]



}
```

Fuzion feature

```
complex(re, im i32) {



}
```

Fuzion vs. Java Constructs

Java method

```
class Complex {
  [..]
  int radiusSq() {
    return re*re + im*im;
  }
}
```

```
complex(re, im i32) {


}
```

Fuzion vs. Java Constructs

Java method

```
class Complex {
  [..]
  int radiusSq() {
    return re*re + im*im;
  }
}
```

Fuzion feature

```
complex(re, im i32) {
  radius² i32 {
    re*re + im*im;
  }
}
```

Fuzion vs. Java Constructs

Java method

```
class Complex {
  [..]
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Fuzion syntax

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complex(re, im i32) {
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Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

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Fuzion syntax

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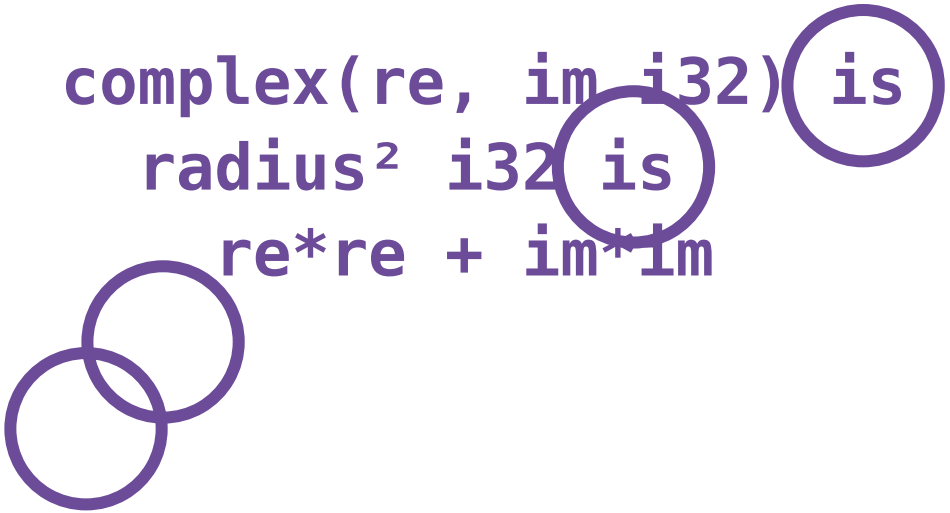

Fuzion vs. Java Constructs

Java method

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Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

Java method

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Fuzion feature

```
complex(re, im i32) is
  radius² =>
    re*re + im*im
```

Fuzion vs. Java Constructs

Java package

```
package myMath;
class Complex {
  [..]



}
```

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complex(re, im i32) is
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```

Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

Java package

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package myMath;
class Complex {
  [..]



}
```

Fuzion feature

```
myMath is
  complex(re, im i32) is
    radius² =>
      re*re + im*im
```

unit type feature

➡ no fields

➡ no runtime code

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Fuzion vs. Java Constructs

```
package myMath;
class Complex {
  [..]



}
```

```
myMath is
  complex(re, im i32) is
    radius² =>
      re*re + im*im
```

Fuzion vs. Java Constructs

Java static method

```
package myMath;
class Complex {
  static Complex origin() {
    return
      new Complex(0,0);
  }
}
```

```
myMath is
  complex(re, im i32) is
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      re*re + im*im
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Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

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Fuzion feature

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  complexes is
```

Fuzion vs. Java Constructs

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Fuzion feature

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myMath is
  complex(re, im i32) is
    radius² =>
      re*re + im*im
  complexes is
    origin => complex 0 0
```

Fuzion vs. Java Constructs

Java static method

```
package myMath;
class Complex {
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    return
      new Complex(0,0);
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```

Fuzion feature

```
myMath is
  complex(re, im i32) is
    radius² =>
      re*re + im*im
  complexes is
    origin => complex 0 0
  complex => complexes
```

Fuzion vs. Java Constructs

Java calling constructor

```
var c = new myMath.
          Complex(3,4);
```

Fuzion vs. Java Constructs

Java calling constructor

```
var c = new myMath.
          Complex(3,4);
```

Fuzion calling feature

```
c := myMath.complex(3, 4)
```

Fuzion vs. Java Constructs

Java calling constructor

```
var c = new myMath.
          Complex(3,4);
```

Fuzion syntax

```
c := myMath.complex(3, 4)
```

Fuzion vs. Java Constructs

Java calling constructor

```
var c = new myMath.
          Complex(3,4);
```

Fuzion syntax

```
c := myMath.complex 3 4
```

Fuzion vs. Java Constructs

Java calling constructor

```
var c = new myMath.
          Complex(3,4);
```

Fuzion

```
c := myMath.complex 3 4
```

Fuzion vs. Java Constructs

Java importing package

```
import myMath.Complex;
[..]
var c = new Complex(3,4);
```

Fuzion

```
c := myMath.complex 3 4
```

Fuzion vs. Java Constructs

Java importing package

```
import myMath.Complex;
[..]
var c = new Complex(3,4);
```

Fuzion calling feature

```
m := myMath
[..]
c := m.complex 3 4
```

Fuzion vs. Java Constructs

Java calling method

```
import myMath.Complex;
[..]
var c = new Complex(3,4);
var rSq = c.radiusSq();
```

Fuzion

```
m := myMath
[..]
c := m.complex 3 4
```

Fuzion vs. Java Constructs

Java calling method

```
import myMath.Complex;
[..]
var c = new Complex(3,4);
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```

Fuzion calling feature

```
m := myMath
[..]
c := m.complex 3 4
r² := c.radius²
```

Fuzion vs. Java Constructs

Java calling static method

```
import myMath.Complex;
[..]
var c = new Complex(3,4);
var rSq = c.radiusSq();
var o = Complex.origin();
```

Fuzion

```
m := myMath
[..]
c := m.complex 3 4
r² := c.radius²
```

Fuzion vs. Java Constructs

Java calling static method

```
import myMath.Complex;
[..]
var c = new Complex(3,4);
var rSq = c.radiusSq();
var o = Complex.origin();
```

Fuzion calling feature

```
m := myMath
[..]
c := m.complex 3 4
r² := c.radius²
o := m.complexes.origin
```

Fuzion vs. Java Constructs

Java calling static method

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import myMath.Complex;
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var c = new Complex(3,4);
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Fuzion vs. Java Constructs

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Fuzion vs. Java Constructs

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Fuzion calling feature

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m := myMath
[..]
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r² := c.radius²
o := m.complex.origin
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Fuzion Toolchain Design

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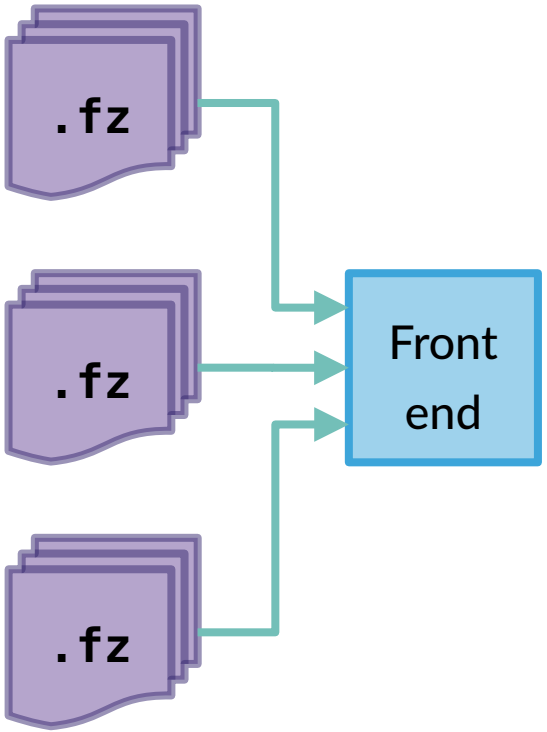

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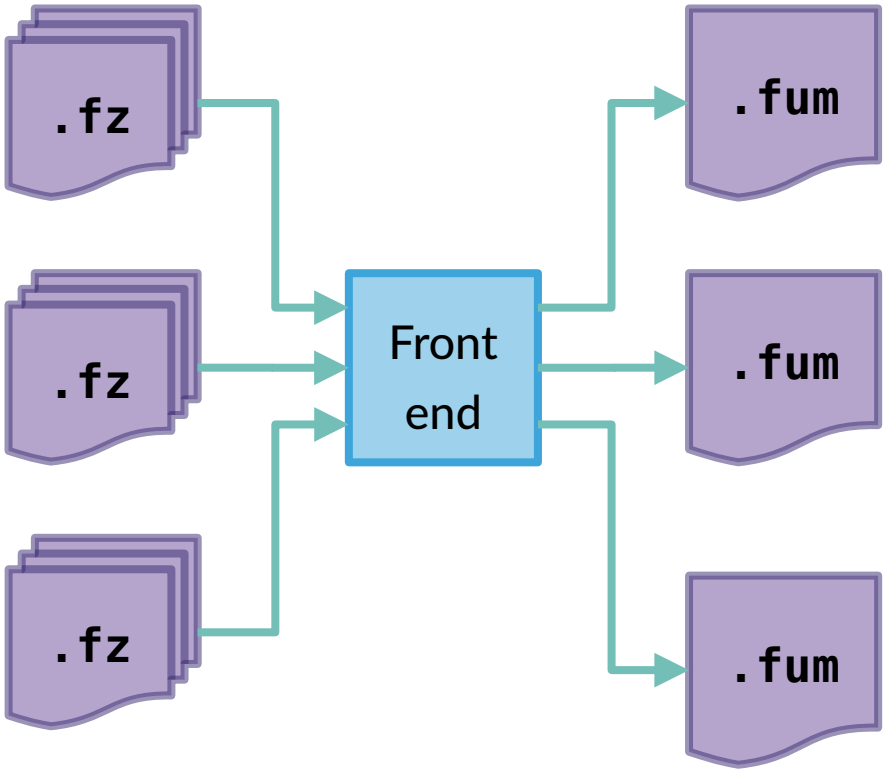

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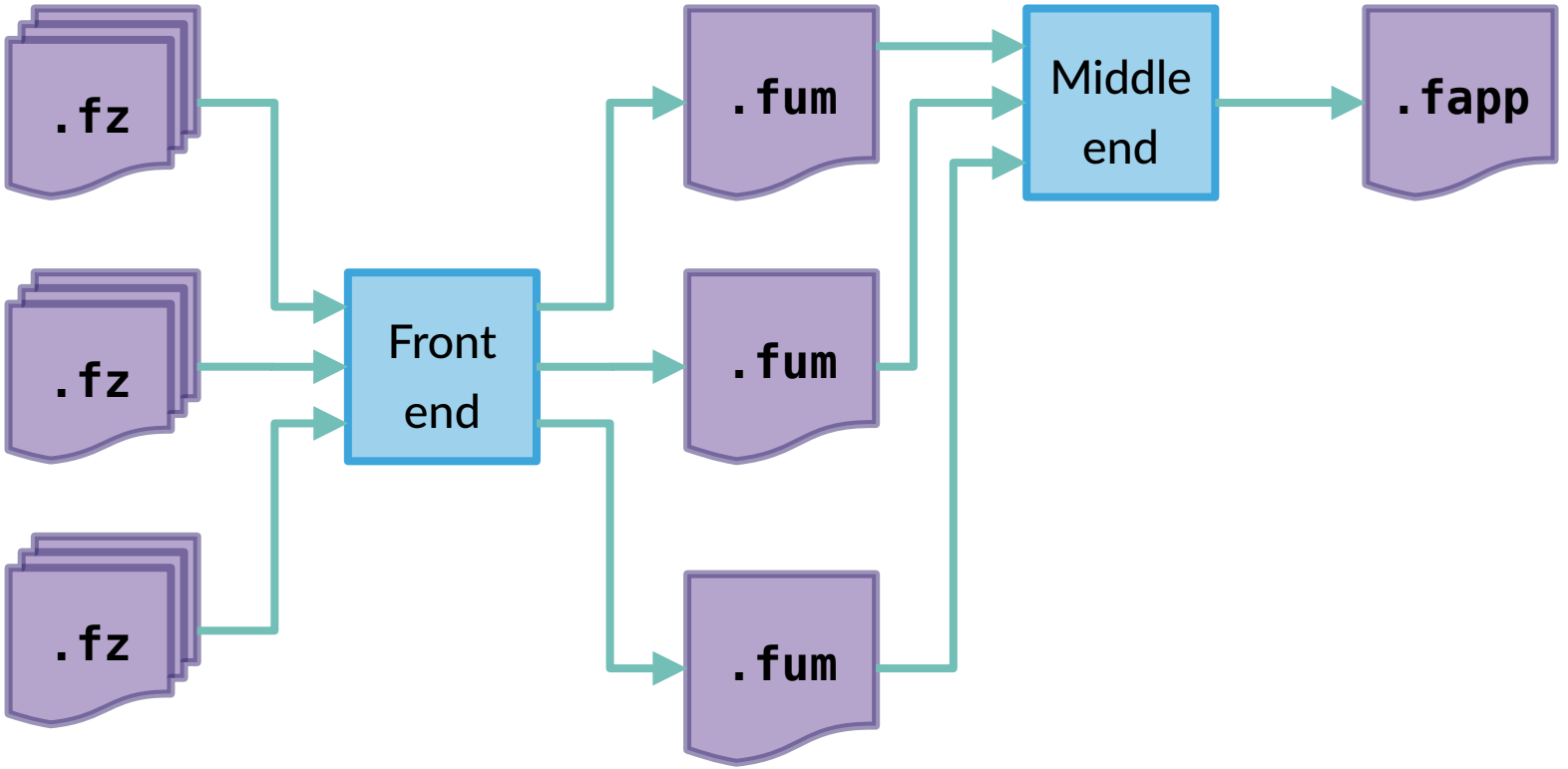

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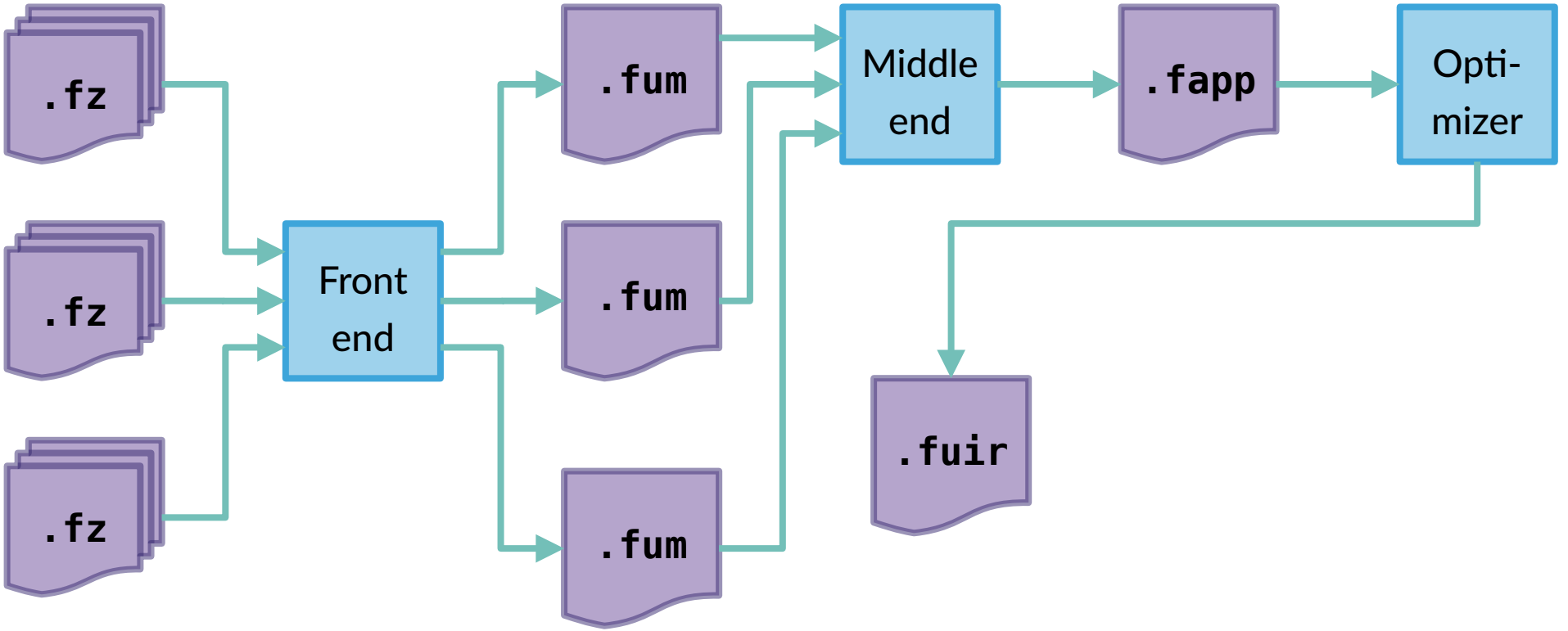

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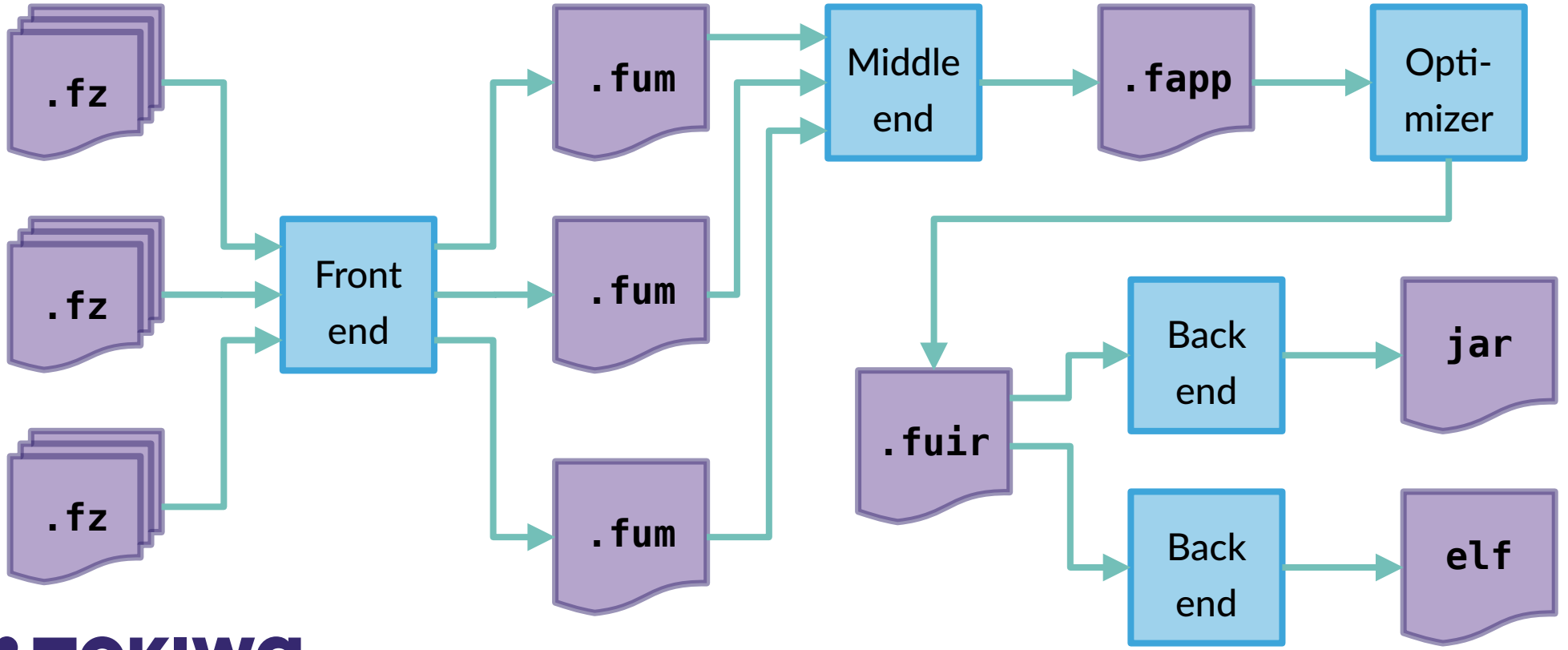

FZJava Tool

Create Fuzion interface to Java module

FZJava Tool

Create Fuzion interface to Java module

FZJava Tool

Create Fuzion interface to Java module


```
java.lang.System.out.println "Hello Java 🌍!"
```

FZJava Tool: Basic approach

FZJava Tool: Basic approach

```
package x.y;
class MyClass {
  MyClass(String arg) {
  }
  void myMethod() {
  }
  static void
    myStaticMethod() {
  }
}
```

FZJava Tool: Basic approach

```
package x.y;
class MyClass {
  MyClass(String arg) {
  }
  void myMethod() {
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  static void
    myStaticMethod() {
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}
```

```
Java.x.y.MyClass(f void) is
  unit myMethod is
    ...
```

FZJava Tool: Basic approach

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package x.y;
class MyClass {
  MyClass(String arg) {
  }
  void myMethod() {
  }
  static void
    myStaticMethod() {
  }
}
```

```
Java.x.y.MyClass(f void) is
  unit myMethod is
    ...
Java.x.y.MyClass_static is
  new(arg string) is
    ...
  myStaticMethod is
    ...
```

FZJava Tool: Basic approach

```
package x.y;
class MyClass {
  MyClass(String arg) {
  }
  void myMethod() {
  }
  static void
    myStaticMethod() {
  }
}
```

```
Java.x.y.MyClass(f void) is
  unit myMethod is
    ...
Java.x.y.MyClass_static is
  new(arg string) is
    ...
  myStaticMethod is
    ...
Java.x.y.MyClass =>
  Java.x.y.MyClass_static
```

FZJava Tool: Small Example

```
o = new MyClass(“test”);
o.myMethod();
MyClass.myStaticMethod();
```

```
o := Java.x.y.MyClass_static
       .new “test”
o.myMethod
Java.x.y.MyClass.myStaticMethod
```

FZJava Tool: Small Example

```
                                    MyClass := Java.x.y.MyClass

o = new MyClass("test");            o := MyClass.new "test"
o.myMethod();                       o.myMethod
MyClass.myStaticMethod();           MyClass.myStaticMethod
```

FZJava Tool: Small Example

```
                                    mc := Java.x.y.MyClass

o = new MyClass("test");            o := mc.new "test"
o.myMethod();                       o.myMethod
MyClass.myStaticMethod();           mc.myStaticMethod
```

FZJava Tool: Exceptions

Checked exceptions are mapped to choice type `outcome<T>`:

- ➡ use of `match` required to extract result type `T`
- ➡ `void` result and checked exception mapped to `outcome<unit>`

Unchecked exceptions cause runtime error.

- ➡ in future, may use exception monad

FZJava Tool: Inheritance

Generated features re-build inheritance relation of Java code:

- ➡ assignment compatible if the Java classes are
- ➡ ‘feels’ very similar to the Java code

FZJava Tool: Interfaces

Fuzion supports multiple inheritance for features:

- ➡ interfaces treated like classes

FZJava Tool: Overloading

Java overloading more permissive.

In case of name clash

- ➡ short names for ‚common‘ types
- ➡ fallback: name mangling

FZJava Tool: Example

```
webserver is
  net := Java.java.net
  io  := Java.java.io

  port := 8080
  serversocket := net.ServerSocket.new port
  match serversocket
    err error => say "#### $err ####"
    ss Java.java.net.ServerSocket =>
      match ss.accept
        ...
```

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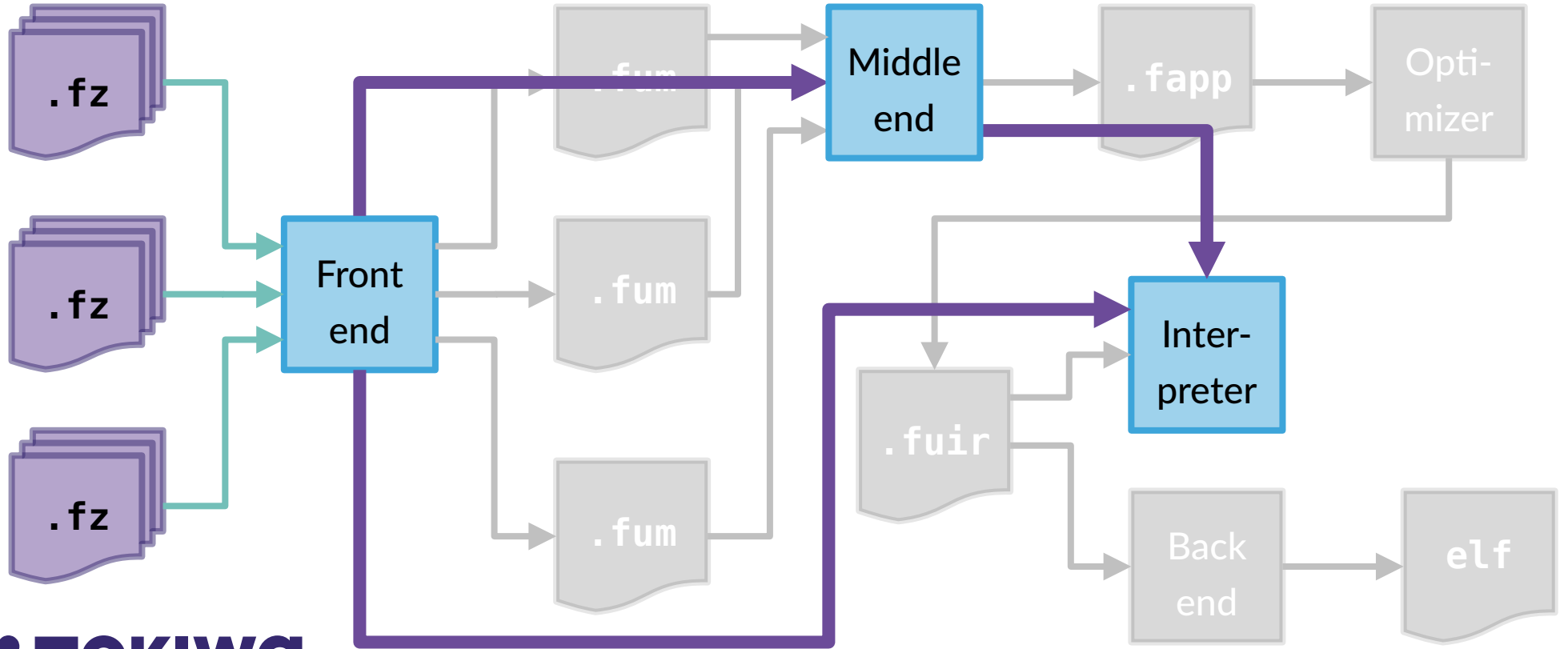
Fuzion Interpreter Backend

First quick & dirty back end

➡ direct accesses to front end

Fuzion Interpreter Backend



Fuzion Interpreter Backend

First quick & dirty back end

➡ direct accesses to front end

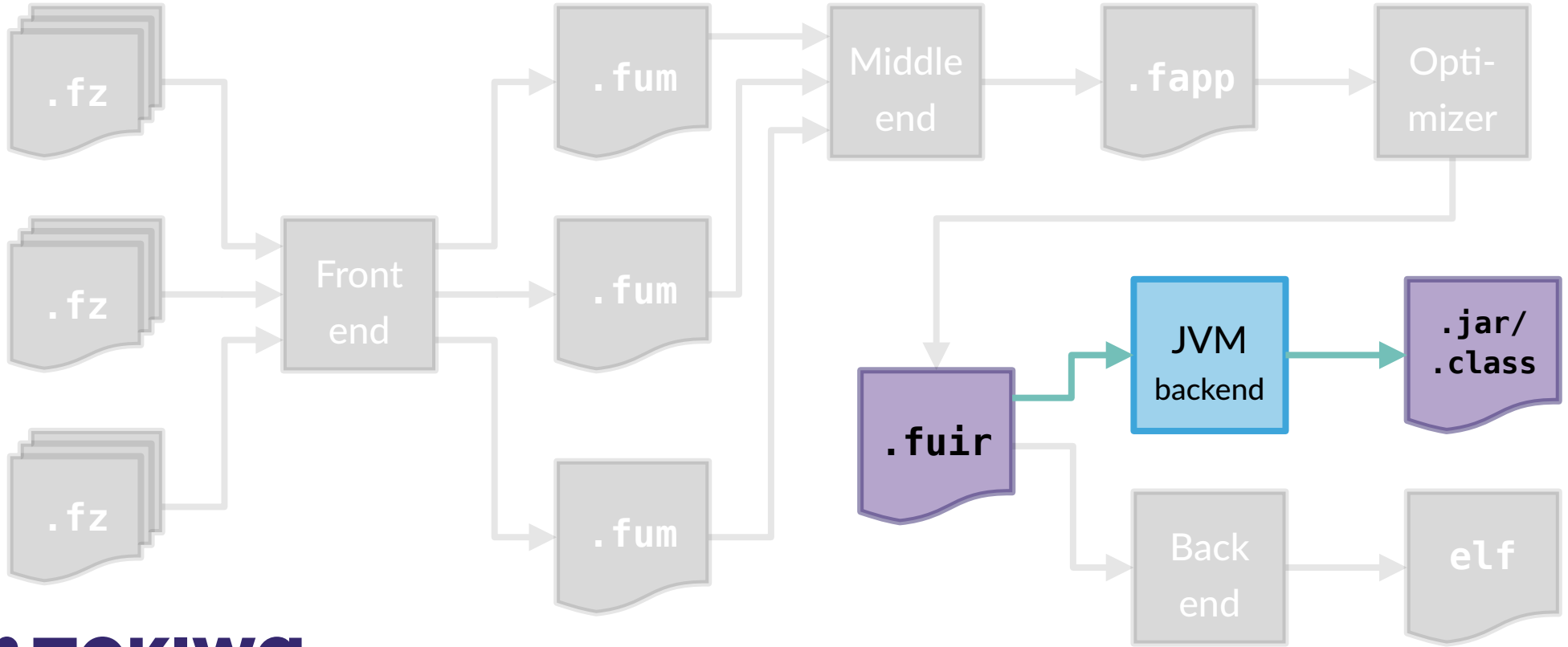
Fuzion Interpreter Backend

First quick & dirty back end

- ➡ direct accesses to front end
- ➡ Fuzion Instances represented as Java Objects with
  - `Object[]` for reference fields
  - `int[]` for non-reference fields
- ➡ Not optimized

Planned Bytecode Backend

Planned Bytecode Backend



Planned Bytecode Backend

Input is FUIR intermediate code

- ➡ Fuzion **clazzes**
  - Features specialized for
    - actual type parameters
    - actual outer clazz
  - five kinds: routine, field, intrinsic, abstract, choice
- ➡ Clazzes of kind routine contain code
  - 14 instructions: assign, call, match, current, const, pop, …
  - no loops, only one branch: match

Planned Bytecode Backend

Probable implementation decisions

- ➡ Java interfaces to implement dynamic dispatch
  - `invokeinterface` highly optimized by JVM
  - `invokedynamic` probably more expensive
- ➡ Fuzion dynamic (ref) instances as Java classes
  - implementing interfaces
  - specialized for type arguments
- ➡ Fuzion value instances as inline primitive values

Fuzion: Next Steps

Development Plan

- ➡ intermediate files: .fum, .fapp, .fuir
- ➡ simple analysis tools: field init, immutability
- ➡ C back-end: GC, floats, etc.
  - interfacing C library code
- ➡ Standard Library
- ➡ Modeling I/O, thread communication and immutability
  - using automatic monadic lifting?

Conclusion

Fuzion is an exciting new language

- ➡ Java used to implement tools
- ➡ OpenJDK important execution target
- ➡ we need
  - to grow our team
  - get developer feedback
  - secure long-term funding
- ➡ please get involved!

http://flang.dev

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github.com/tokiwa-software/fuzion