Web Engines Hackfest 2023

Inside Kotlin/Wasm

(or how your language could benefit from new proposals)

Zalim Bashorov
@bashorov

Kotlin

Kotlin

Programming Language

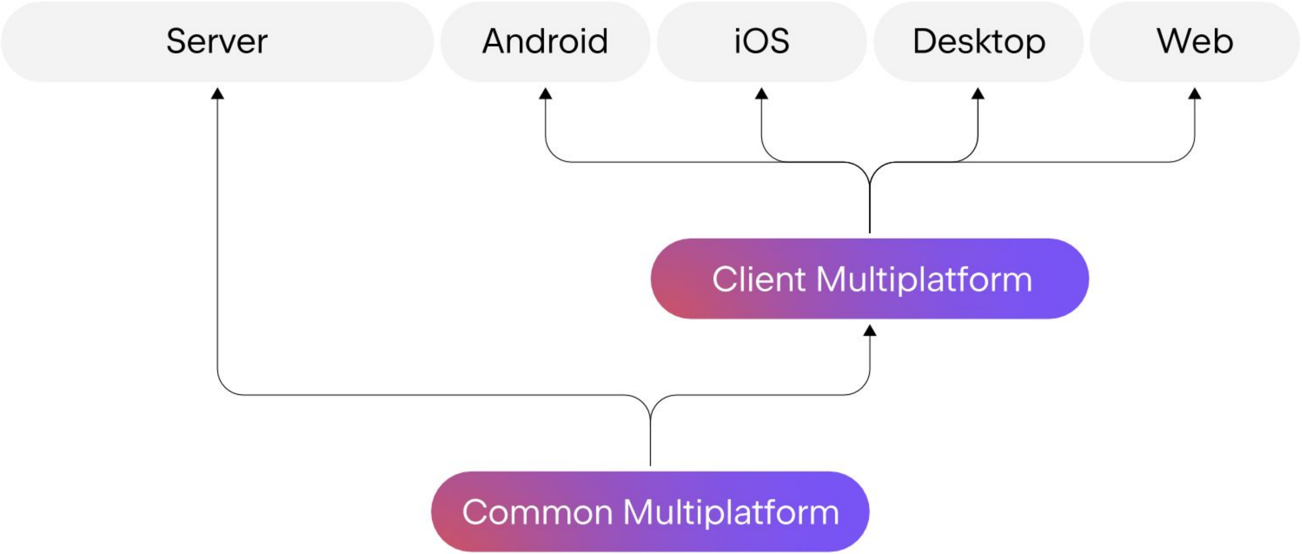
- Statically typed
- Concise and expressive
- Pragmatic but elegant
- Imperative and functional
- **Null-safety**

Kotlin

Ecosystem

- Multiple target platforms
  - JVM
  - Native (iOS, Linux, Windows, ….)
  - JavaScript
  - WebAssembly
- JVM based tooling
- Compiler plugins (Experimental)

Kotlin


Server
Android
iOS
Desktop
Web
Client Multiplatform
Common Multiplatform

WA

Kotlin/Wasm new compiler

- Fast Compilation
- Incremental Compilation (later)

Kotlin/Wasm new compiler

- Fast Compilation
- Incremental Compilation (later)
- Great integration with hosts

Kotlin/Wasm new compiler

- Fast Compilation
- Incremental Compilation (later)
- Great integration with hosts
- Good Interop with hosts

```kotlin
import kotlinx.browser.document
import kotlinx.dom.appendText

fun main() {
    val p = document.createElement("p")
    p.innerHTML = "Hello World!"
    document.body?.appendChild(p)
}
```

Kotlin/Wasm new compiler

- Fast Compilation
- Incremental Compilation (later)
- Great integration with hosts
- Good Interop with hosts
- Small binaries

3K

```
import k                    ment
import k                    xt

fun main
    val                     Element("p")
    p.innerHTML = "Hello World!"
    document.body?.appendChild(p)
}
```

WebAssembly proposals we are using

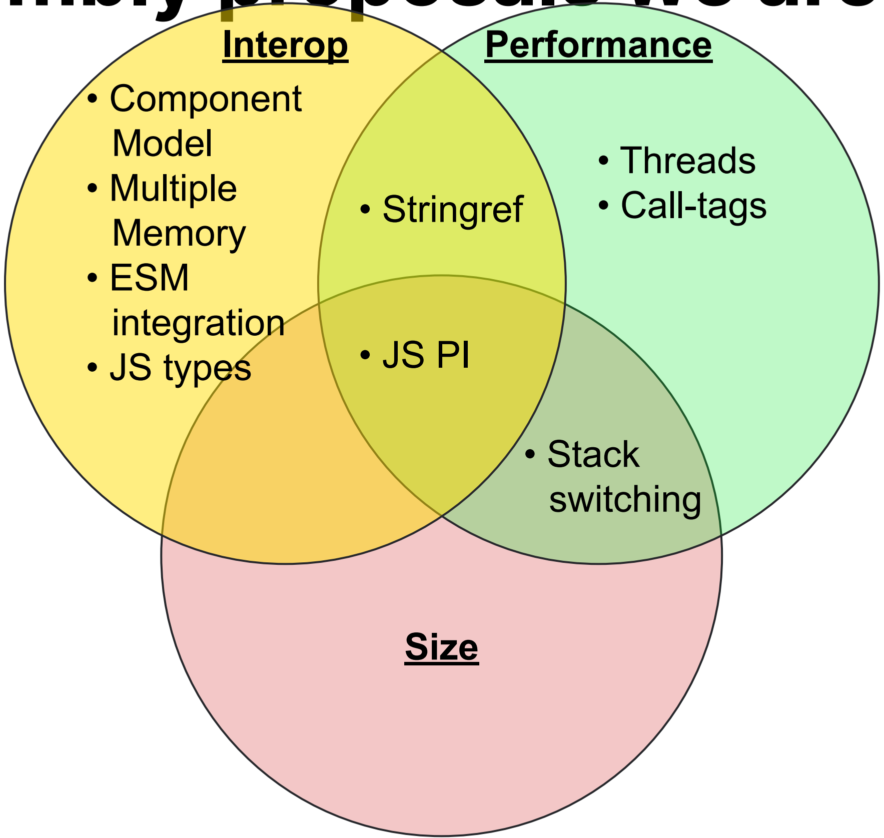
✅	Reference Types	🟩🟩🟩🟩
✅	Exception Handling	🟩🟩🟩⬜
✅	Extended Name Section	🟩⬜⬜⬜
🏗️	Typed Function References	🟩🟩🟩⬜
🏗️	Garbage Collection	🟩🟩🟩⬜

Trial for Wasm GC in Chrome 112.* 🎉🎉🎉

Turn on Wasm GC for your site!

https://zal.im/tryWasmGC

WebAssembly proposals we are **interested in**



Interop

- Component Model
- Multiple Memory
- ESM integration
- JS types

Performance

- Threads
- Call-tags

- Stringref

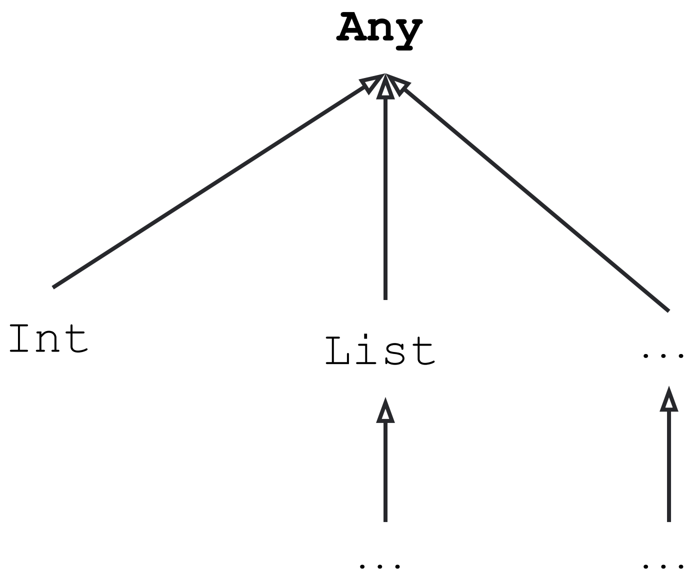
- JS PI

- Stack switching

Size

Kotlin/Wasm deep dive

Class kotlin.Any



Any

Int

List

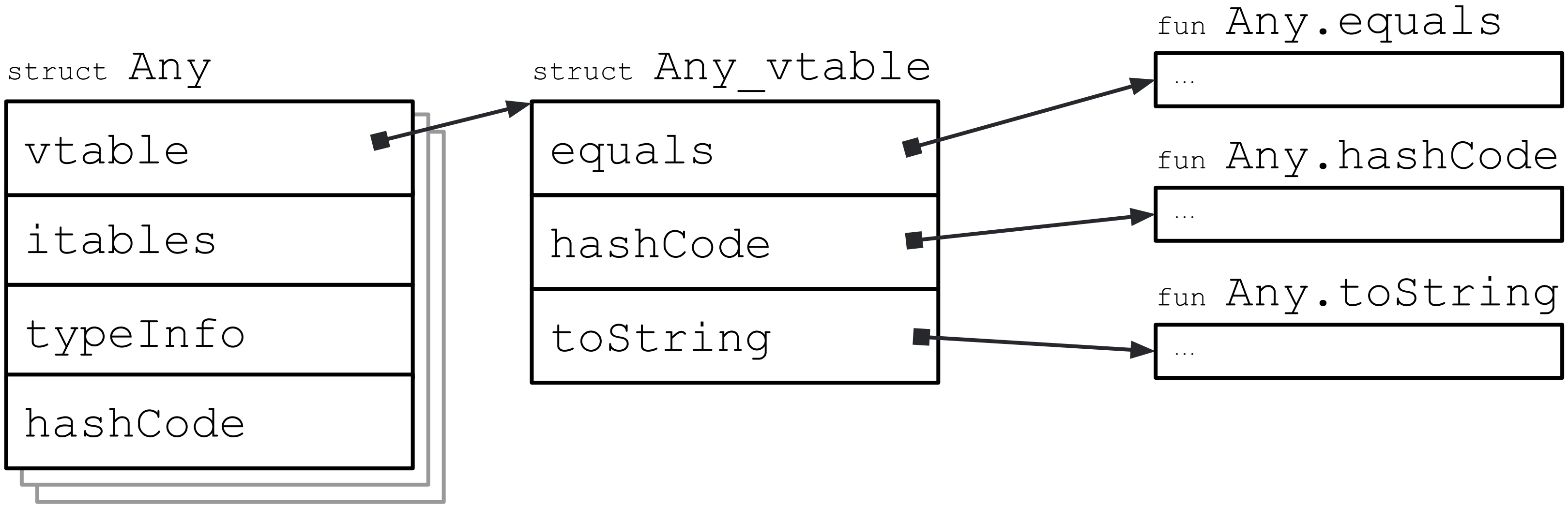
...

...

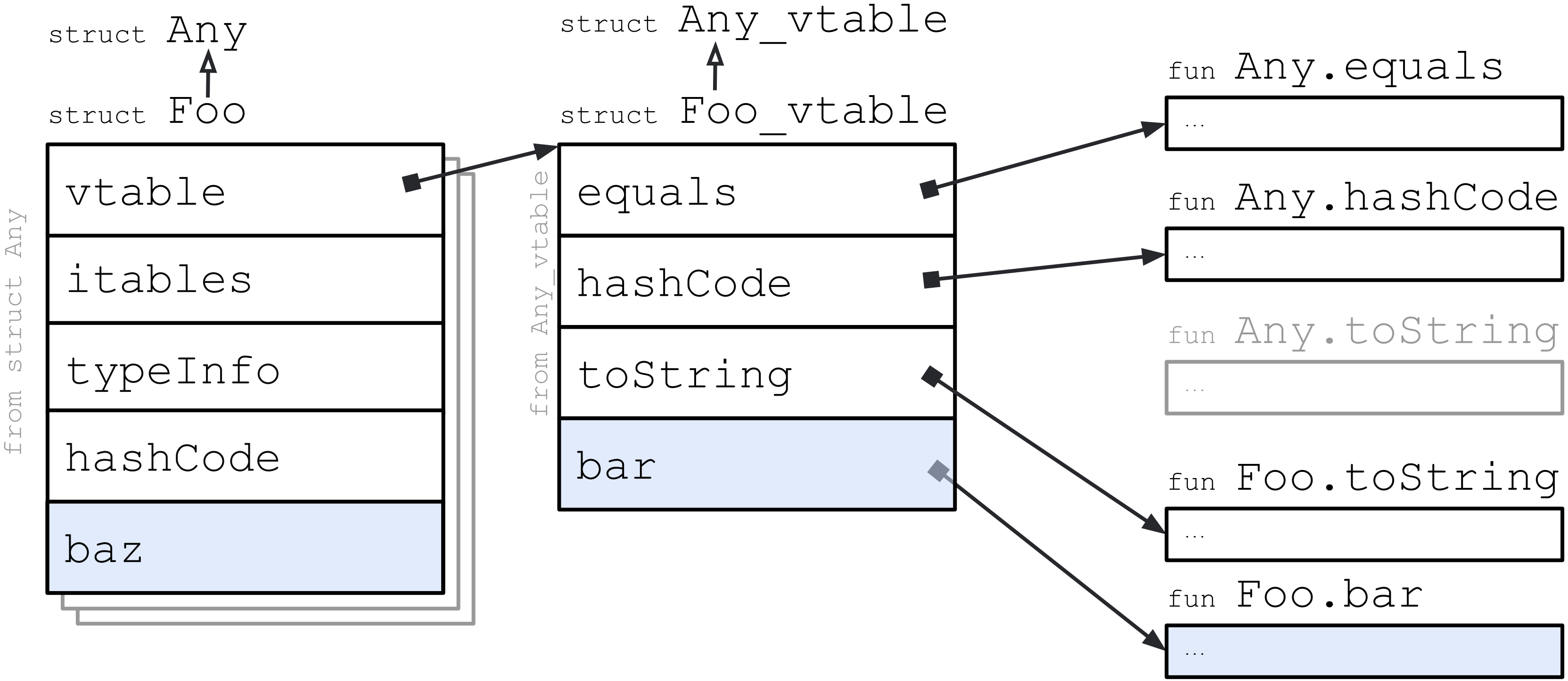
...

```
open class Any {

    open fun equals(other: Any?): Boolean

    open fun hashCode(): Int

    open fun toString(): String
}
```

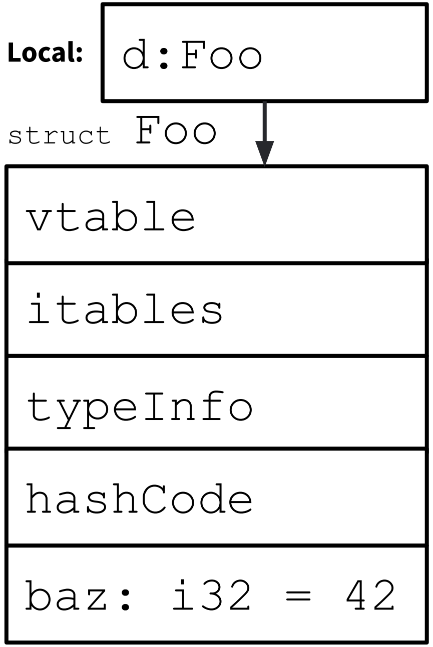
Class kotlin.Any



Class extension



Access to fields



Local: d:Foo

struct Foo

vtable

itables

typeInfo

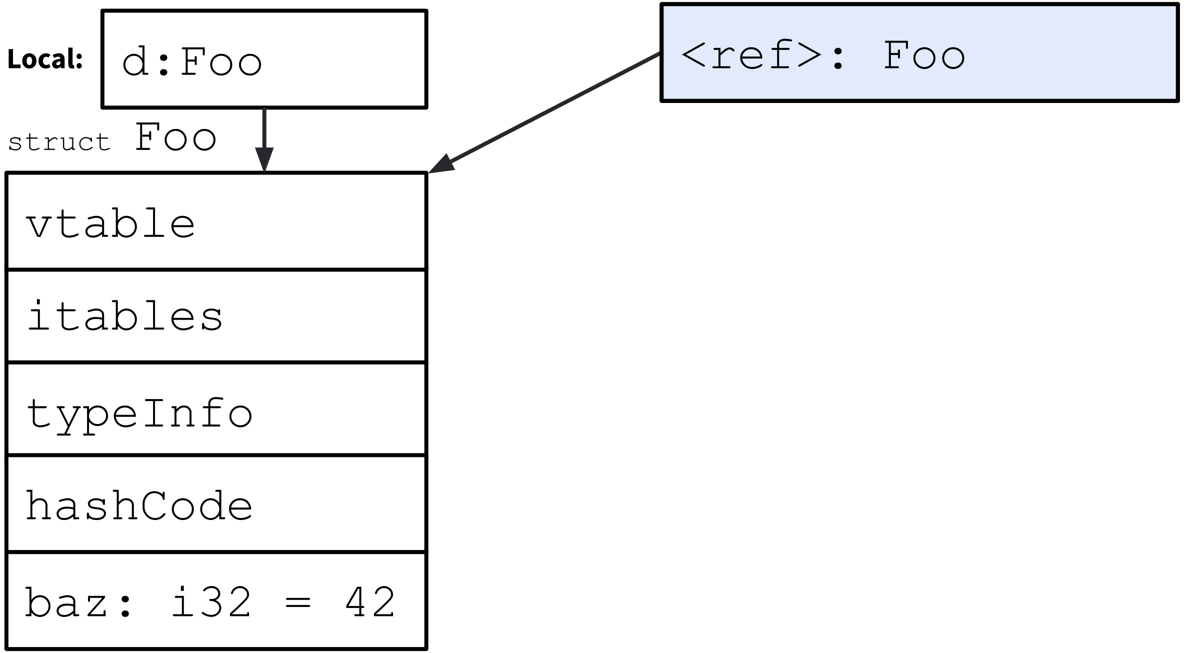
hashCode

baz: i32 = 42

Stack:

Instructions:

Access to fields



Local: `d:Foo`

`struct Foo`

`vtable`

`itables`

`typeInfo`

`hashCode`

`baz: i32 = 42`

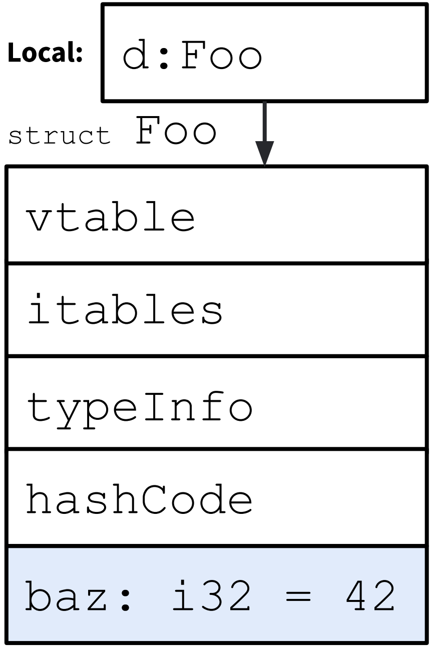
Stack:

`<ref>: Foo`

Instructions:

`local.get $d`

Access to fields



Local: d:Foo

struct Foo

```
vtable
itables
typeInfo
hashCode
baz: i32 = 42
```

Stack:

```
42
```

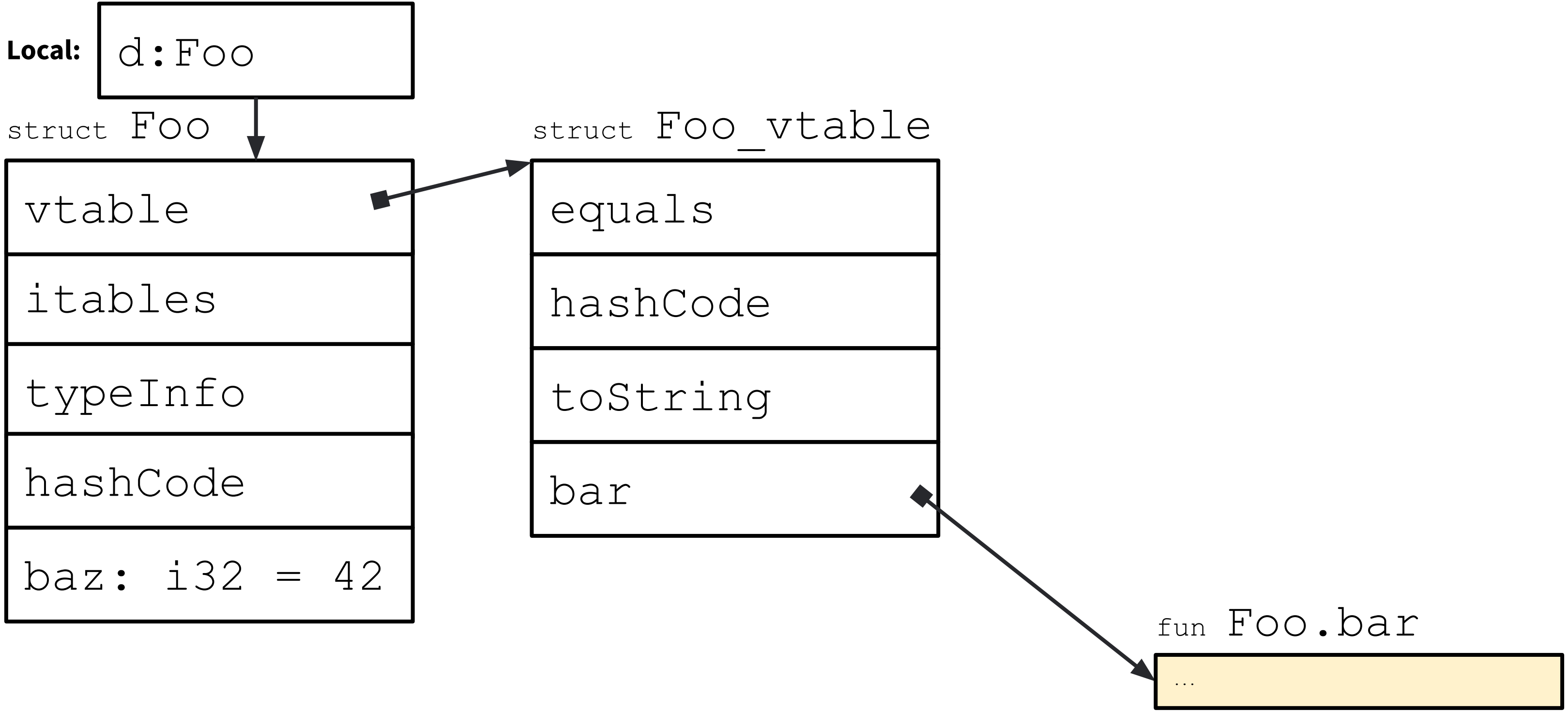
Instructions:

```
local.get $d
struct.get $baz
```

Stack:

Instructions:

Virtual Method ca



Local: d:Foo

struct Foo

vtable

itables

typeInfo

hashCode

baz: i32 = 42

struct Foo_vtable

equals

hashCode

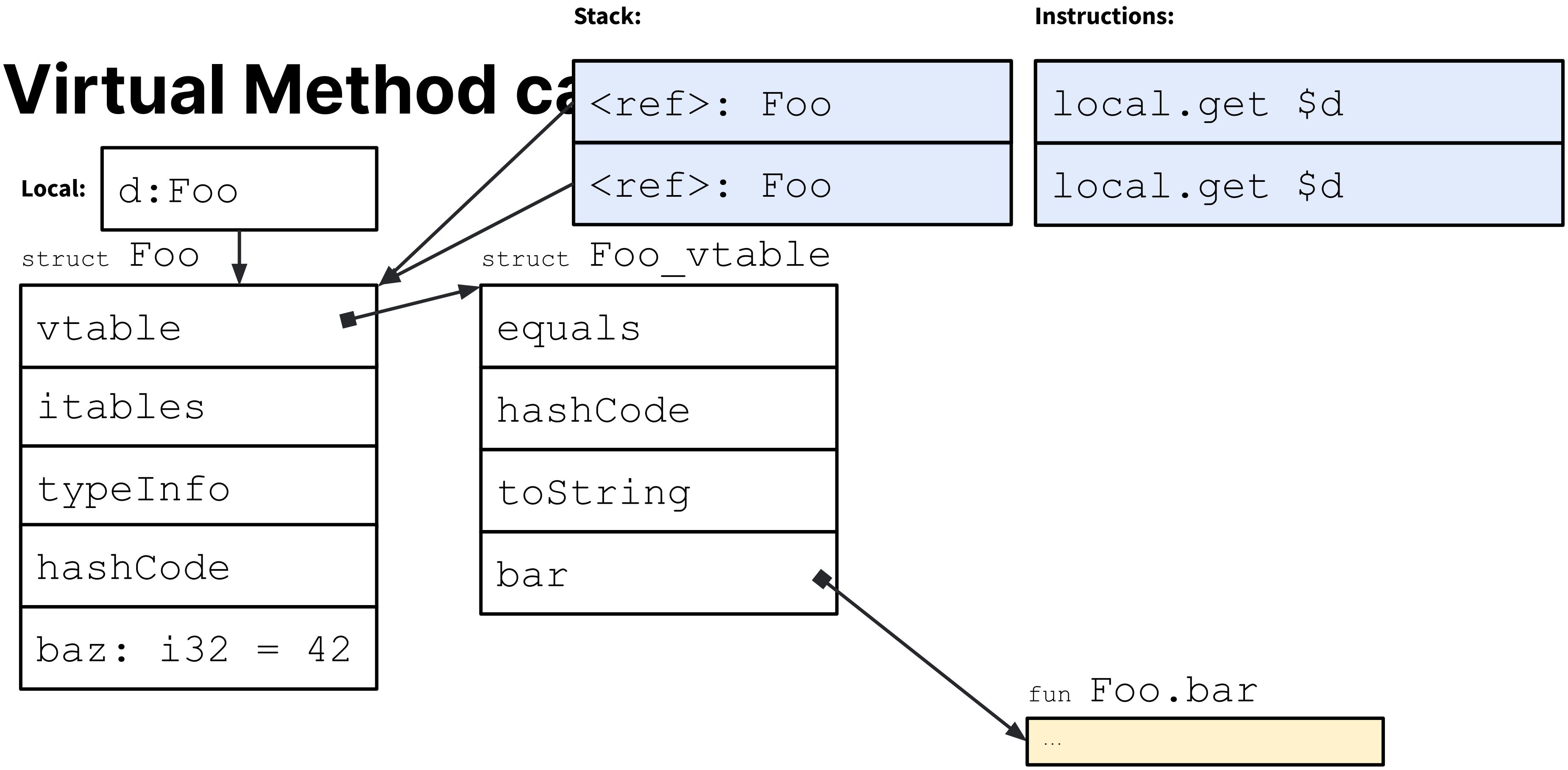
toString

bar

fun Foo.bar

...

Virtual Method ca



Stack:

`<ref>: Foo`

`<ref>: Foo`

Instructions:

`local.get $d`

`local.get $d`

Local: `d:Foo`

struct `Foo`

- `vtable`
- `itables`
- `typeInfo`
- `hashCode`
- `baz: i32 = 42`

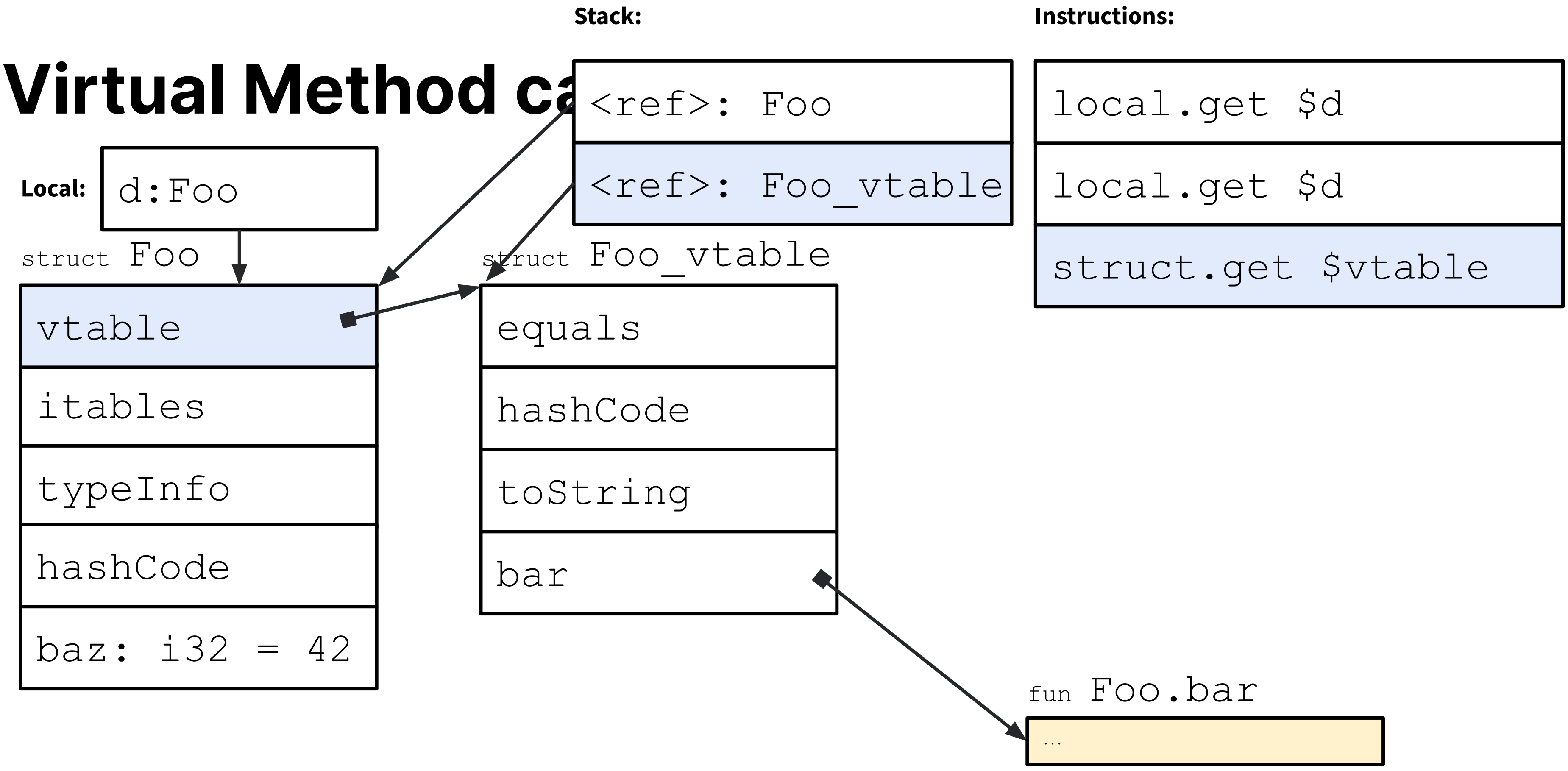
struct `Foo_vtable`

- `equals`
- `hashCode`
- `toString`
- `bar`

fun `Foo.bar`

…

Virtual Method ca



Stack:

<ref>: Foo

<ref>: Foo_vtable

Instructions:

```
local.get $d
local.get $d
struct.get $vtable
```

Local: d:Foo

struct Foo

vtable

itables

typeInfo

hashCode

baz: i32 = 42

struct Foo_vtable

equals

hashCode

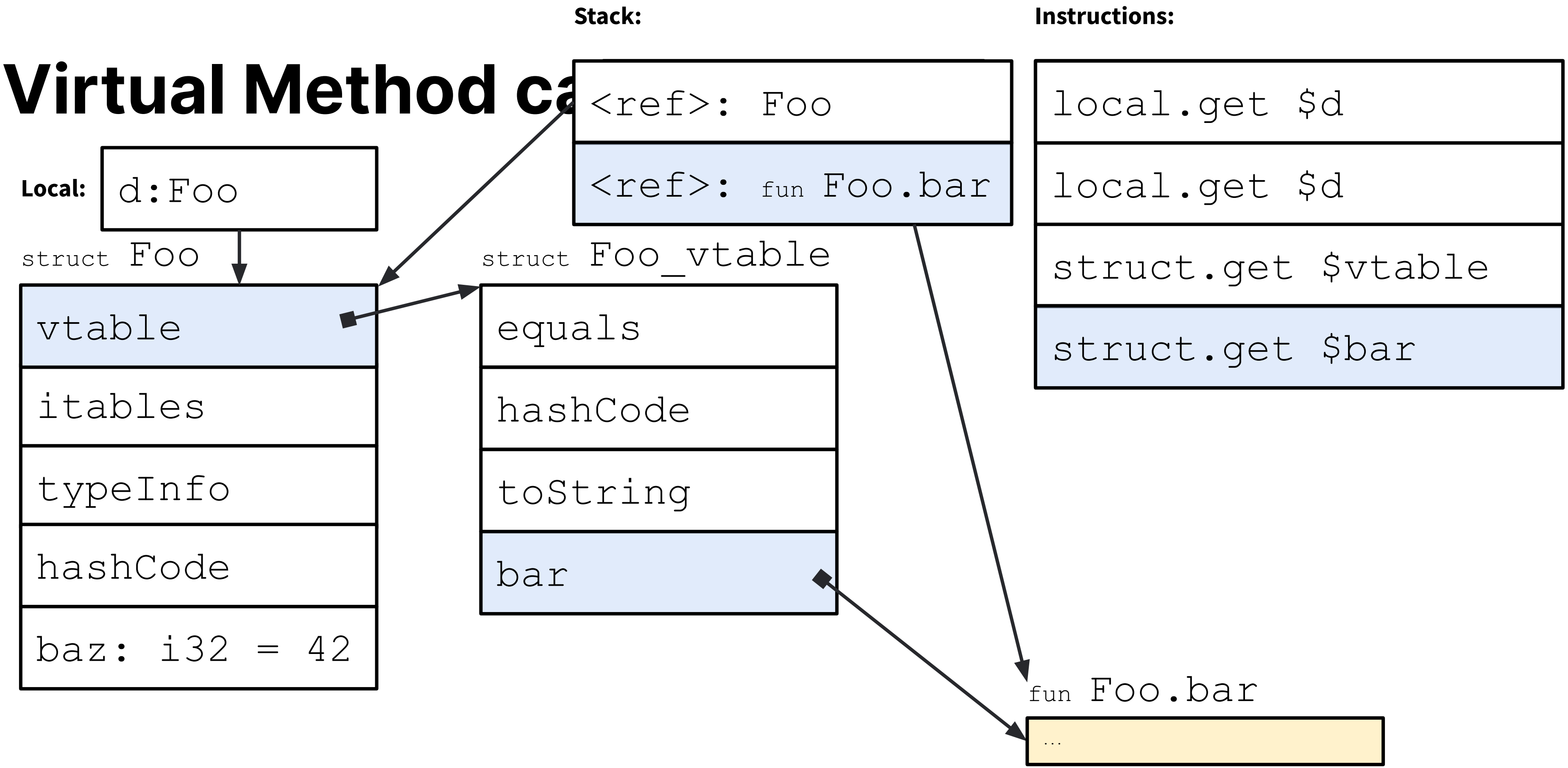
toString

bar

fun Foo.bar

…

Virtual Method ca



Local: d:Foo

struct Foo

- vtable
- itables
- typeInfo
- hashCode
- baz: i32 = 42

struct Foo_vtable

- equals
- hashCode
- toString
- bar

Stack:

- <ref>: Foo
- <ref>: fun Foo.bar

Instructions:

```
local.get $d
local.get $d
struct.get $vtable
struct.get $bar
```

fun Foo.bar

```
...
```

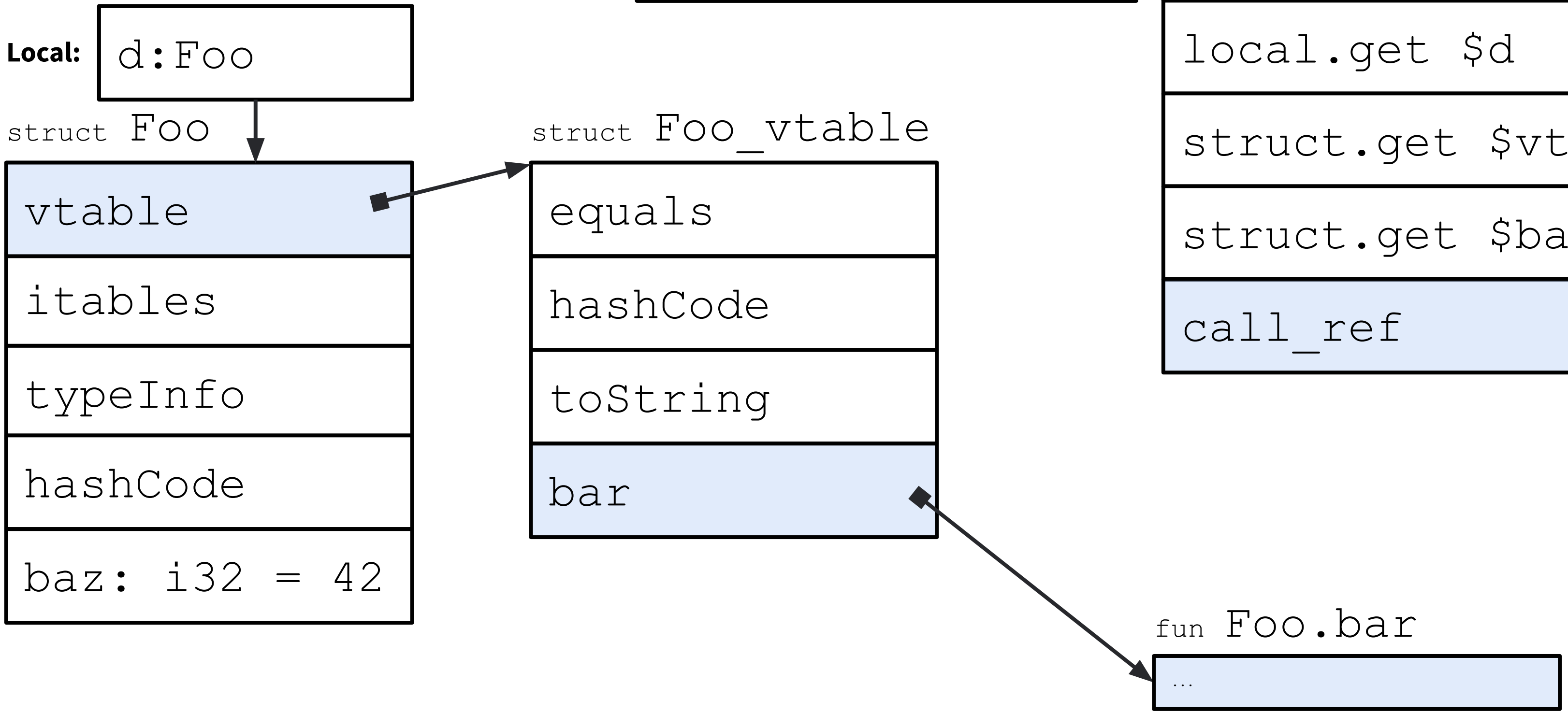
Virtual Method ca

Stack:

27

Instructions:

```
local.get $d
local.get $d
struct.get $vtable
struct.get $bar
call_ref
```



Local: d:Foo

struct Foo

- vtable
- itables
- typeInfo
- hashCode
- baz: i32 = 42

struct Foo_vtable

- equals
- hashCode
- toString
- bar

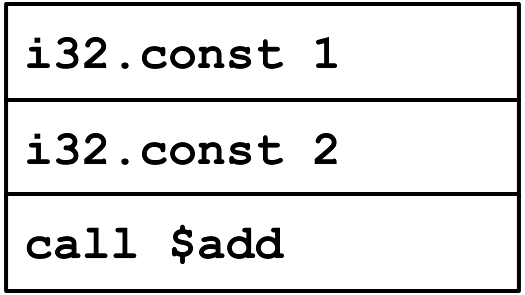
fun Foo.bar

...

Static Method calls

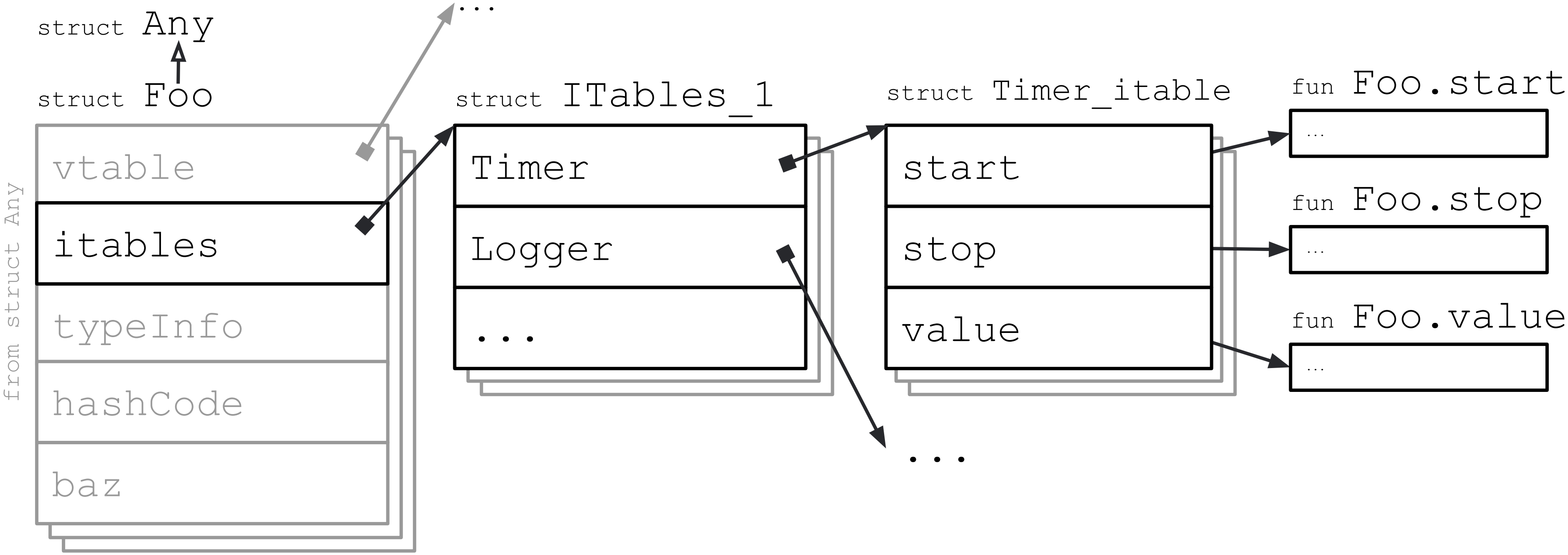
```
call $getTime
```

Static Method calls



```
i32.const 1
i32.const 2
call $add
```

Interfaces



struct Any
struct Foo
from struct Any
vtable
itables
typeInfo
hashCode
baz
...
struct ITables_1
Timer
Logger
...
...
struct Timer_itable
start
stop
value
fun Foo.start
...
fun Foo.stop
...
fun Foo.value
...

Different kind of calls

Static function

```
call $getTime
```

Class / virtual method

```
local.get $d
local.get $d
struct.get $vtable
struct.get $bar
call_ref
```

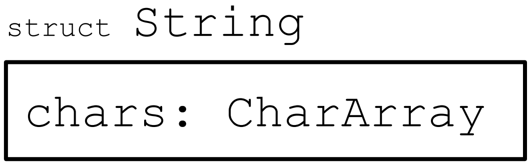
Interface method

```
local.get $d
local.get $d
struct.get $itables
ref.cast $Itables_1
struct.get $Timer
struct.get $value
call_ref
```

Strings

Strings are everywhere!

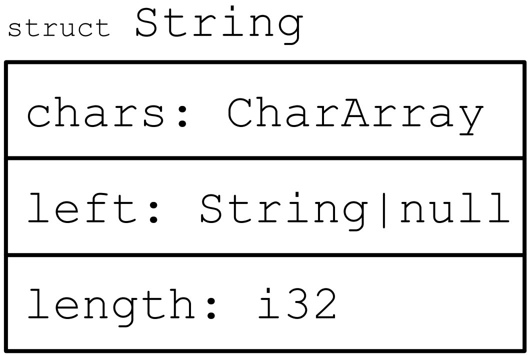
String naïve impl



struct String

chars: CharArray

String optimized



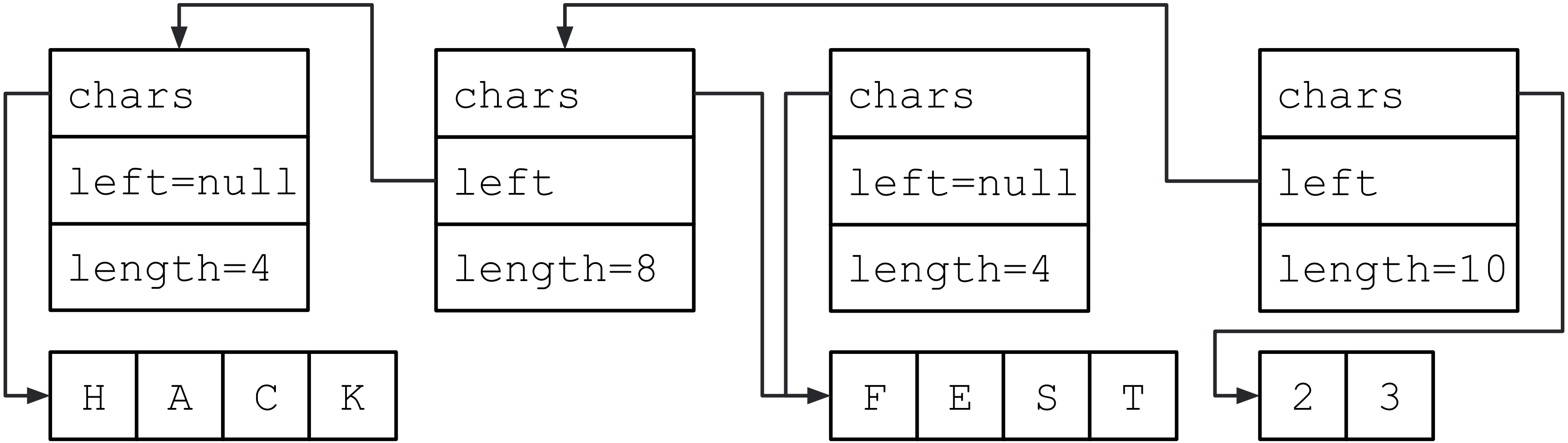
struct String

chars: CharArray

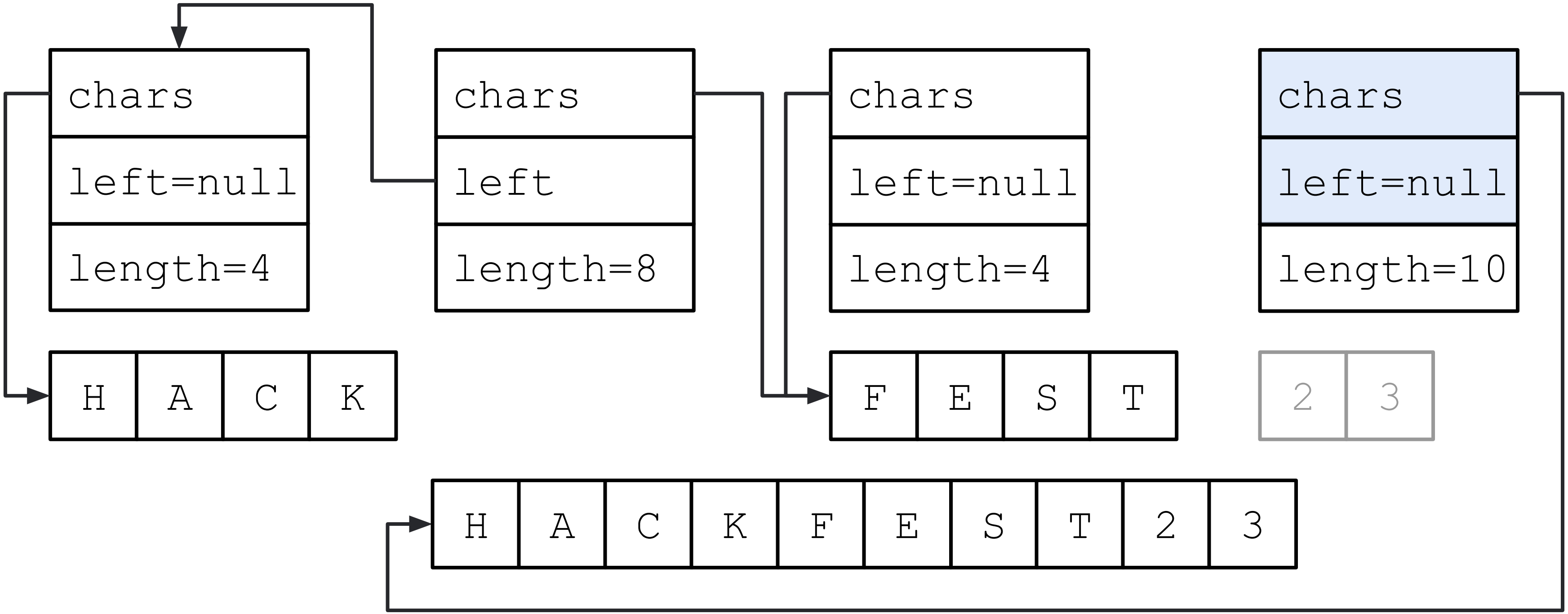
left: String|null

length: i32

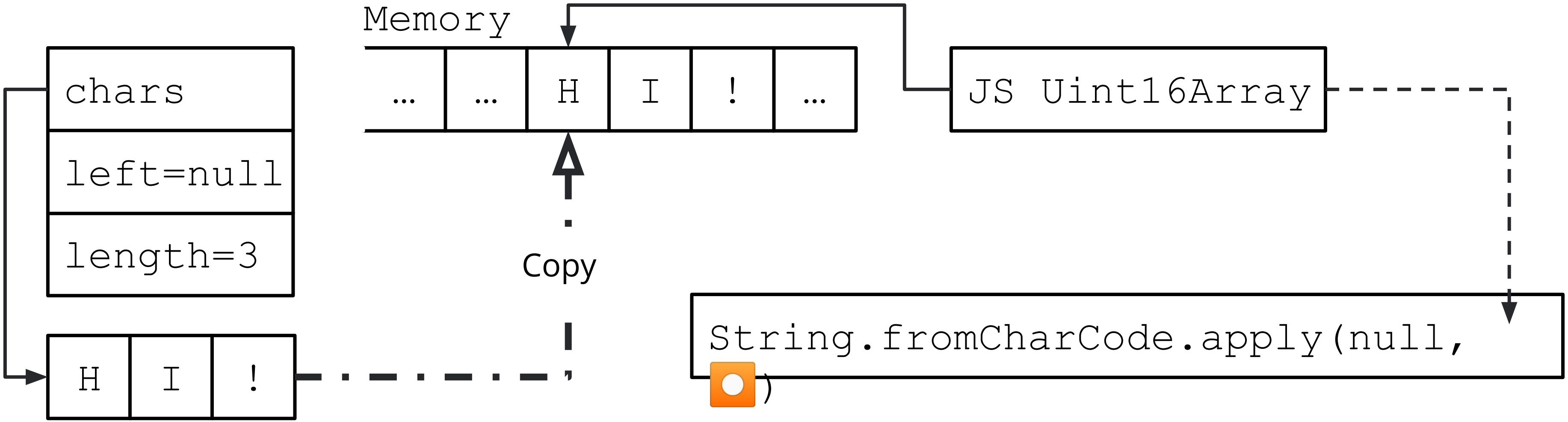
String optimized: example



String optimized: example



String transfer to JS



Memory

chars

left=null

length=3

H I !

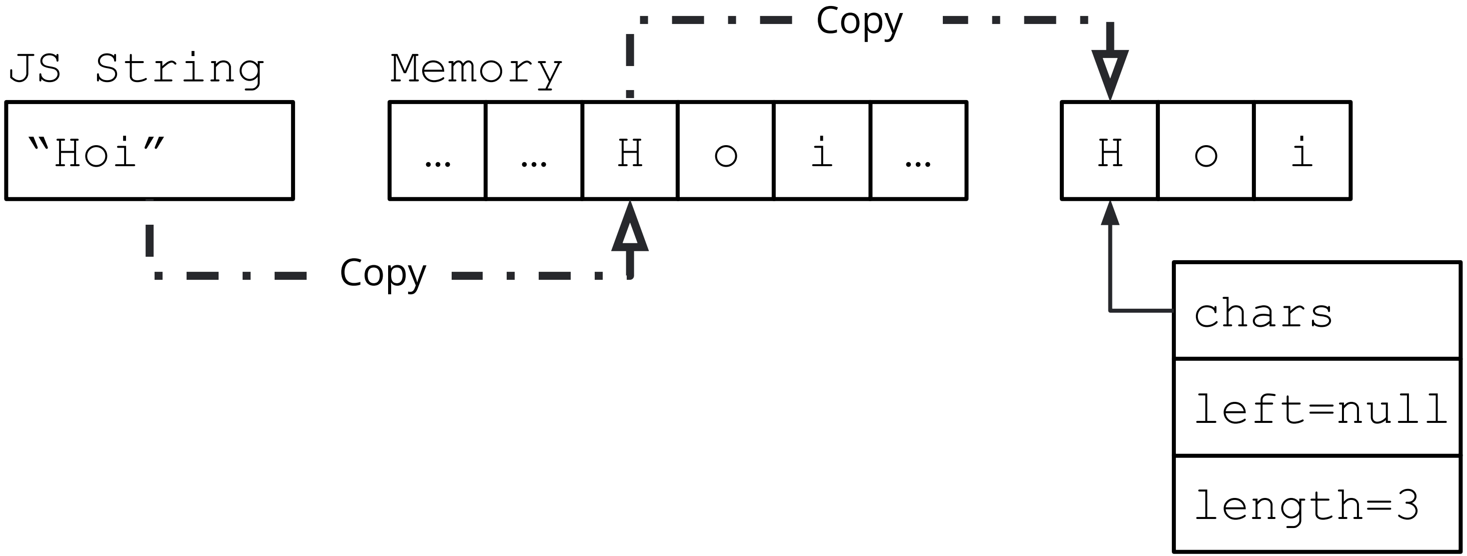
… … H I ! …

Copy

JS Uint16Array

`String.fromCharCode.apply(null, ⏺ )`

String transfer from JS



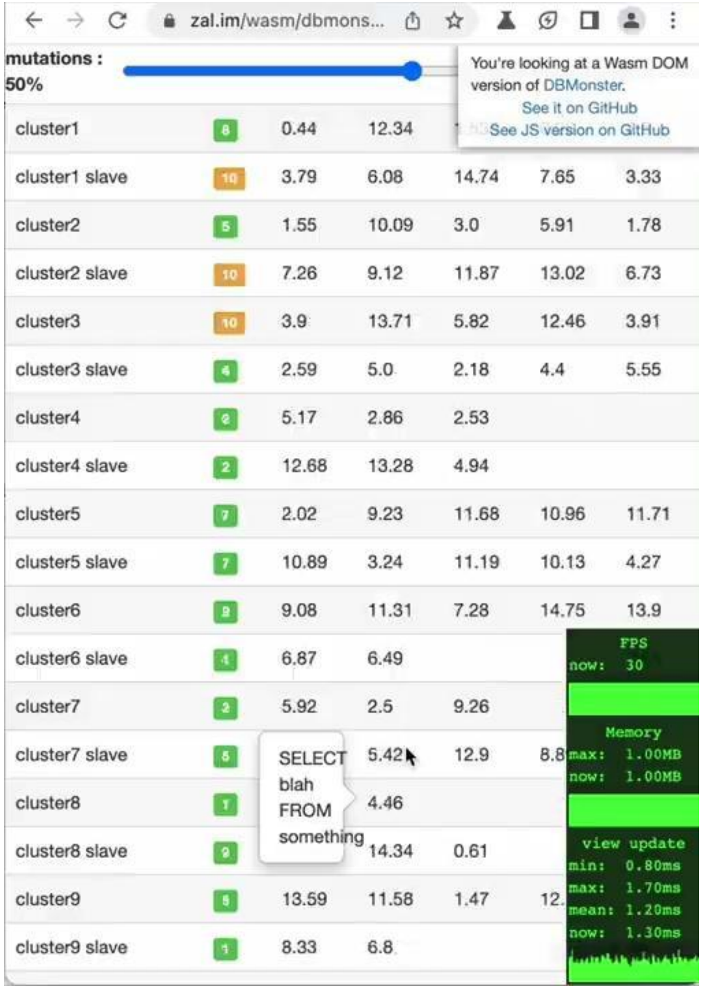
String literals

- **Intern** all compile time string constants
- Store in **data section**
  - Fast at runtime (`array.new_data`)
- Runtime **cache** for string literals
- Optimize for Latin1

Stringref proposal 🚀

Preliminary results:

- 60 times faster on interop microbenchmarks
- Up to 3 times faster on DBMonster benchmark[1] [2]



mutations : 50%

You're looking at a Wasm DOM version of DBMonster.
See it on GitHub
See JS version on GitHub

cluster1	8	0.44	12.34			
cluster1 slave	10	3.79	6.08	14.74	7.65	3.33
cluster2	5	1.55	10.09	3.0	5.91	1.78
cluster2 slave	10	7.26	9.12	11.87	13.02	6.73
cluster3	10	3.9	13.71	5.82	12.46	3.91
cluster3 slave	4	2.59	5.0	2.18	4.4	5.55
cluster4	2	5.17	2.86	2.53		
cluster4 slave	2	12.68	13.28	4.94		
cluster5	7	2.02	9.23	11.68	10.96	11.71
cluster5 slave	7	10.89	3.24	11.19	10.13	4.27
cluster6	9	9.08	11.31	7.28	14.75	13.9
cluster6 slave	4	6.87	6.49			
cluster7	2	5.92	2.5	9.26		
cluster7 slave	5		5.42	12.9	8.8	
cluster8	1		4.46			
cluster8 slave	9		14.34	0.61		
cluster9	5	13.59	11.58	1.47	12.	
cluster9 slave	1	8.33	6.8			

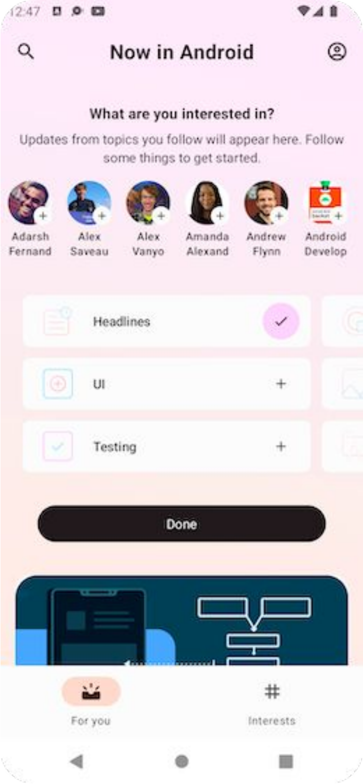
SELECT blah FROM something

```
FPS
now:  30

Memory
max:  1.00MB
now:  1.00MB

view update
min:  0.80ms
max:  1.70ms
mean: 1.20ms
now:  1.30ms
```

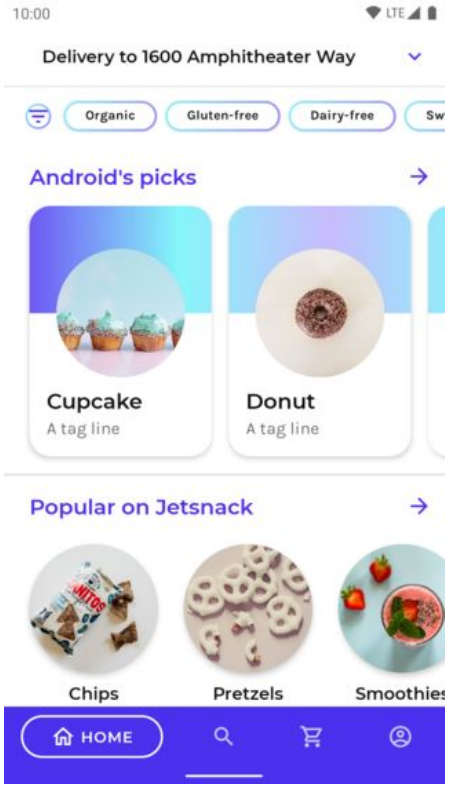
[1] https://zal.im/wasm/dbmonster/
[2] https://zal.im/wasm/dbmonster-stringref/

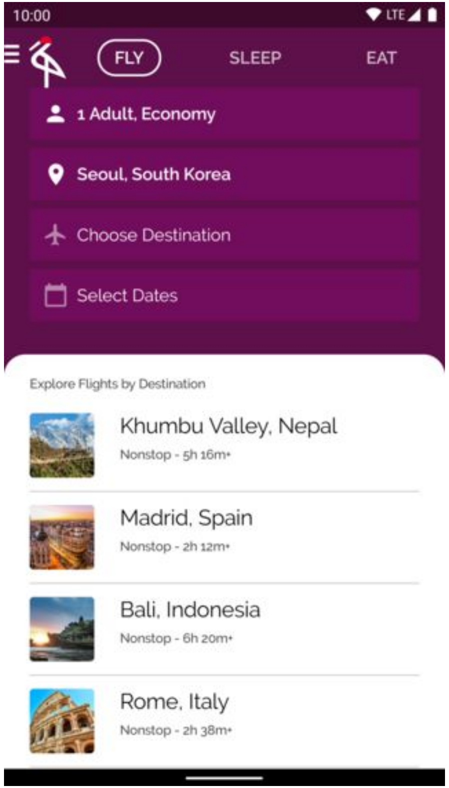
Kotlin/Wasm applications today and tomorrow

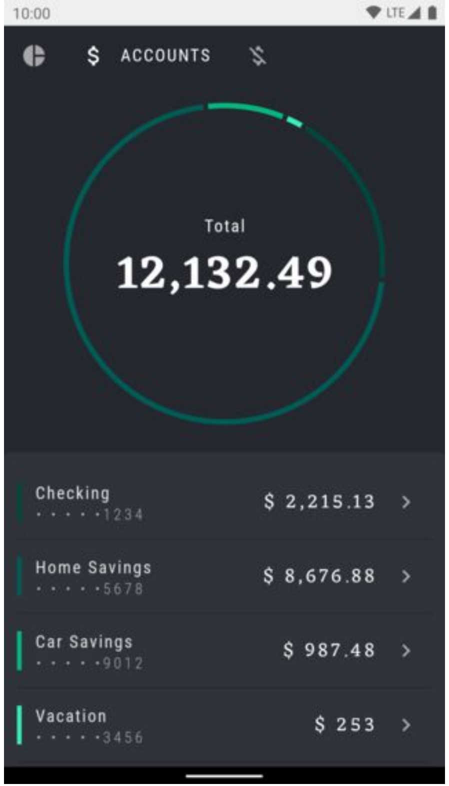
Jetpack Compose (Android)



Updates from topics you follow will appear here. Follow some things to get started.

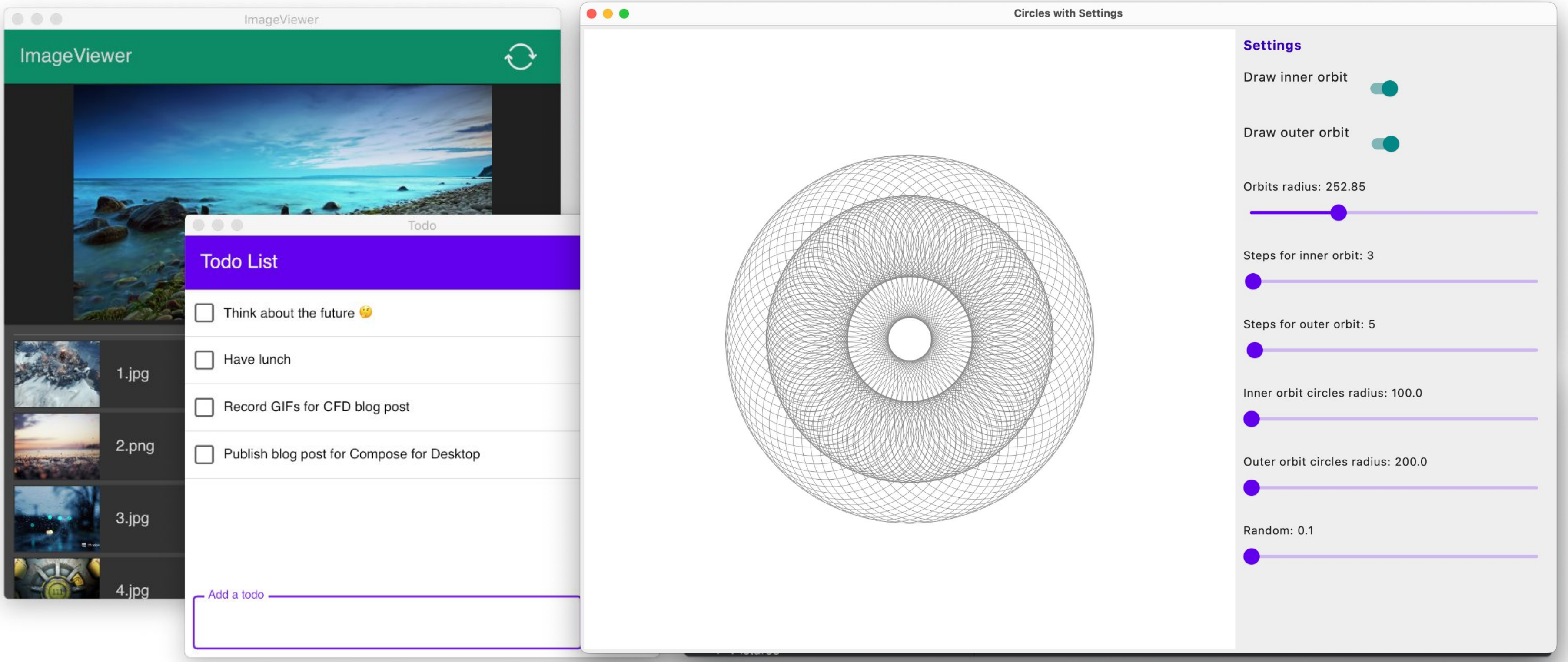






source: https://github.com/android/compose-samples

Compose Multiplatform for Desktop



Todo List

- □ Think about the future 🤔
- □ Have lunch
- □ Record GIFs for CFD blog post
- □ Publish blog post for Compose for Desktop

Add a todo

Settings

Draw inner orbit ●

Draw outer orbit ●

Orbits radius: 252.85

Steps for inner orbit: 3

Steps for outer orbit: 5

Inner orbit circles radius: 100.0

Outer orbit circles radius: 200.0

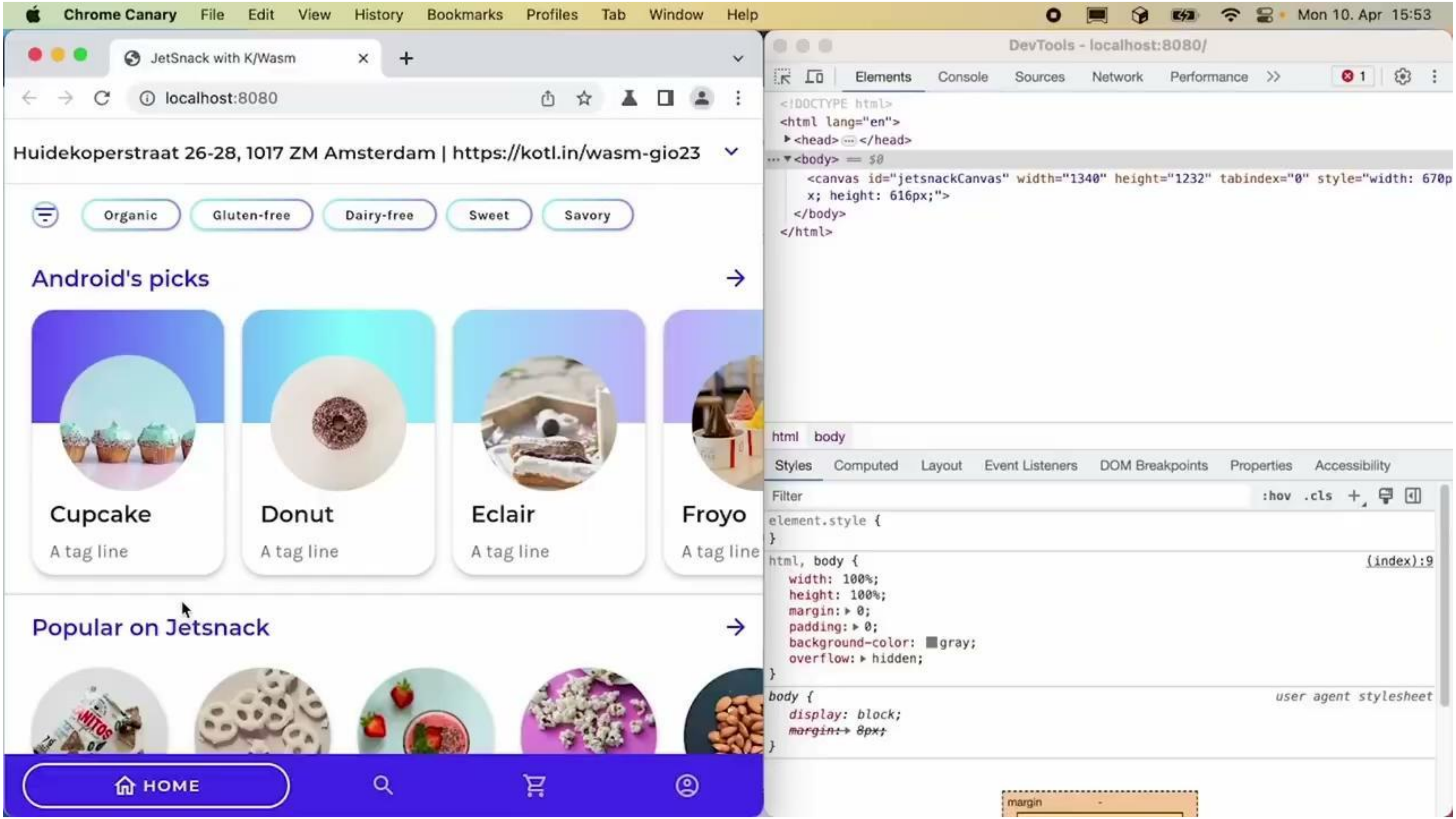
Random: 0.1

source: https://blog.jetbrains.com/wp-content/uploads/2020/11/example-apps.png

Compose Multiplatform: example

```
fun CircleOfCirlesWithSettings () = application {
   Window(title = "Circles with Settings" ) {
       MaterialTheme {
           var settings by remember { mutableStateOf(Settings())  }

           Row(modifier = Modifier.padding(5.dp)) {
               Canvas(...) {
                   if(settings.drawOuterOrbit){
                       outerOrbit(settings)
                   }
                   if (settings.drawInnerOrbit) {
                       innerOrbit(settings)
                   }
               }
               SettingsPanel(settings) { settings = it }
           }
       }
   }
}
```

zal.im/wasm/jetsnack/



Chrome Canary File Edit View History Bookmarks Profiles Tab Window Help
Mon 10. Apr 15:53
JetSnack with K/Wasm
localhost:8080
DevTools - localhost:8080/
Elements Console Sources Network Performance
html body
Styles Computed Layout Event Listeners DOM Breakpoints Properties Accessibility
Filter :hov .cls
HOME
margin

Huidekoperstraat 26-28, 1017 ZM Amsterdam | https://kotl.in/wasm-gio23

Organic Gluten-free Dairy-free Sweet Savory

Android's picks

Cupcake
A tag line

Donut
A tag line

Eclair
A tag line

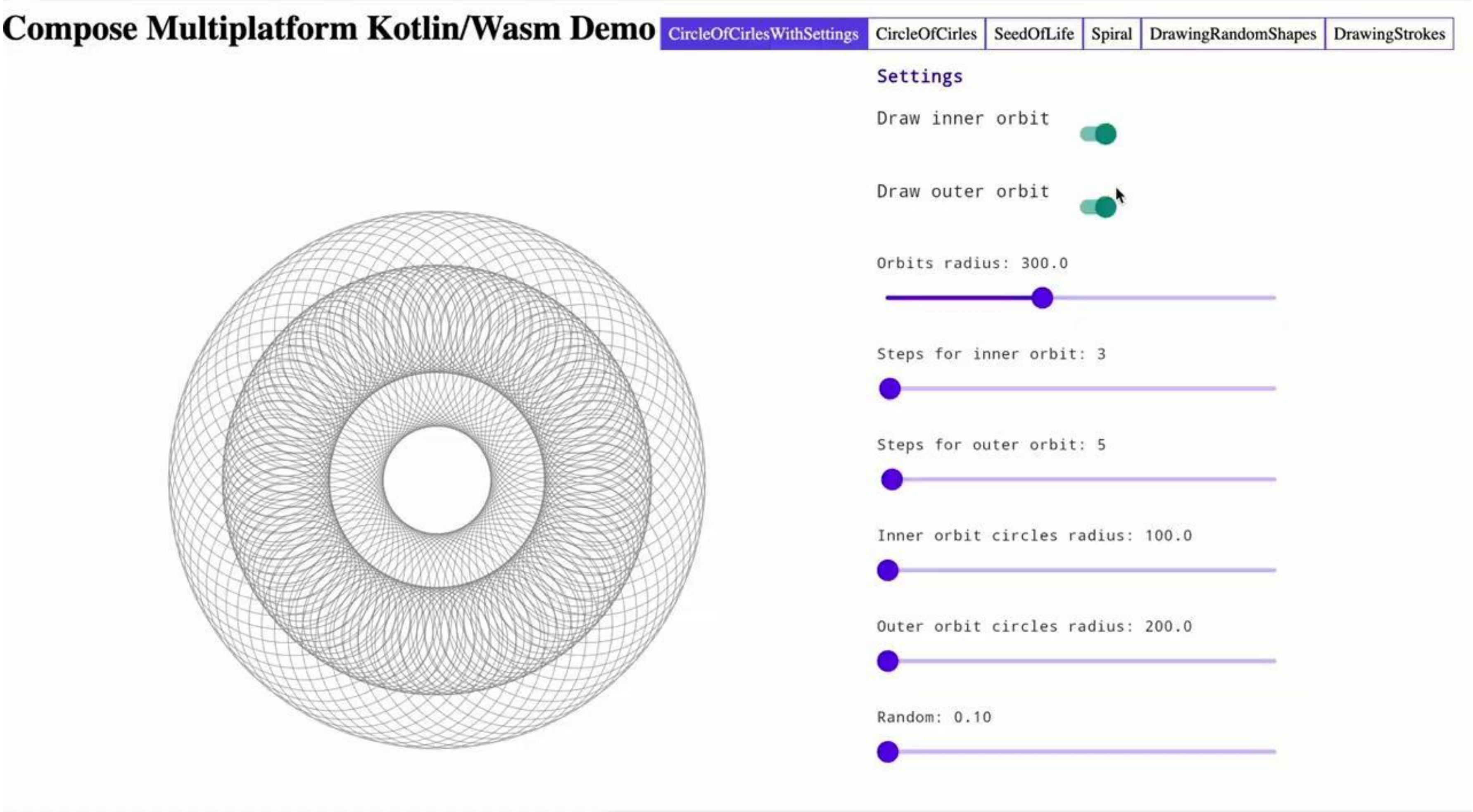
Froyo
A tag line

Popular on Jetsnack

```
<!DOCTYPE html>
<html lang="en">
 ▶<head> ⋯ </head>
 ▼<body> == $0
    <canvas id="jetsnackCanvas" width="1340" height="1232" tabindex="0" style="width: 670p
    x; height: 616px;">
   </body>
</html>
```

```
element.style {
}
html, body {                                                    (index):9
  width: 100%;
  height: 100%;
  margin: ▸ 0;
  padding: ▸ 0;
  background-color: ■gray;
  overflow: ▸ hidden;
}
body {                                              user agent stylesheet
  display: block;
  ~~margin:▸ 8px;~~
}
```

zal.im/wasm/creative/



Compose Multiplatform Kotlin/Wasm Demo

Settings

Draw inner orbit

Draw outer orbit

Orbits radius: 300.0

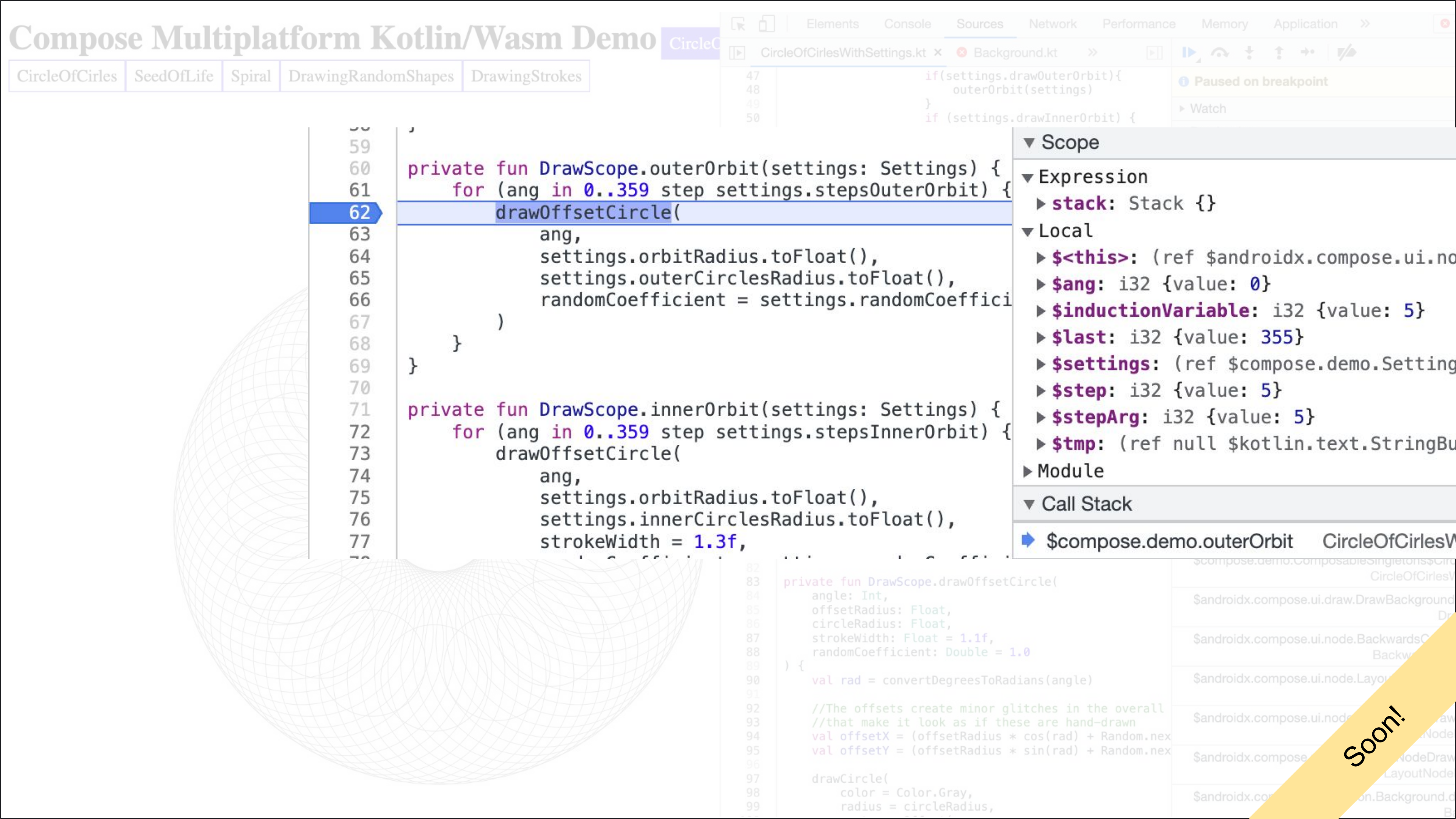
Steps for inner orbit: 3

Steps for outer orbit: 5

Inner orbit circles radius: 100.0

Outer orbit circles radius: 200.0

Random: 0.10



```kotlin
            if(settings.drawOuterOrbit){
                outerOrbit(settings)
            }
            if (settings.drawInnerOrbit) {
```

```kotlin
private fun DrawScope.outerOrbit(settings: Settings) {
    for (ang in 0..359 step settings.stepsOuterOrbit) {
        drawOffsetCircle(
            ang,
            settings.orbitRadius.toFloat(),
            settings.outerCirclesRadius.toFloat(),
            randomCoefficient = settings.randomCoeffici
        )
    }
}

private fun DrawScope.innerOrbit(settings: Settings) {
    for (ang in 0..359 step settings.stepsInnerOrbit) {
        drawOffsetCircle(
            ang,
            settings.orbitRadius.toFloat(),
            settings.innerCirclesRadius.toFloat(),
            strokeWidth = 1.3f,
```

```
▼ Scope
▼ Expression
  ▶ stack: Stack {}
▼ Local
  ▶ $<this>: (ref $androidx.compose.ui.no
  ▶ $ang: i32 {value: 0}
  ▶ $inductionVariable: i32 {value: 5}
  ▶ $last: i32 {value: 355}
  ▶ $settings: (ref $compose.demo.Setting
  ▶ $step: i32 {value: 5}
  ▶ $stepArg: i32 {value: 5}
  ▶ $tmp: (ref null $kotlin.text.StringBu
▶ Module
▼ Call Stack
  $compose.demo.outerOrbit        CircleOfCirlesW
  $compose.demo.ComposableSingletons$Circ
                                  CircleOfCirlesW
  $androidx.compose.ui.draw.DrawBackground
  $androidx.compose.ui.node.BackwardsC
  $androidx.compose.ui.node.Layou
  $androidx.compose.ui.node
  $androidx.compose
  $androidx.co
```

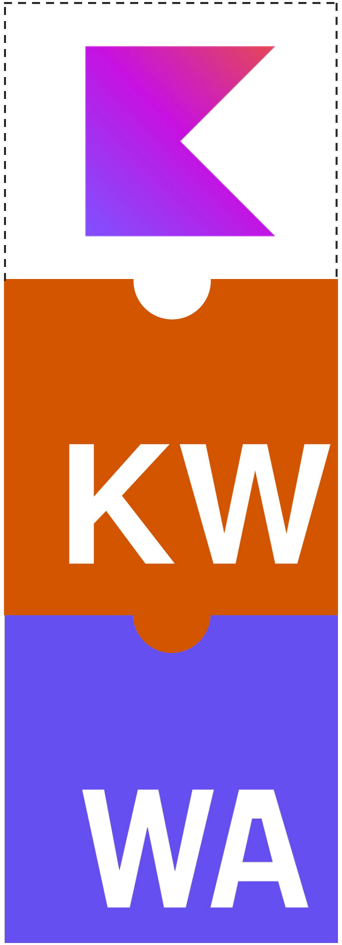
```kotlin
private fun DrawScope.drawOffsetCircle(
    angle: Int,
    offsetRadius: Float,
    circleRadius: Float,
    strokeWidth: Float = 1.1f,
    randomCoefficient: Double = 1.0
) {
    val rad = convertDegreesToRadians(angle)

    //The offsets create minor glitches in the overall
    //that make it look as if these are hand-drawn
    val offsetX = (offsetRadius * cos(rad) + Random.nex
    val offsetY = (offsetRadius * sin(rad) + Random.nex

    drawCircle(
        color = Color.Gray,
        radius = circleRadius,
```

Beyond the browsers

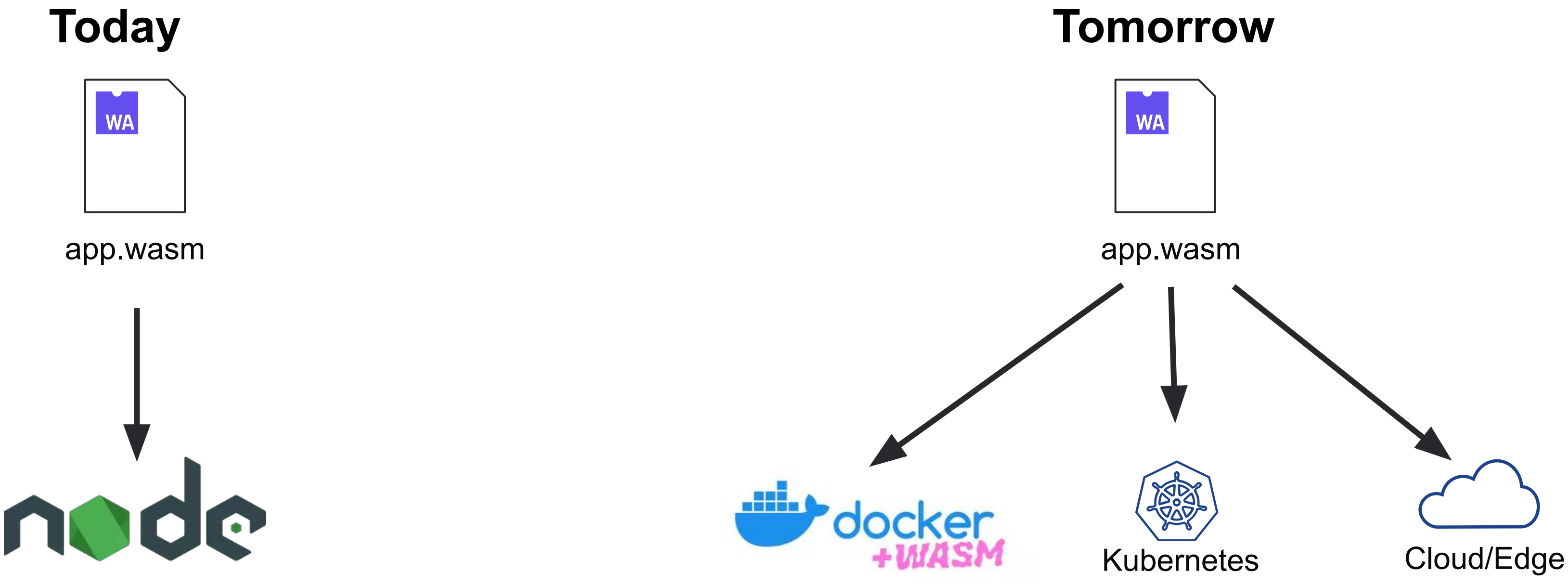
KoWasm (kowasm.org)

by Sébastien Deleuze (@sdeleuze)

Server-side and full stack development with Kotlin and WebAssembly, by leveraging WASI and Component Model



Deployment



Today

app.wasm

Tomorrow

app.wasm

Kubernetes

Cloud/Edge

```
node --experimental-wasi-unstable-preview1 \
--experimental-wasm-gc app.mjs
```

```
docker run -dp 8080:8080
--runtime=io.containerd.wasmtime.v1 \
# or --runtime=io.containerd.wasmedge.v1 \
--platform=wasi/wasm32 \
sdeleuze/app
```

What’s next?

- General availability of Wasm GC in browsers (soon)
- Kotlin/Wasm
  - Developer experience (DX)
  - Compose for Web with Kotlin/Wasm
  - Target standalone runtimes (Wasmtime, WasmEdge, etc.)

kotl.in/wasm

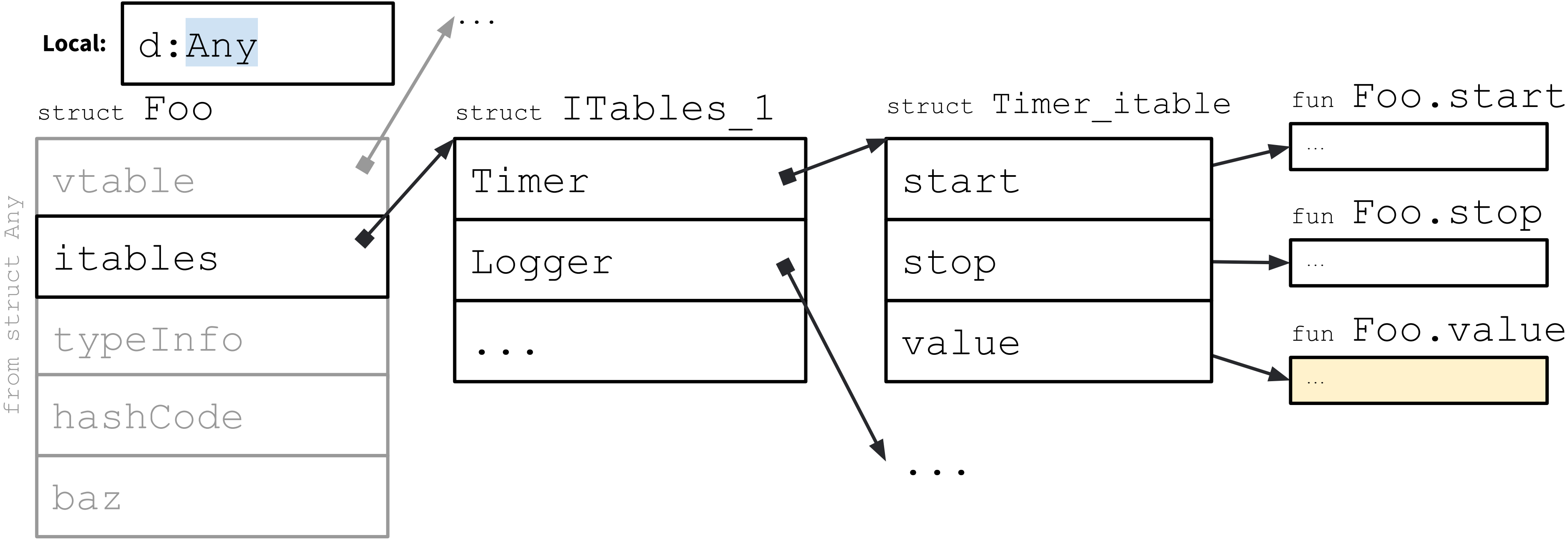
Thank you!

Zalim Bashorov
@bashorov

Interface method

Stack:

Instructions:



Local: d:Any

...

struct Foo

from struct Any

vtable

itables

typeInfo

hashCode

baz

struct ITables_1

Timer

Logger

...

struct Timer_itable

start

stop

value

...

fun Foo.start

...

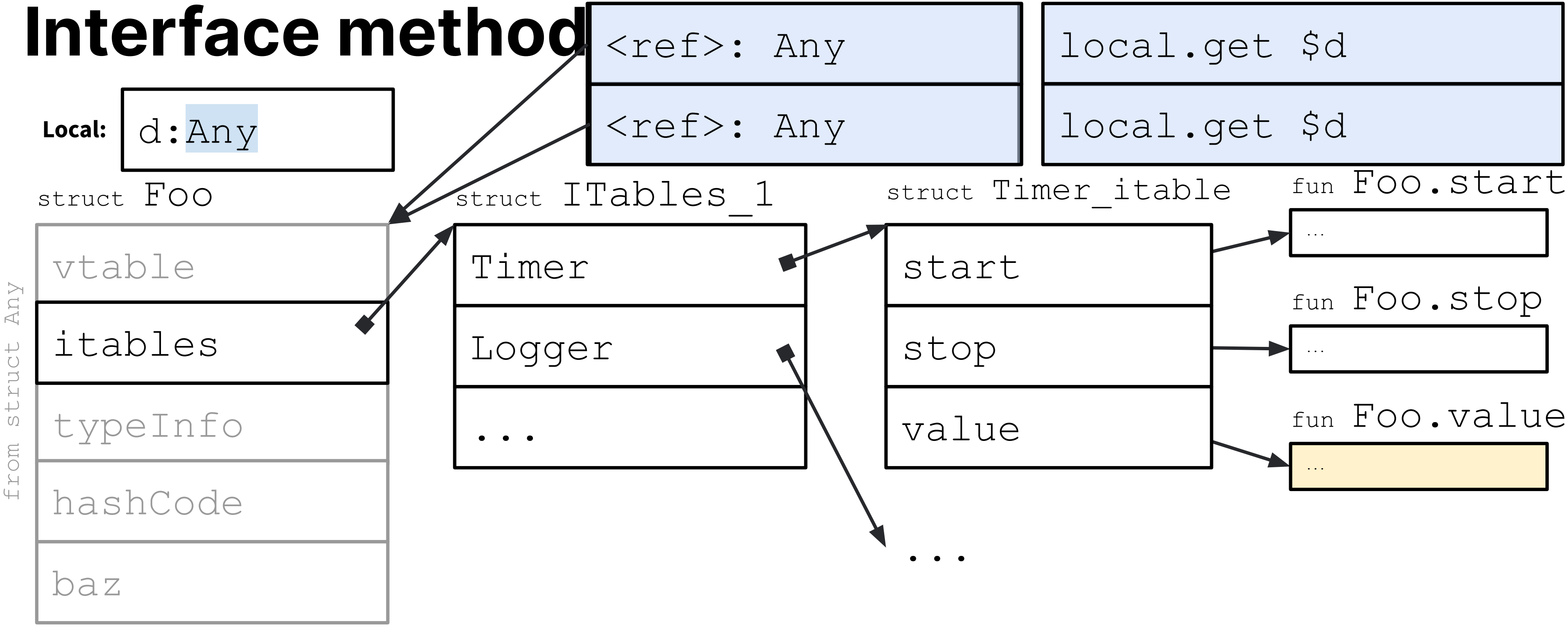
fun Foo.stop

...

fun Foo.value

...

Interface method



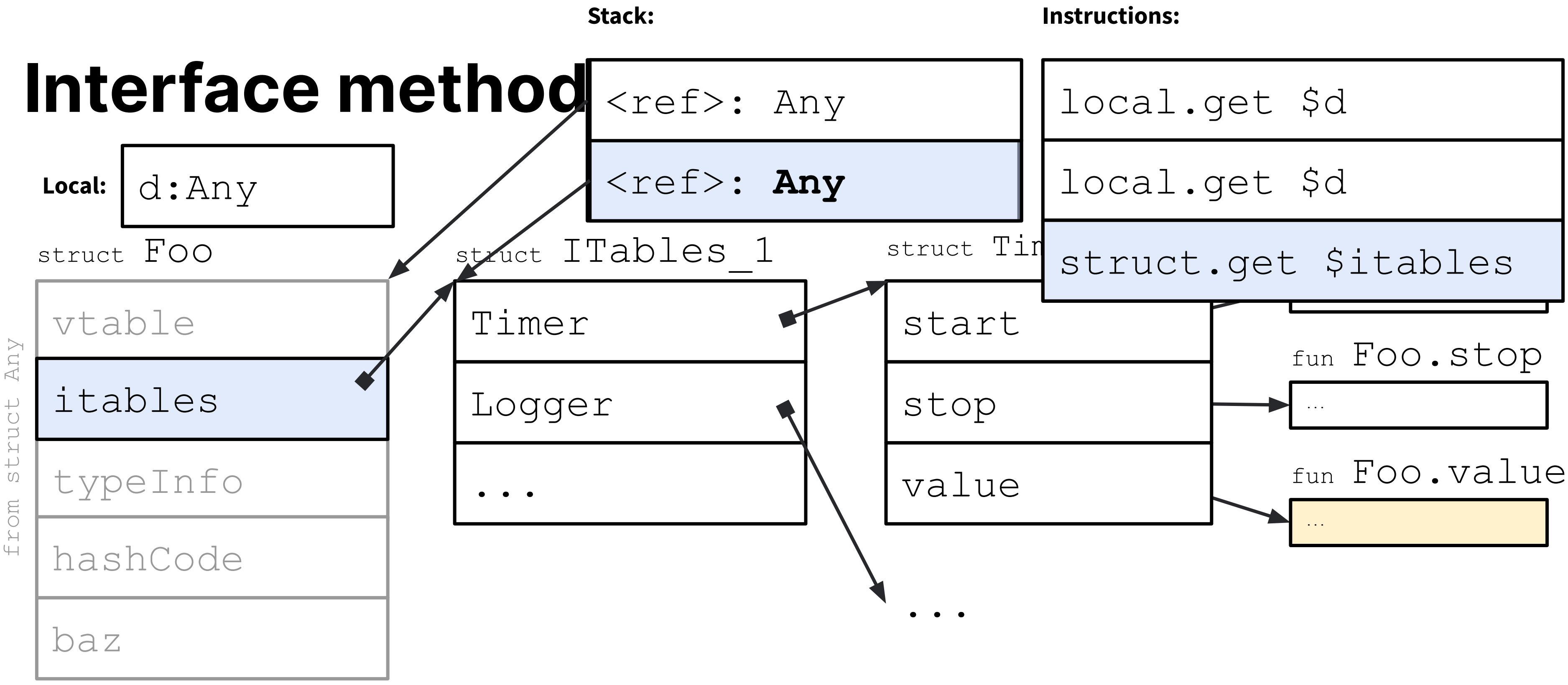
Stack:

```
<ref>: Any
<ref>: Any
```

Instructions:

```
local.get $d
local.get $d
```

Interface method



Stack:

<ref>: Any

<ref>: **Any**

Instructions:

```
local.get $d
local.get $d
struct.get $itables
```

Local: d:Any

struct Foo

vtable

itables

typeInfo

hashCode

baz

from struct Any

struct ITables_1

Timer

Logger

...

struct Ti

start

stop

value

...

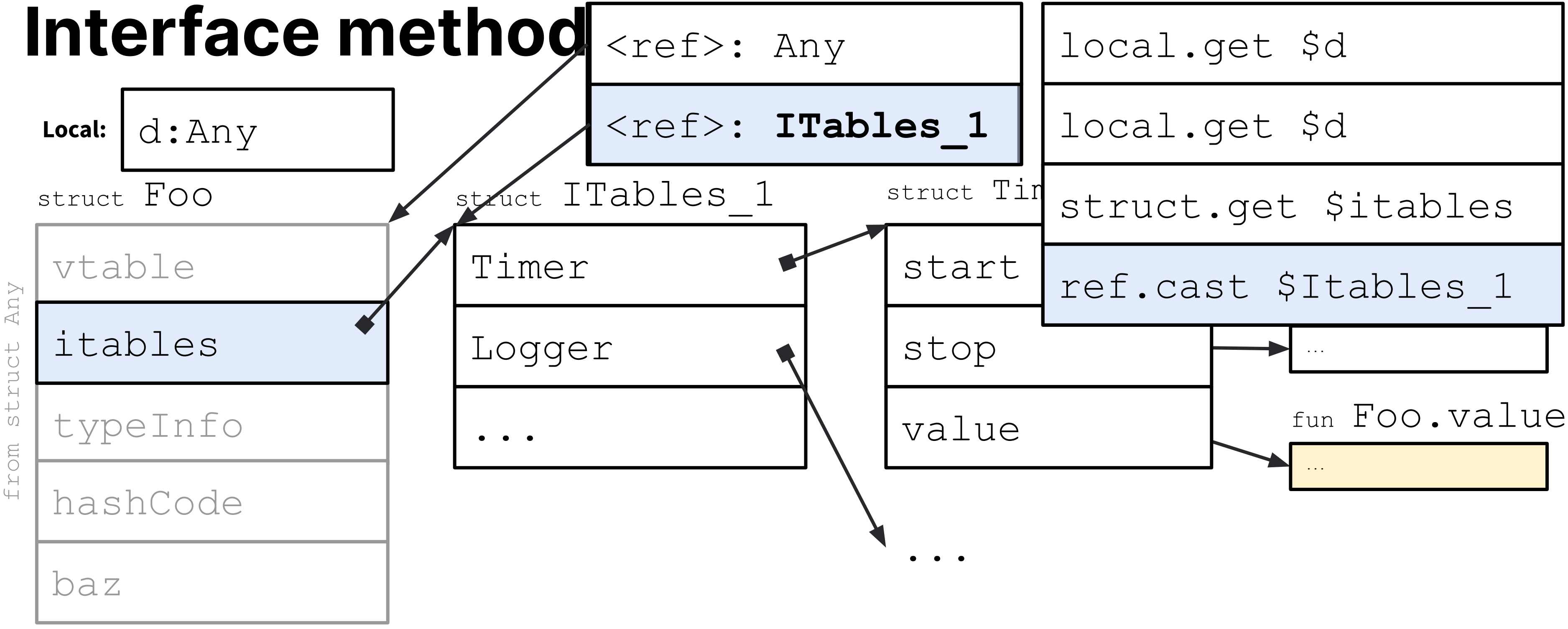
fun Foo.stop

...

fun Foo.value

...

Interface method



Stack:

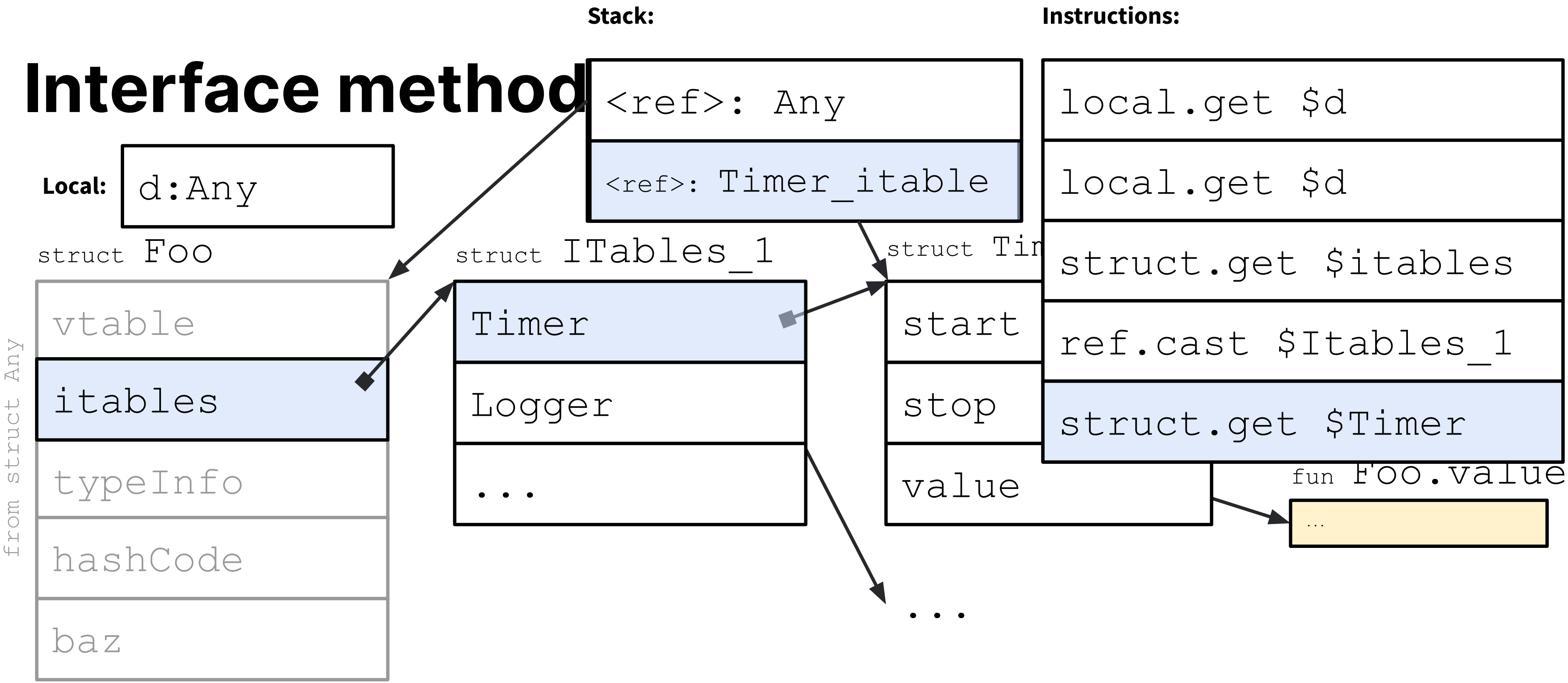
- `<ref>: Any`
- `<ref>: ITables_1`

Instructions:

```
local.get $d
local.get $d
struct.get $itables
ref.cast $Itables_1
```

Local: `d:Any`

Interface method



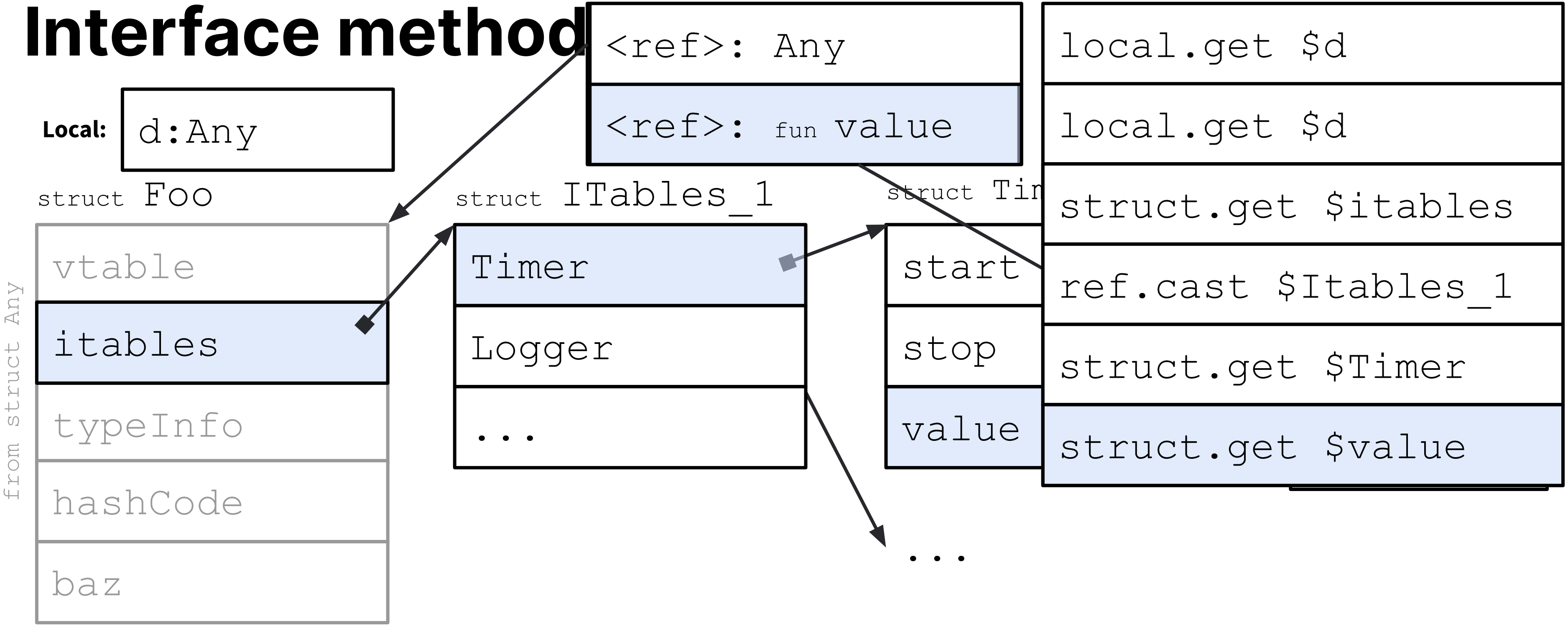
Stack:

```
<ref>: Any
<ref>: Timer_itable
```

Instructions:

```
local.get $d
local.get $d
struct.get $itables
ref.cast $Itables_1
struct.get $Timer
```

Interface method



Stack:

<ref>: Any

<ref>: fun value

Instructions:

```
local.get $d
local.get $d
struct.get $itables
ref.cast $Itables_1
struct.get $Timer
struct.get $value
```

Local: d:Any

struct Foo

from struct Any

vtable

itables

typeInfo

hashCode

baz

struct ITables_1

Timer

Logger

...

struct Ti

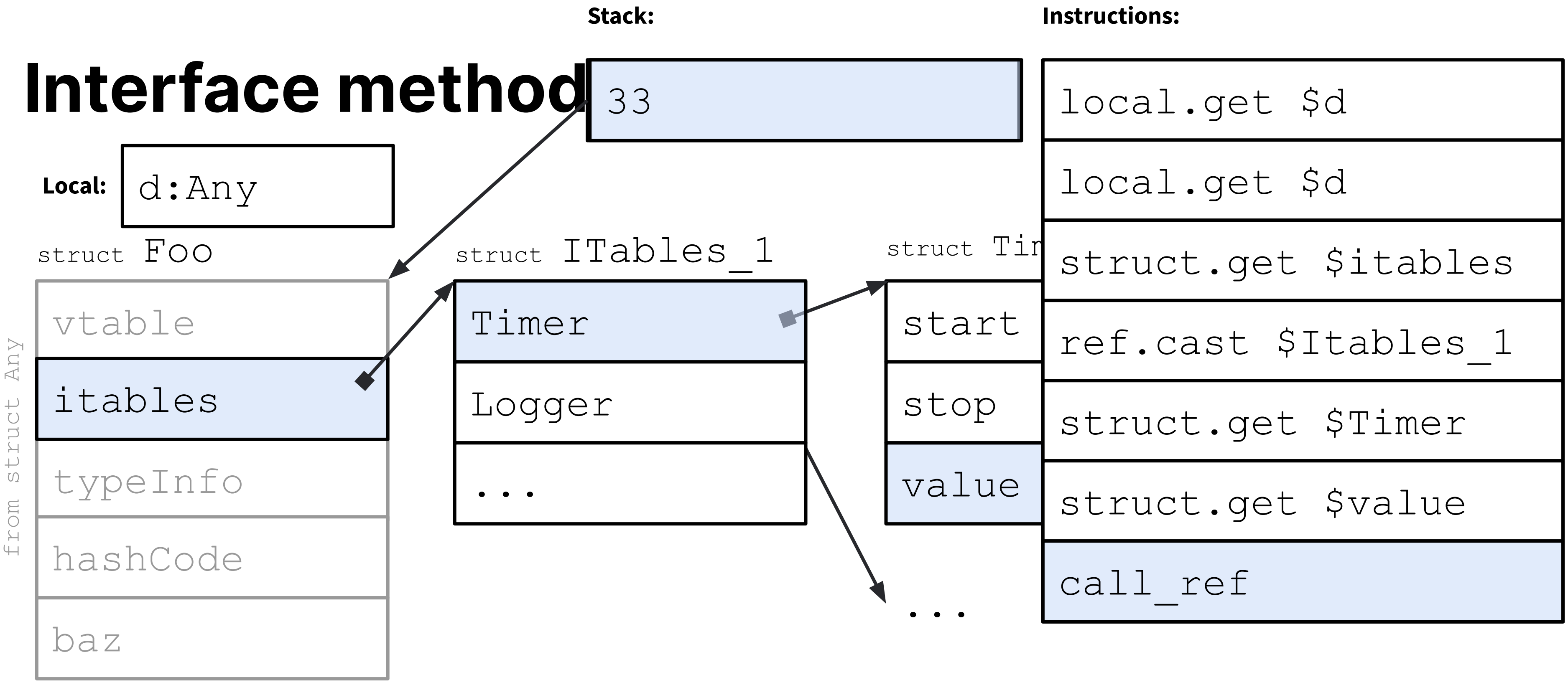
start

stop

value

...

Interface method



Stack:

33

Instructions:

```
local.get $d
local.get $d
struct.get $itables
ref.cast $Itables_1
struct.get $Timer
struct.get $value
call_ref
```

Local: d:Any

struct Foo

from struct Any

vtable

itables

typeInfo

hashCode

baz

struct ITables_1

Timer

Logger

...

struct Ti

start

stop

value

...

Browsers Setup/Requirements

Chrome 112+

Origin Tail https://zal.im/tryWasmGC

Chrome 110+ – in chrome://flags

WebAssembly Garbage Collection

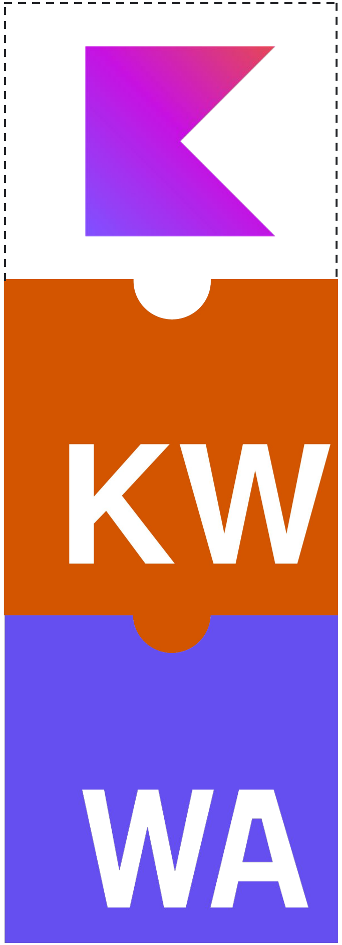
Firefox 112+ – in about:config

- javascript.options.wasm_function_references
- javascript.options.wasm_gc

Introducing KoWasm

https://kowasm.org

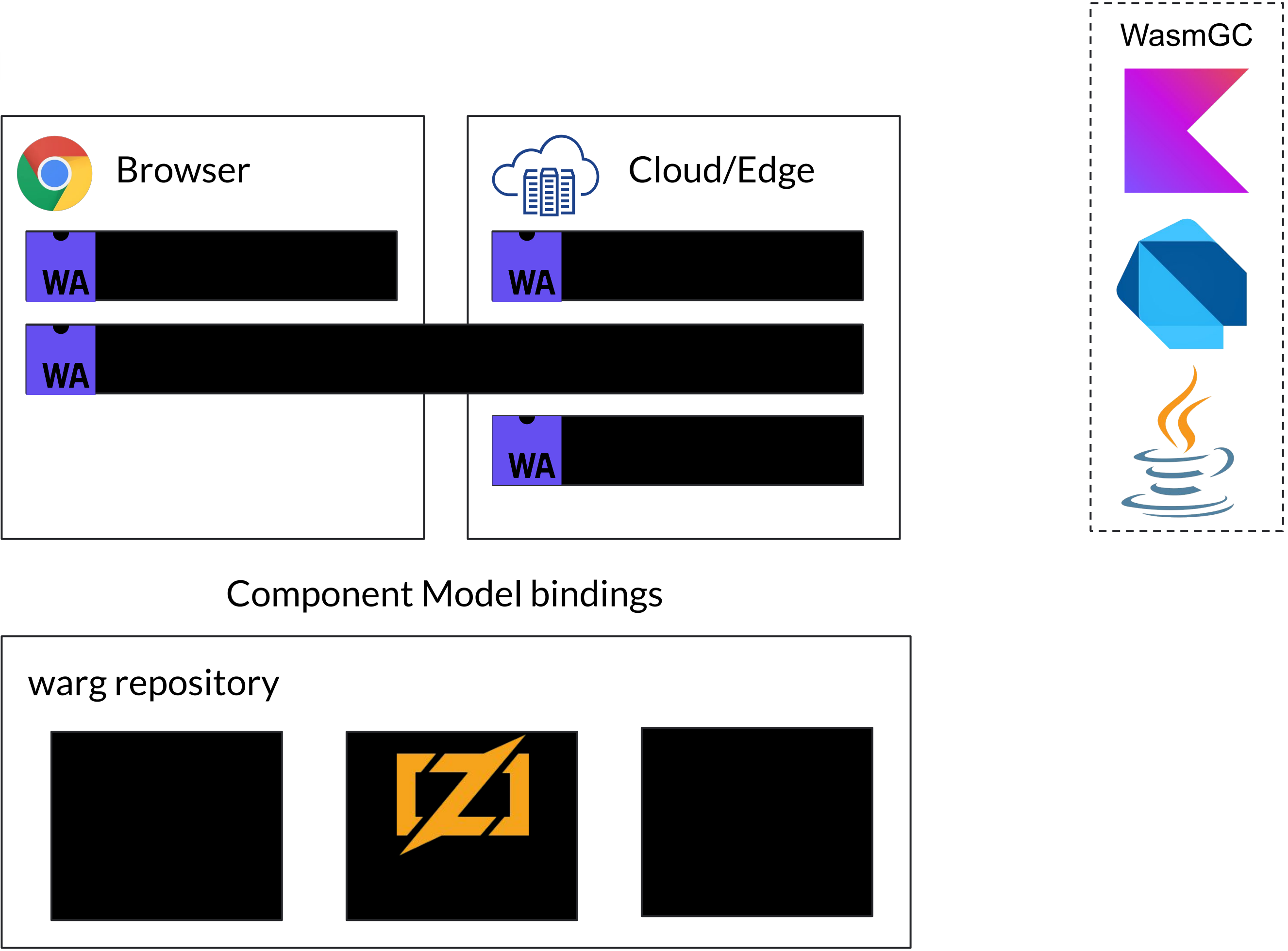
Server-side and full stack development with Kotlin and WebAssembly, by leveraging WASI and Component Model



Introducing KoWasm

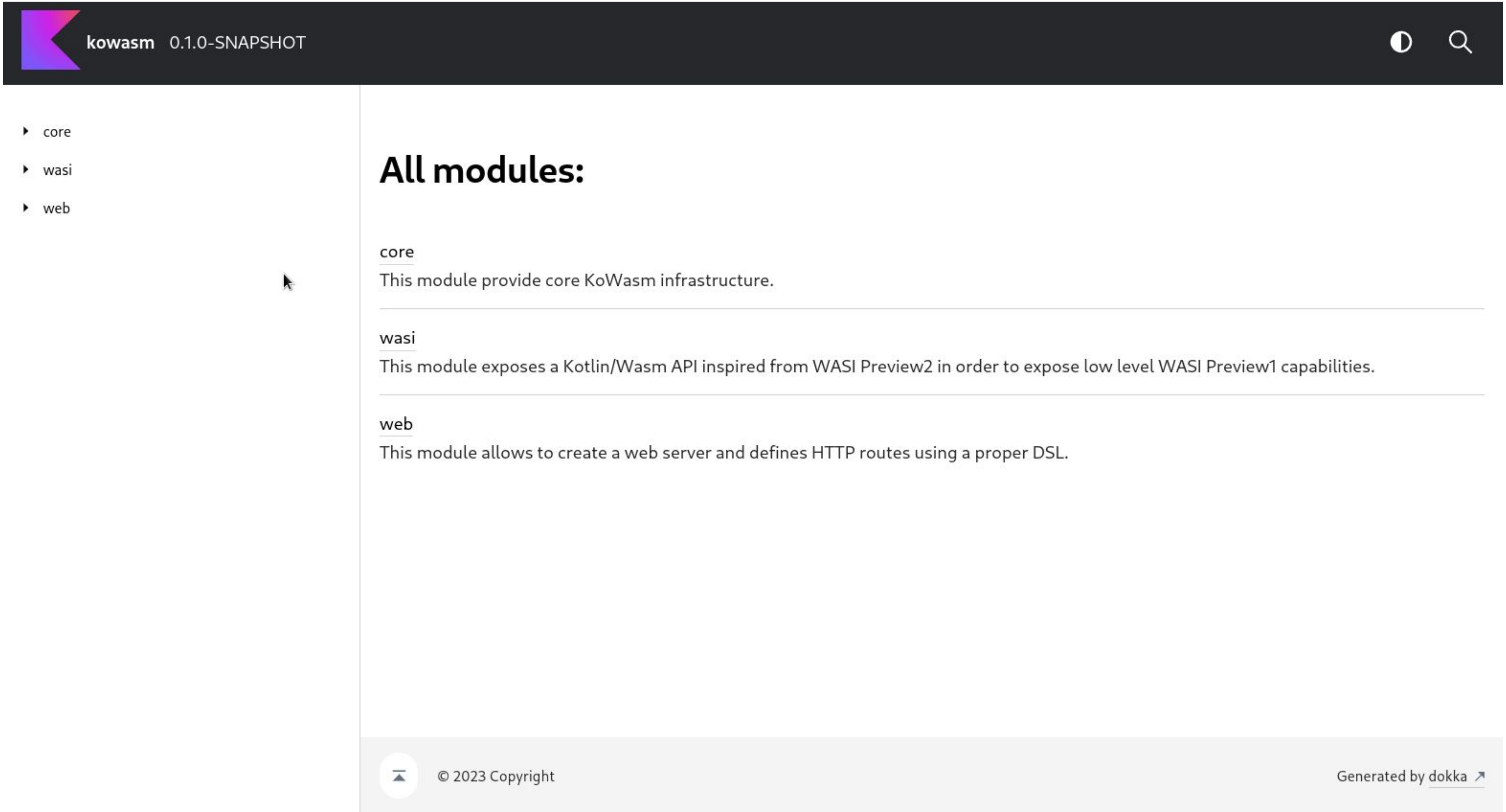
https://kowasm.org

Vision



Component Model bindings

https://kowasm.org/api/



All modules:

core

This module provide core KoWasm infrastructure.

wasi

This module exposes a Kotlin/Wasm API inspired from WASI Preview2 in order to expose low level WASI Preview1 capabilities.

web

This module allows to create a web server and defines HTTP routes using a proper DSL.

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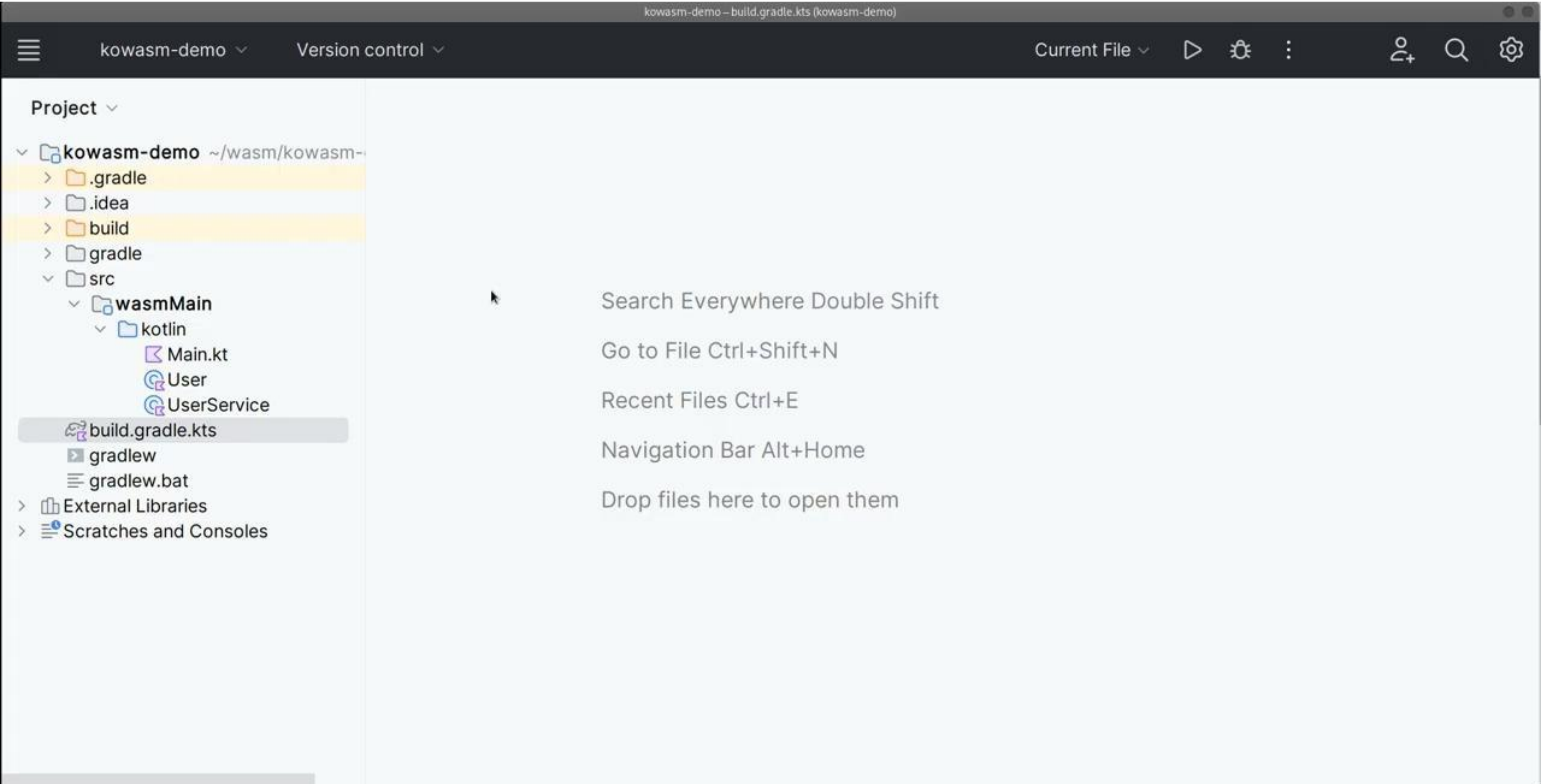
Generated by dokka

Memory allocator to bridge WasmGC with linear memory

```
@WasmImport("wasi_snapshot_preview1", "clock_res_get")
private external fun rawClockResGet(
    arg0: Int,
    arg1: Int,
): Int

fun clockResGet(id: ClockId): Timestamp {
    withScopedMemoryAllocator { allocator ->
        val pointer = allocator.allocate(8)
        val returnCode = rawClockResGet(id.ordinal, pointer.address.toInt())
        return if (returnCode == 0) {
            (Pointer(pointer.address.toInt().toUInt())).loadLong()
        } else {
            throw WasiError(Errno.values()[returnCode])
        }
    }
}
```



Search Everywhere Double Shift

Go to File Ctrl+Shift+N

Recent Files Ctrl+E

Navigation Bar Alt+Home

Drop files here to open them

WIT record to Kotlin

```
record person {
   name: string,
   age: option<u32>,
}
```

```
data class Person(
     val name: String,
     val age: UInt? = null
)
```

WIT variant to Kotlin

```
variant filter {
   all,
   none,
   some(list<string>),
}
```

```
sealed interface Filter {
   object All : Filter
   object None : Filter
   class Some(val value: List<String>): Filter
}
```

WIT result to Kotlin

```
enum code {
   too-big,
   too-small,
}
a: func(input: string) -> result<string, code>
```

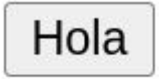
```
enum class Code { TOO_BIG, TOO_SMALL }
class CodeException(val code: Code) : Exception()

fun a(input: String): String {
   if (input.isNotEmpty()) return input
   else throw CodeException(Code.TOO_SMALL)
}
```

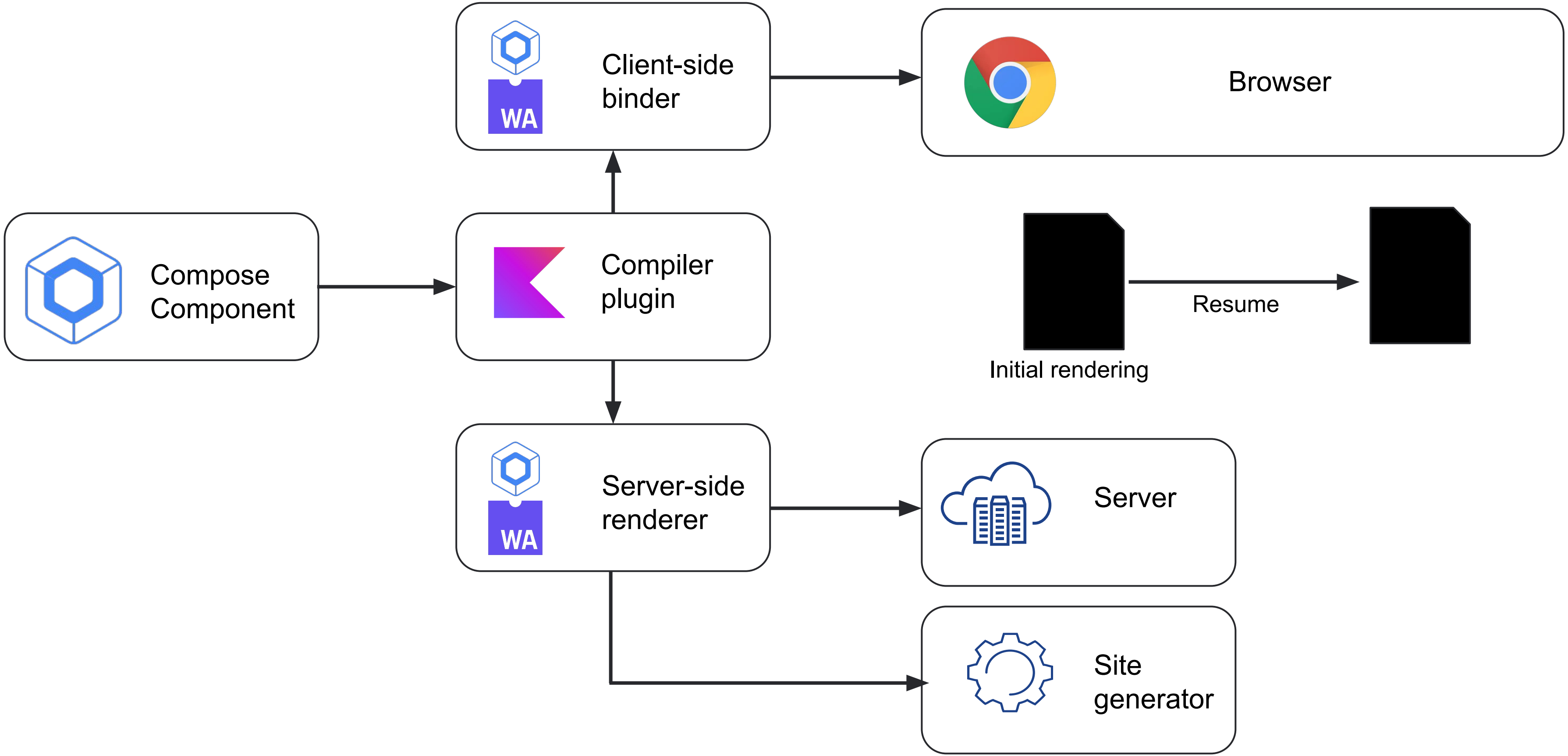
Compose for Web (HTML) with Kotlin/Wasm

```
fun main() {
   fun greet() = listOf("Hello", "Hallo", "Hola", "Servus").random()

   renderComposable("greeting") {
      var greeting by remember { mutableStateOf(greet()) }
      Button(attrs = { onClick { greeting = greet() } }) {
         Text(greeting)
      }
   }
}
```



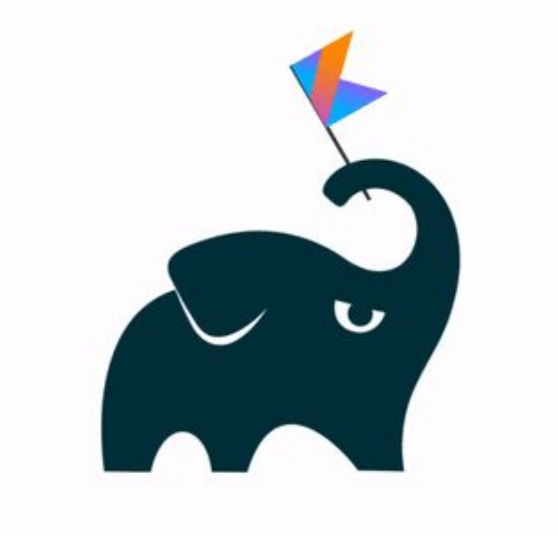
Fullstack rendering with Compose for Web and Kotlin/Wasm



Kotlin

Mobile

Server-side



Build