Miniboxing

Fast Generics on the JVM

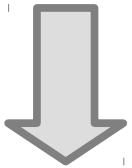
ScalaDays, 18th of June 2014

Vlad Ureche
gh/twitter:@VladUreche

```
class C[T](t: T)
```

class C[T](t: T)

scalac / javac



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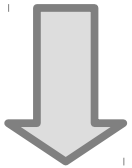

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class C(t: Object)
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class C[T](t: T)

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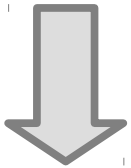

The process is called **erasure**, and it replaces type paramerers by their upper bound

class C(t: Object)

class C[T](t: T)

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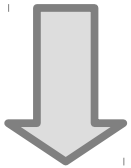

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class C(t: Object)

Requires boxed primitive types (java.lang.Integer, ...)

class C[T](t: T)

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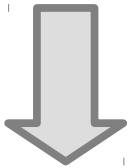

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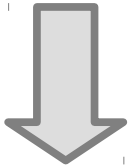

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Requires boxed primitive types (java.lang.Integer, ...)

You don't see it: **scala.Int** can be either **int** or **j.l.Integer**. Scalac does the work for you!

Yet boxing degrades performance
- heap allocations / GC cycles ...
- indirect reads, broken locality

```
class C[T](t: T)
```

@specialized

```
class C[T](t: T)
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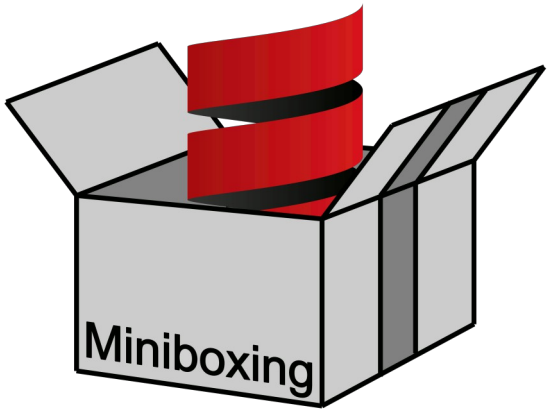
@miniboxed

What is 

?

@miniboxed =

@miniboxed = @specialized

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- the limitations

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- the limitations
- bytecode bloat

opens the way to
@miniboxed
Scala collections

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@specialized

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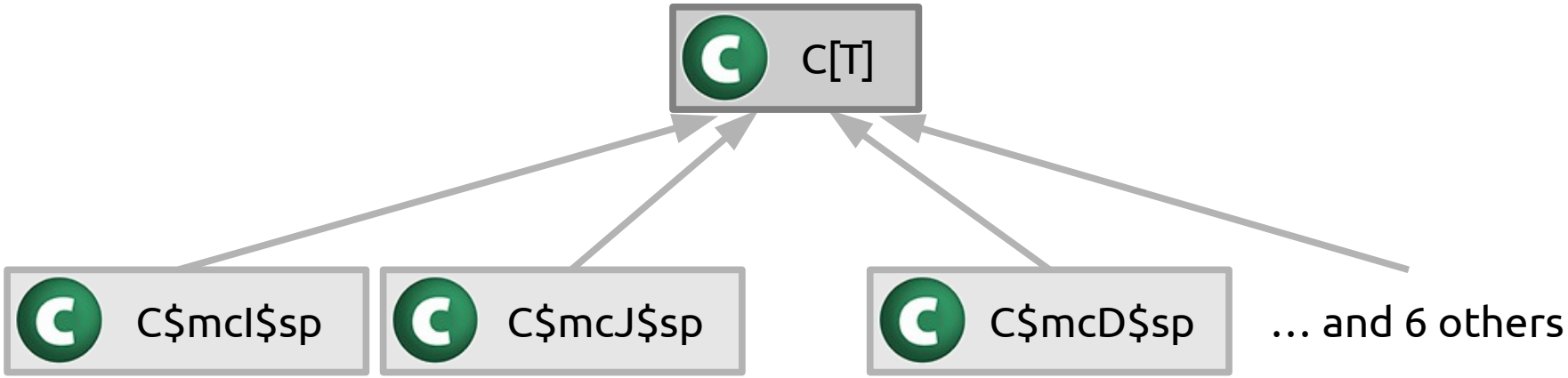

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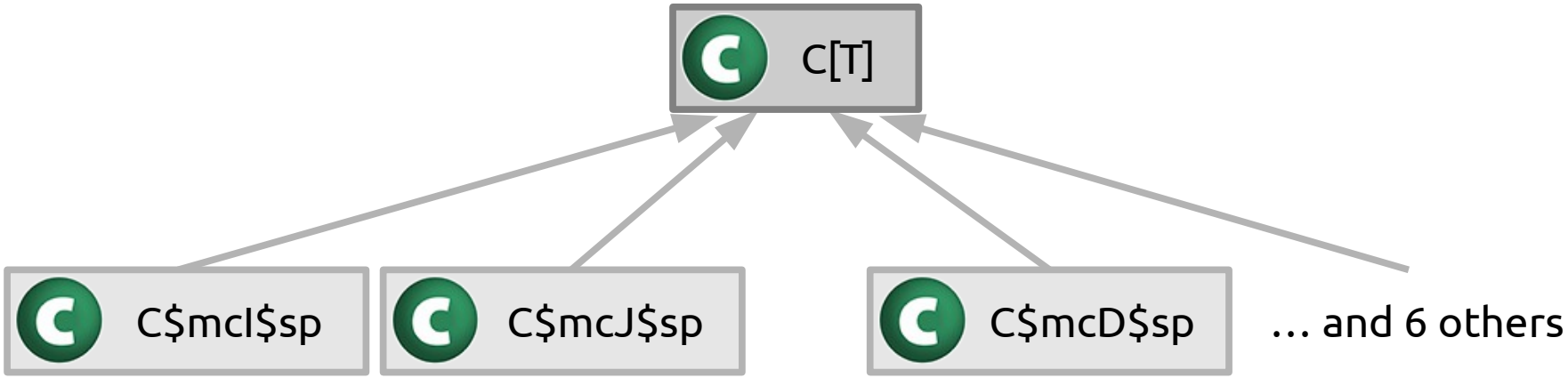

new C[**Int**](4)

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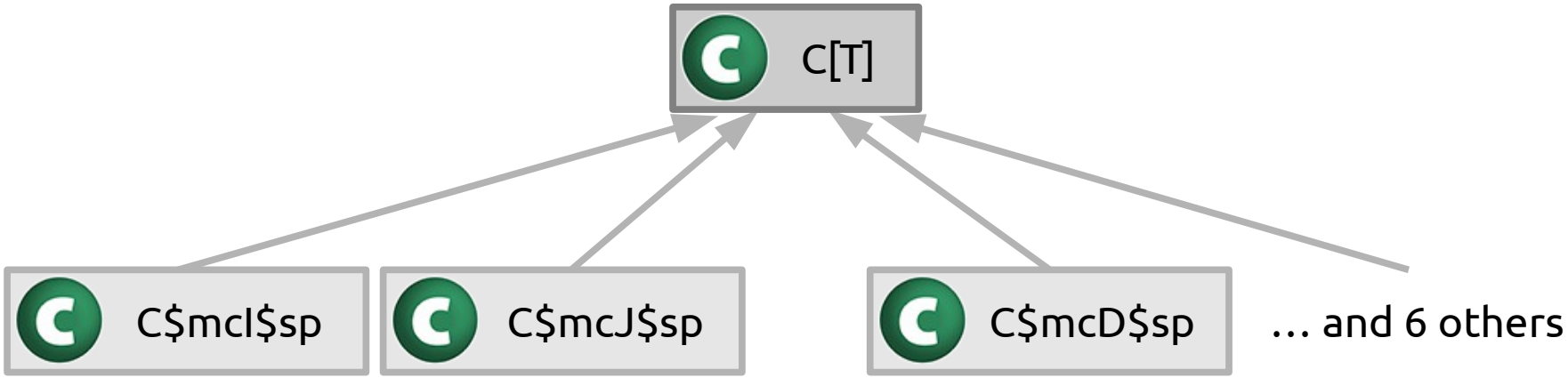
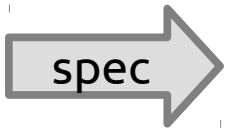


new C[**Int**](4)  new C$mc**I**$sp(4)

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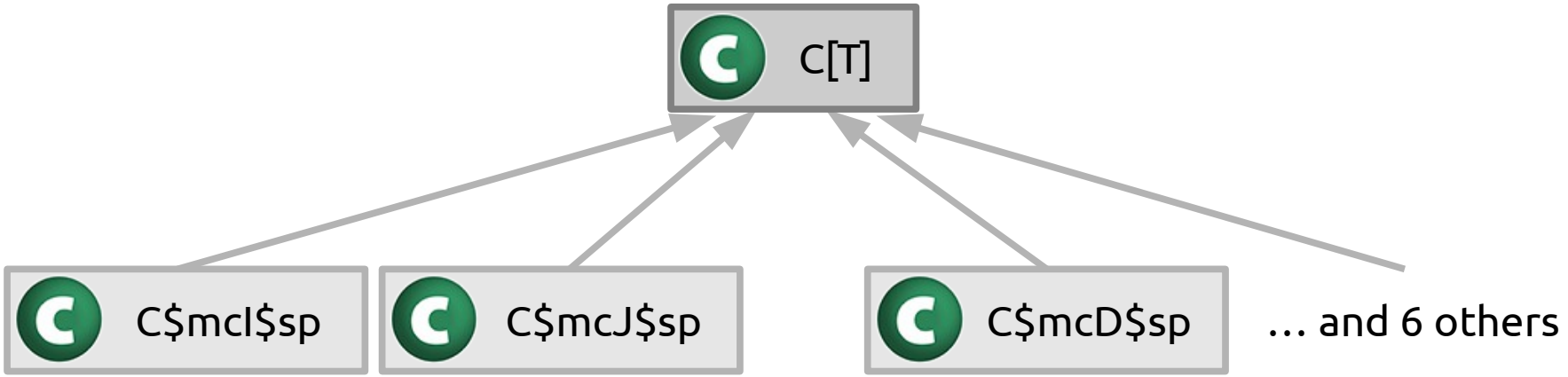

new C[**Int**](4) spec new C$mc**I**$sp(4)

Adapted to integers **(tmcIsp: int)**

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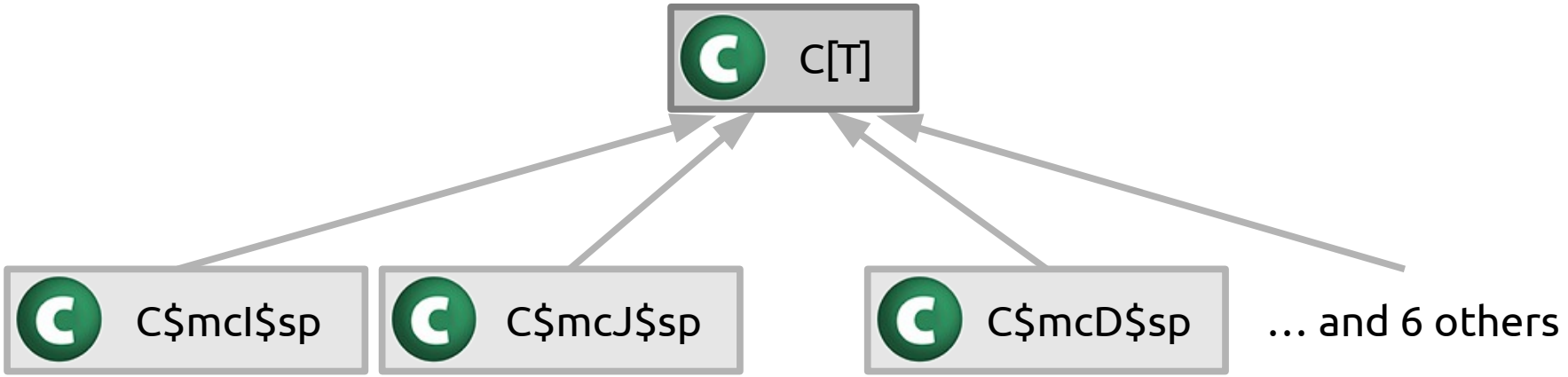

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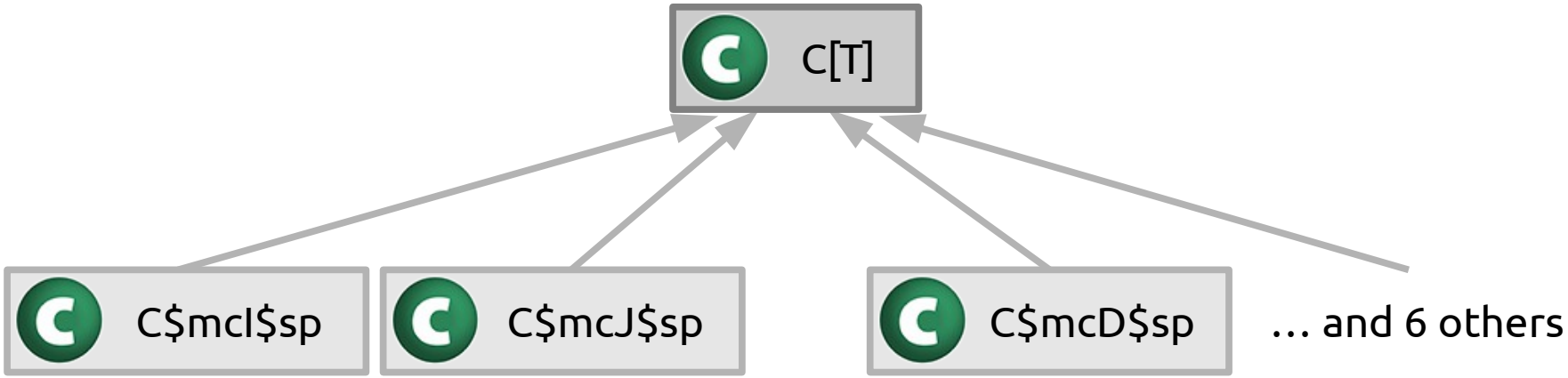

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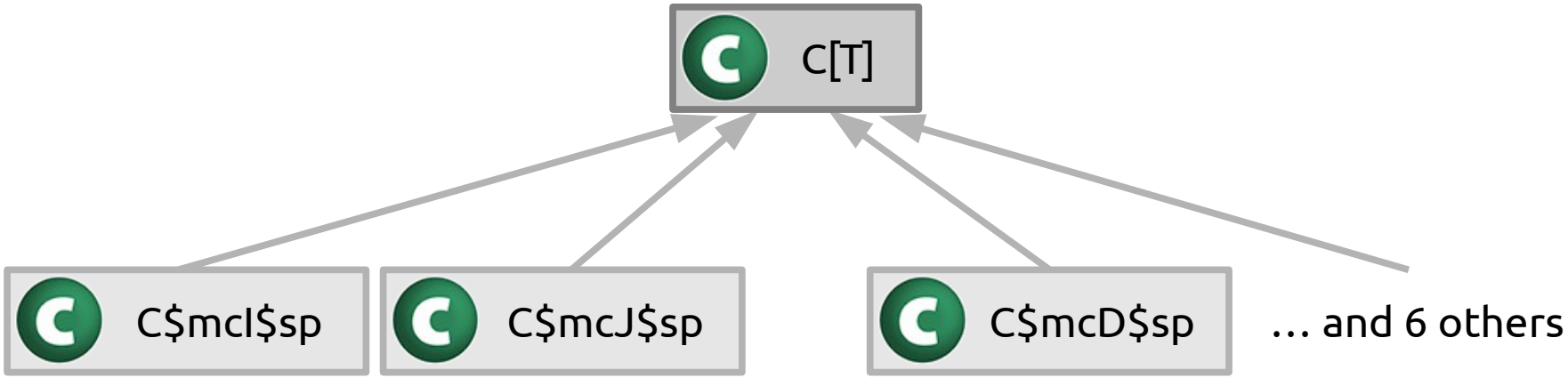

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* similar transformation for methods

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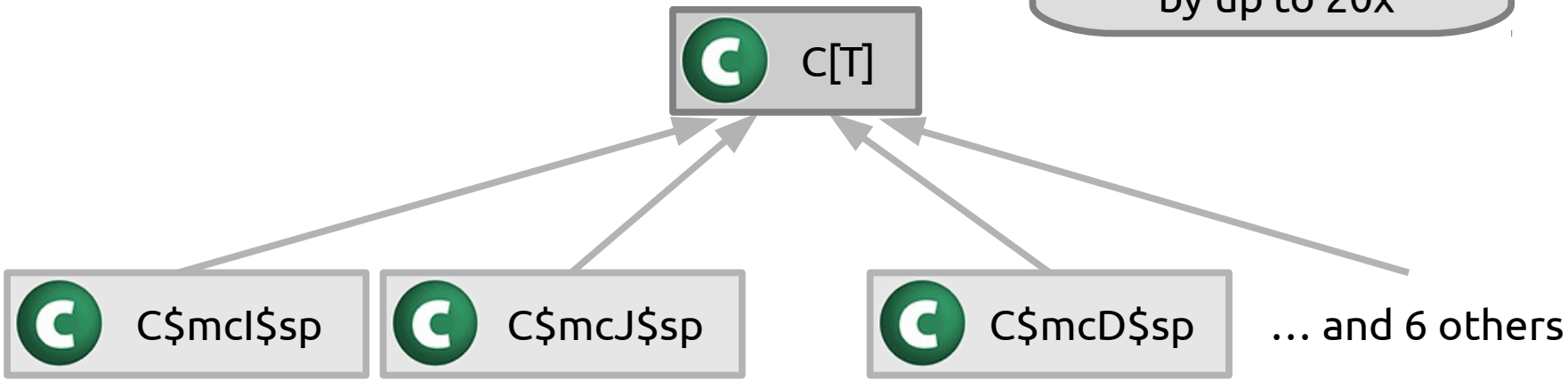
Can speed up
certain code patterns
by up to 20x



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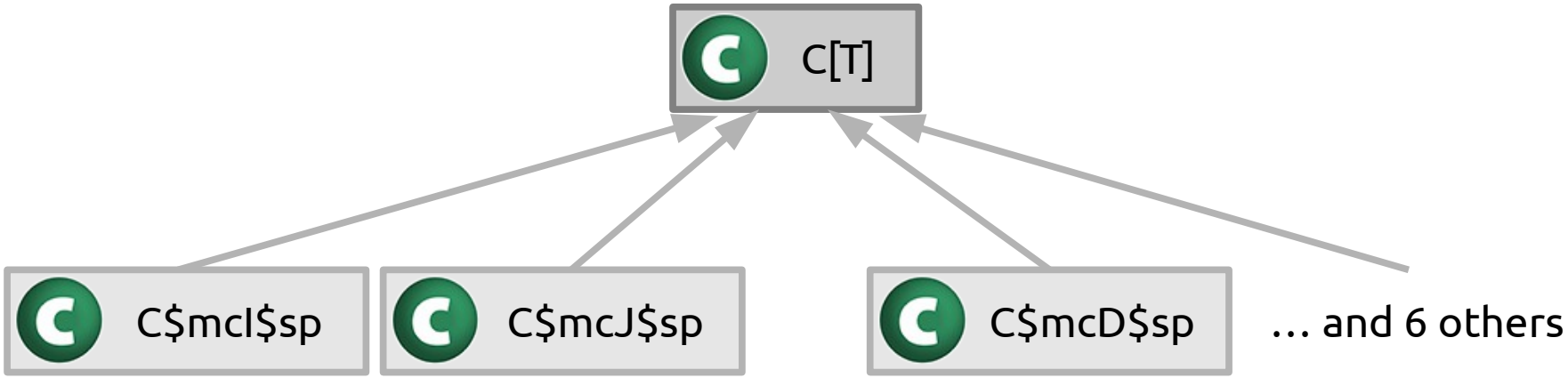

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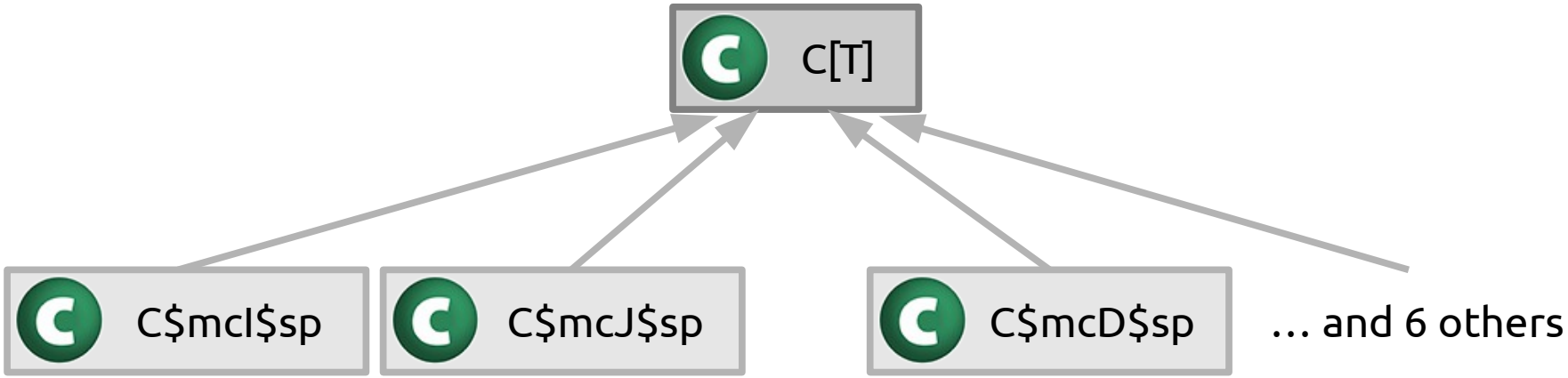
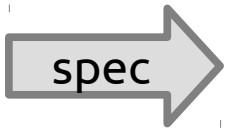


new C("abc") 

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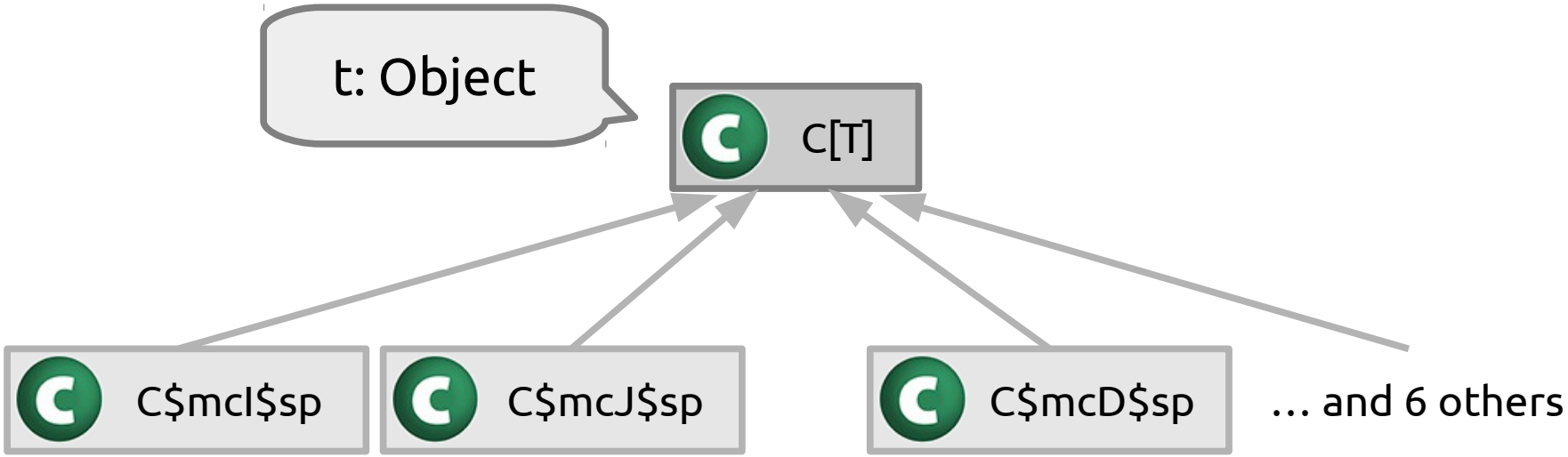

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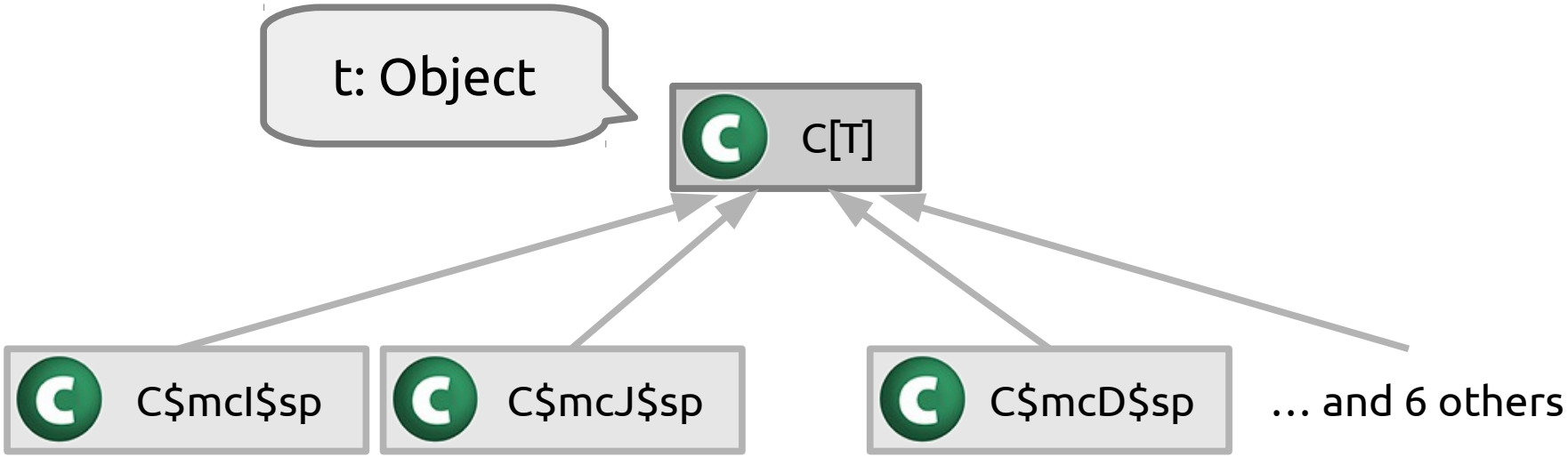

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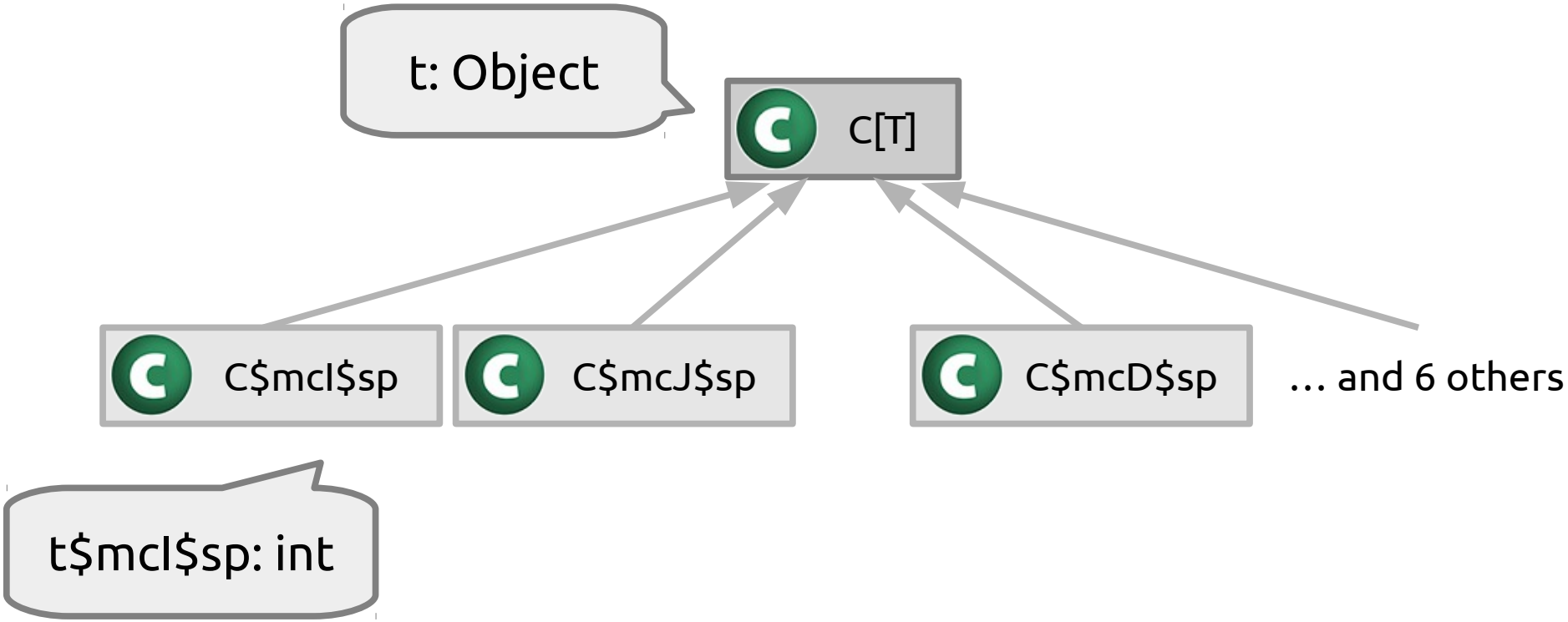

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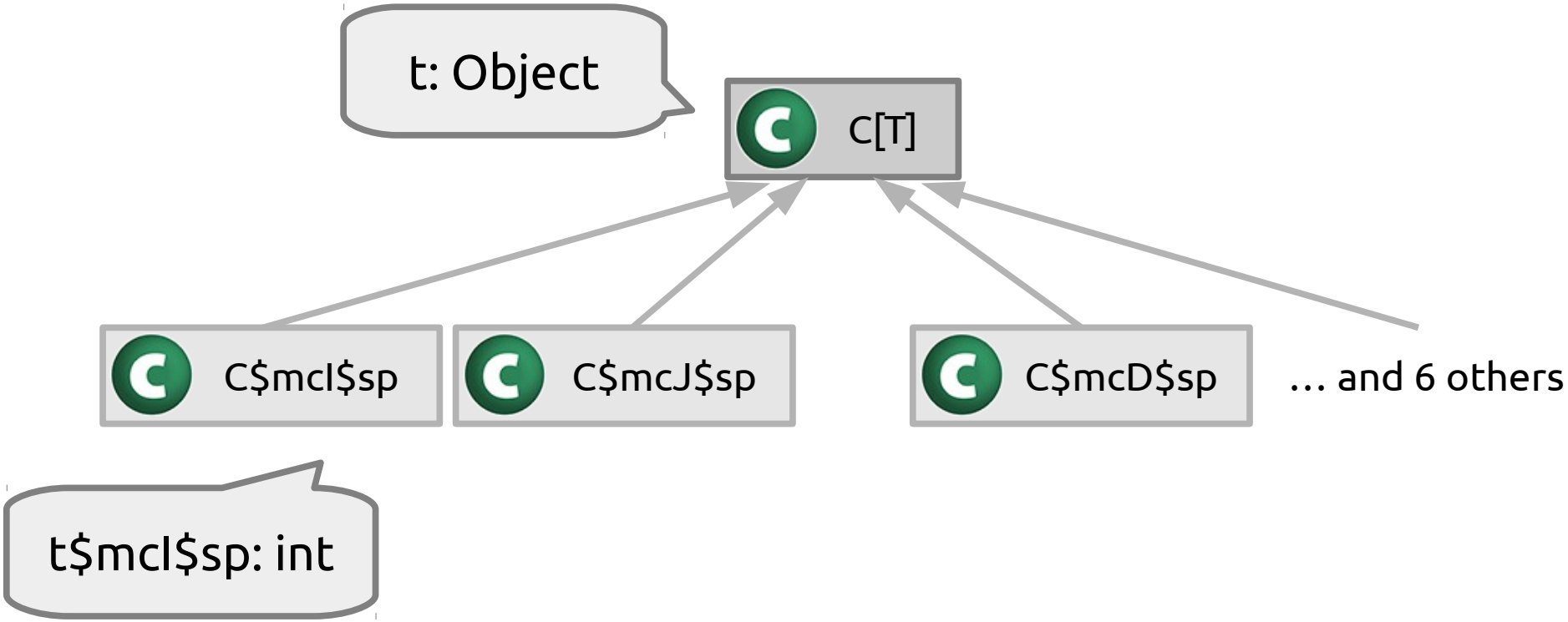

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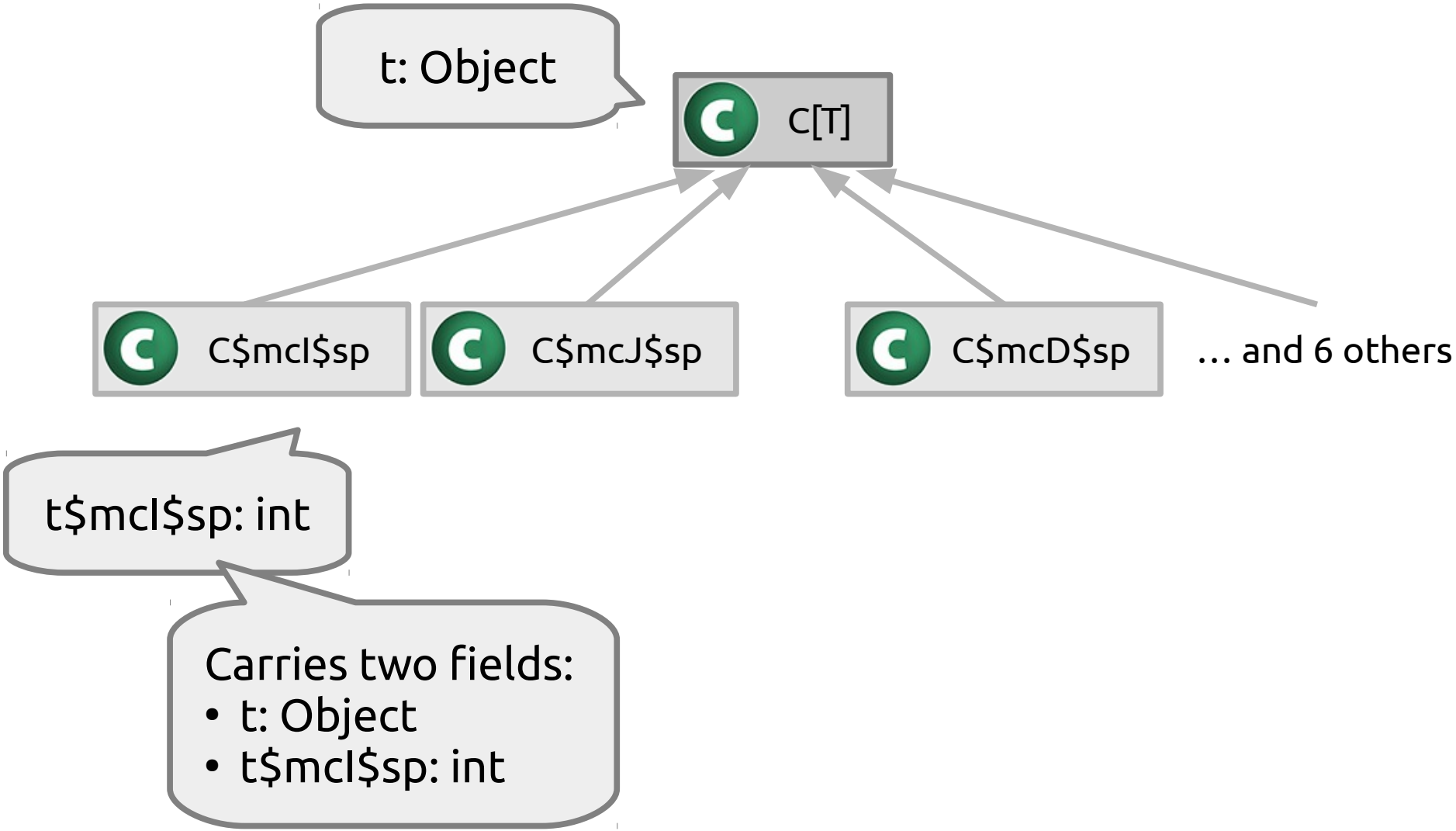

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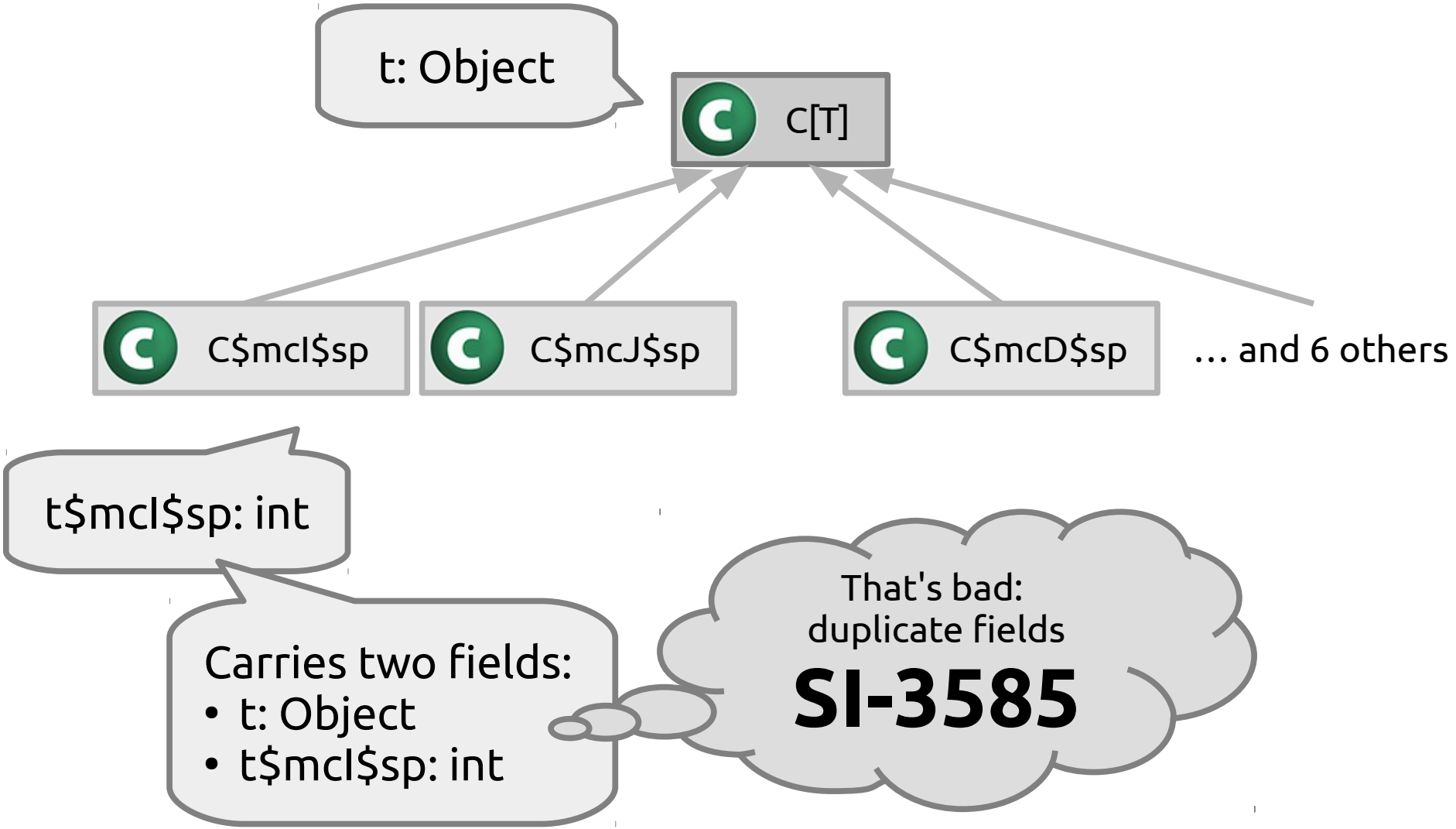

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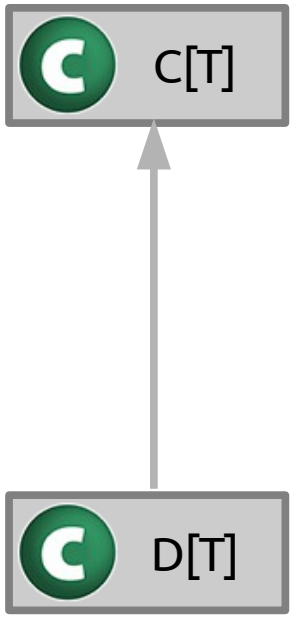

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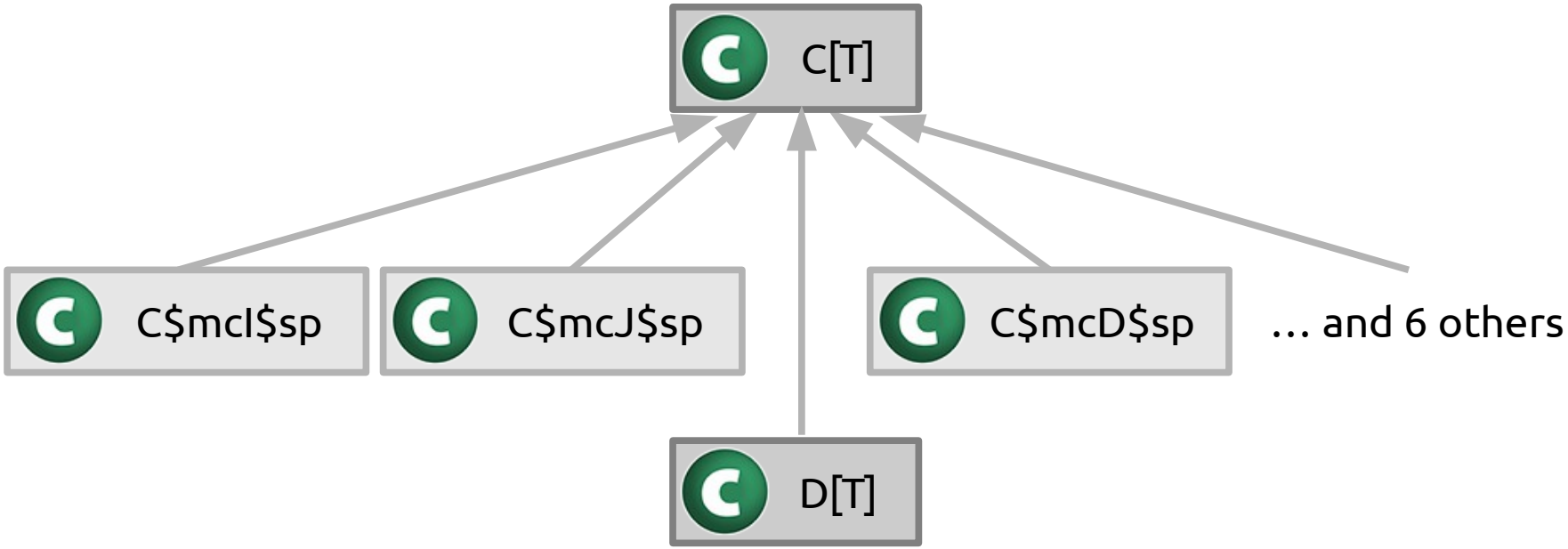

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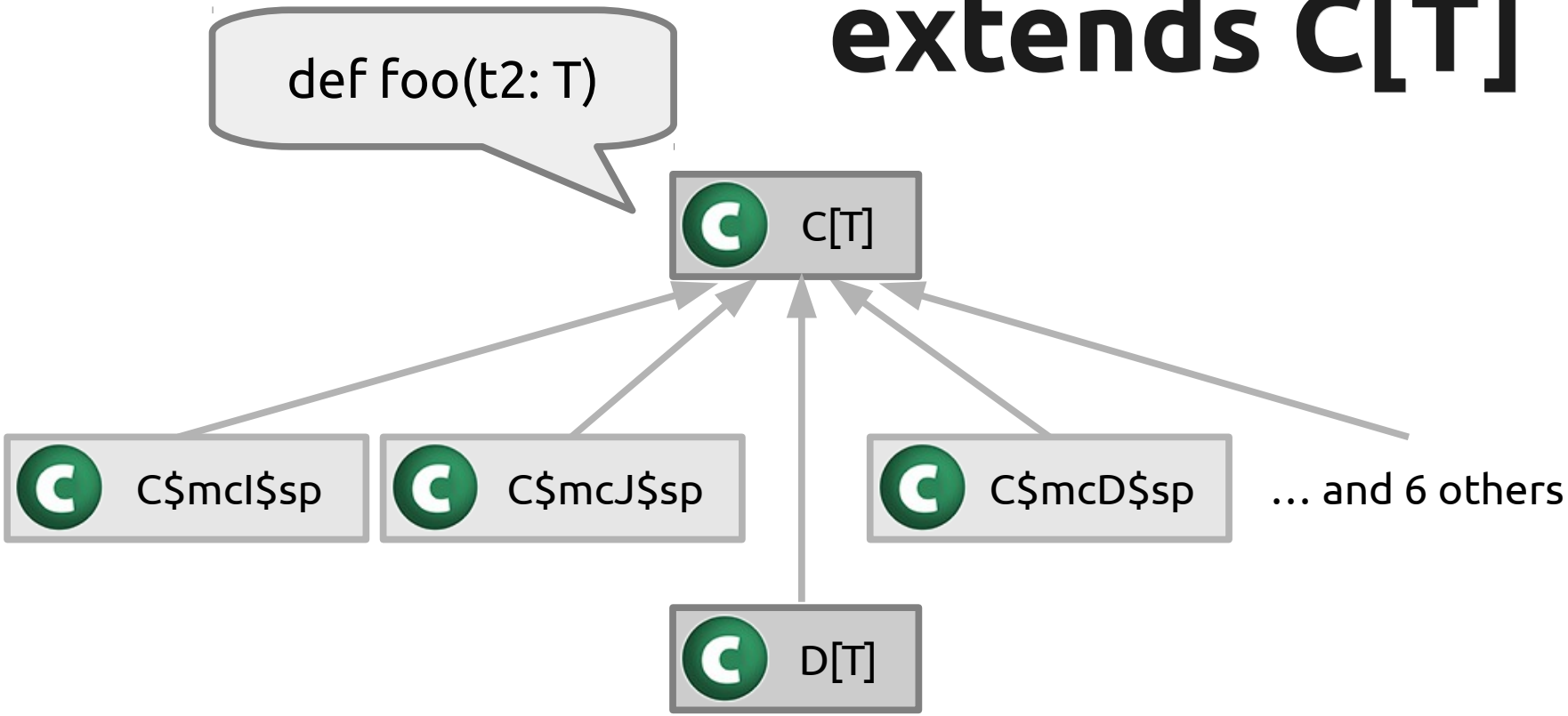

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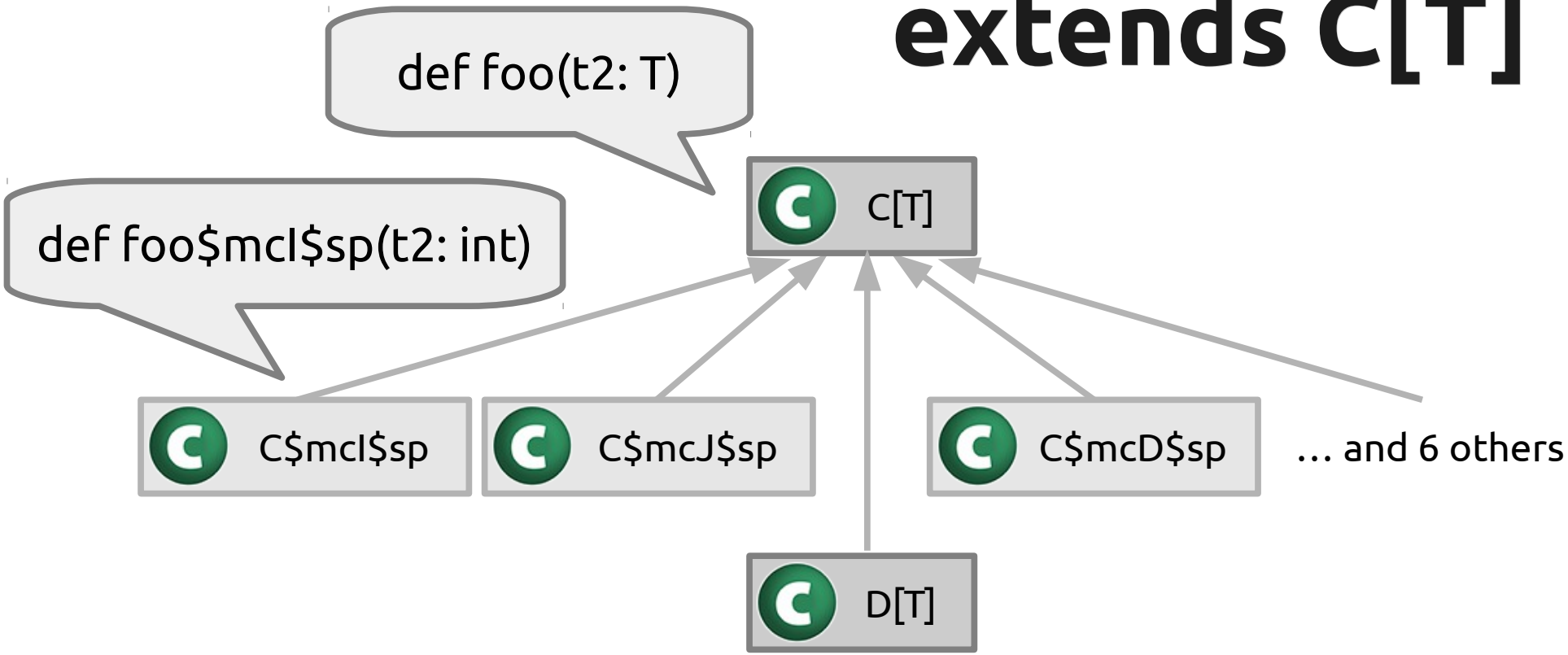

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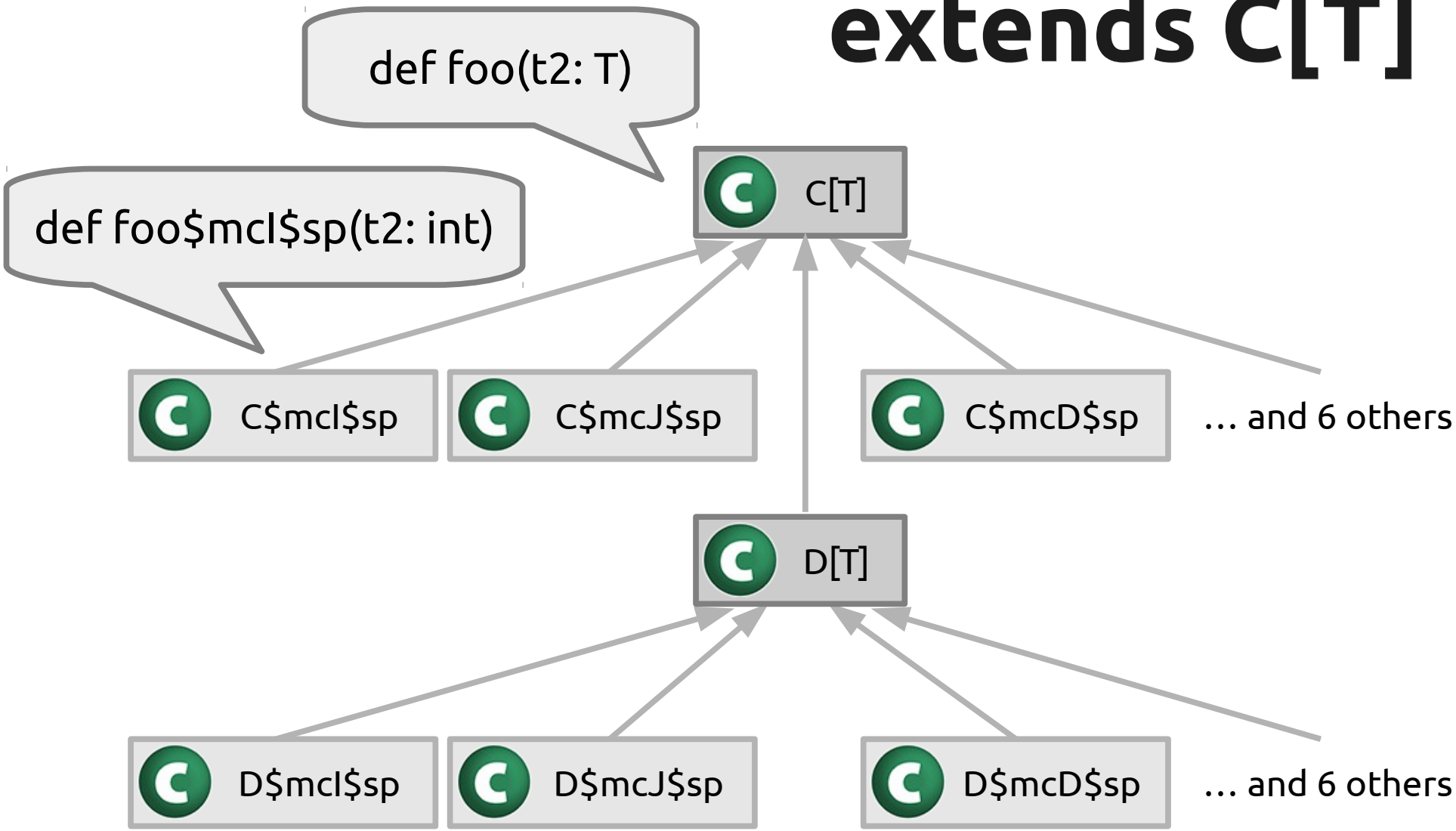

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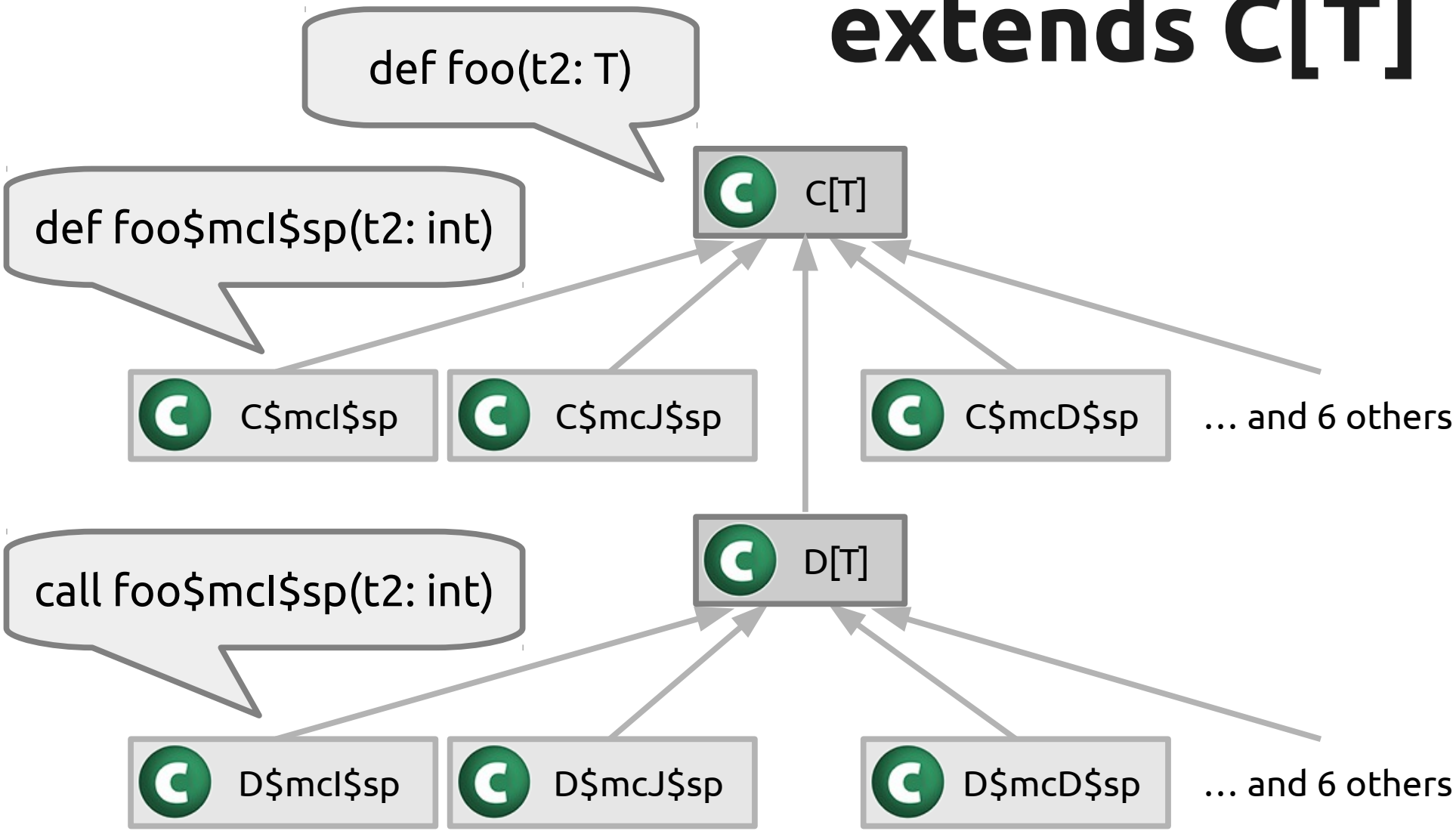

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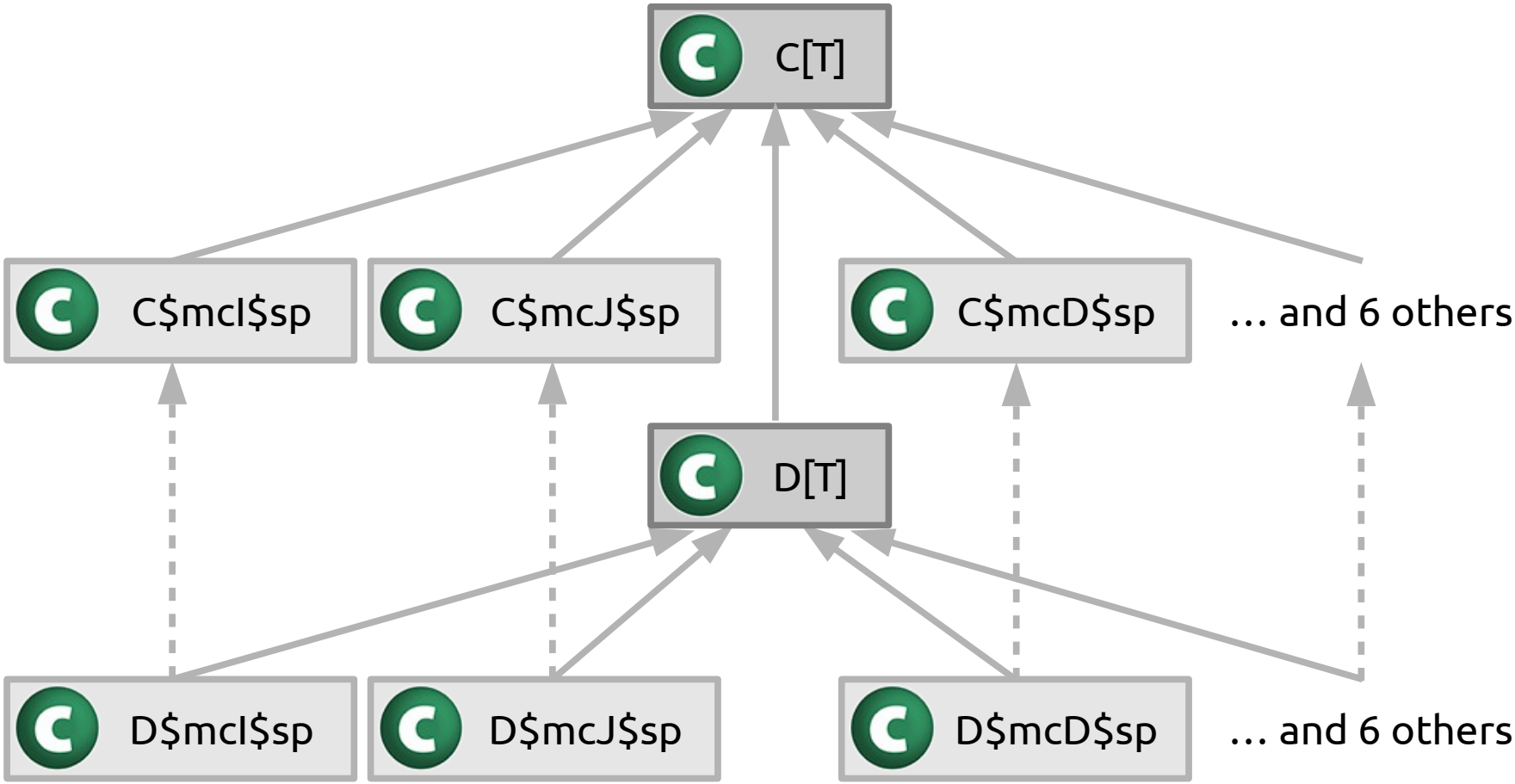

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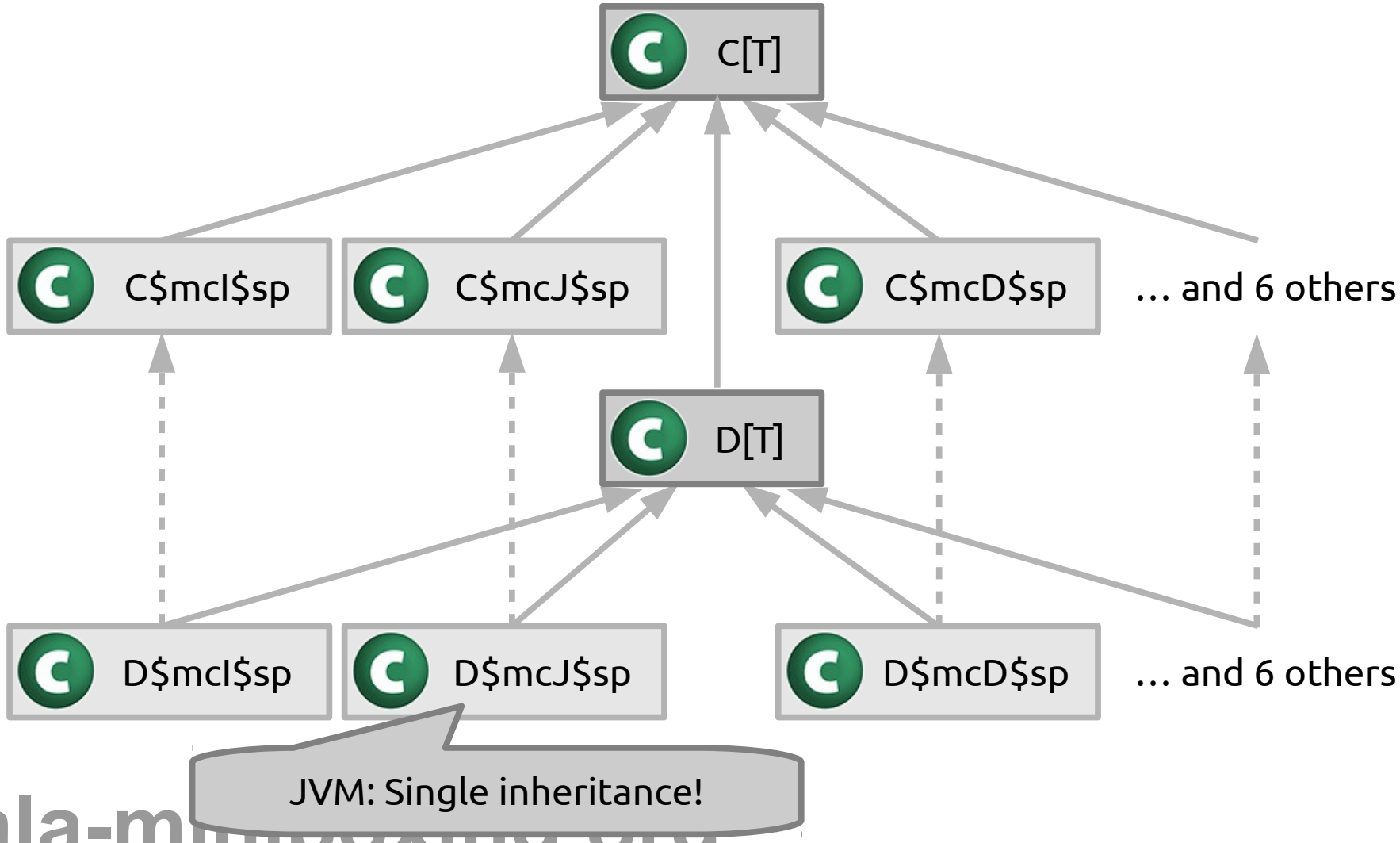

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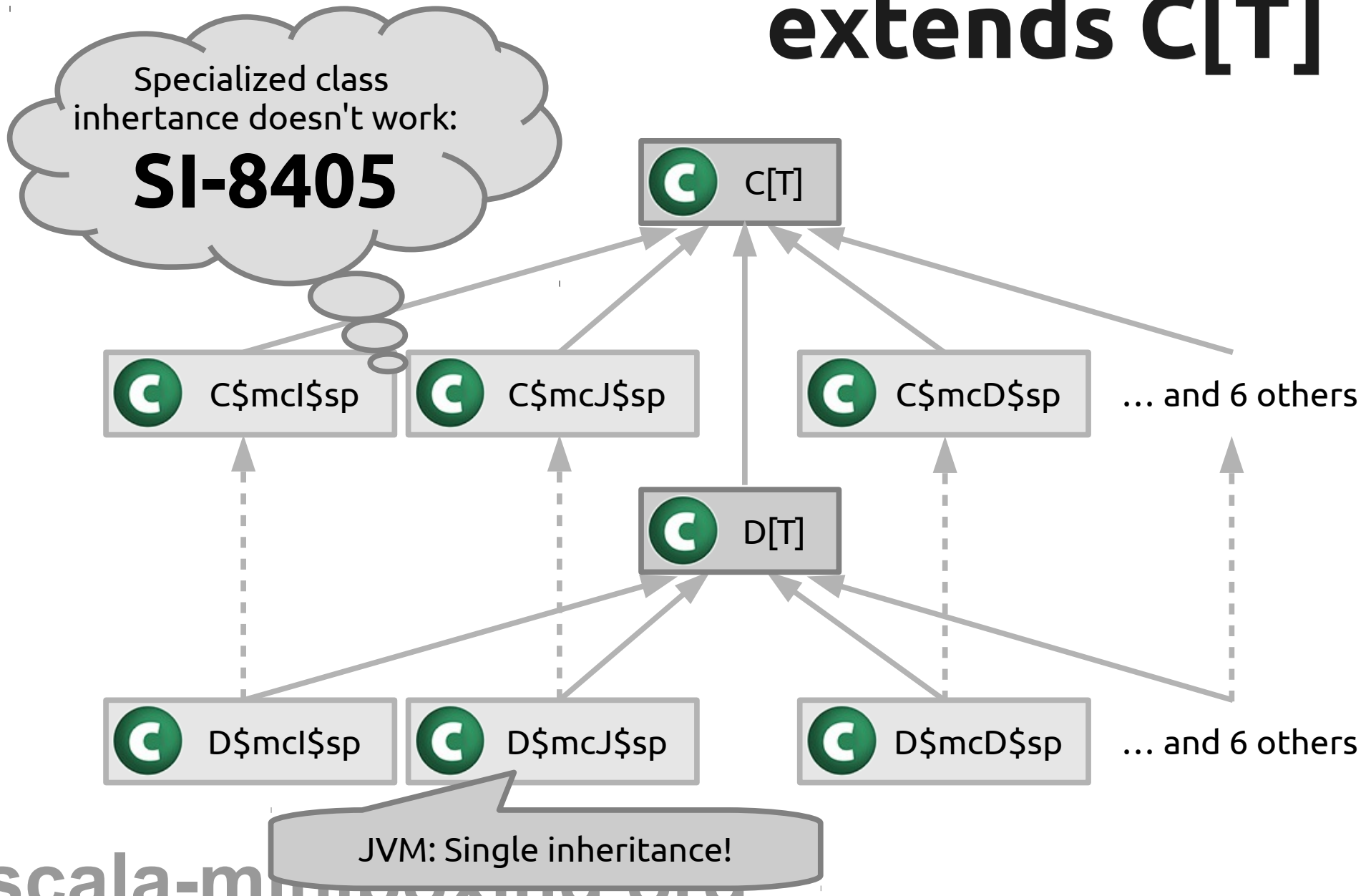

@miniboxing

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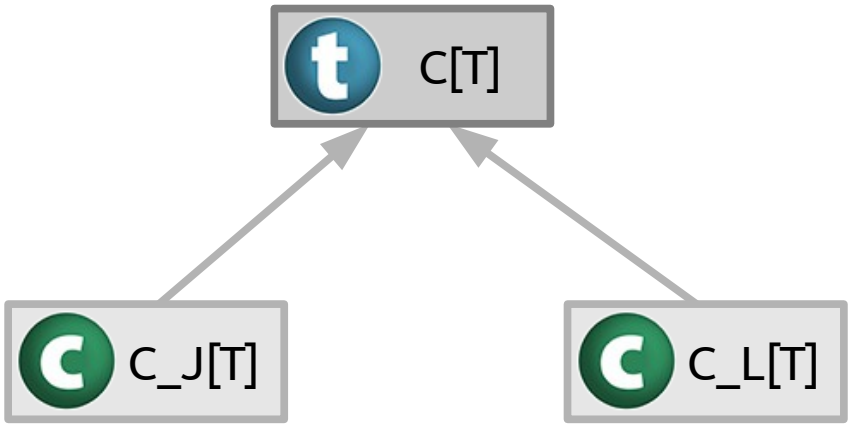

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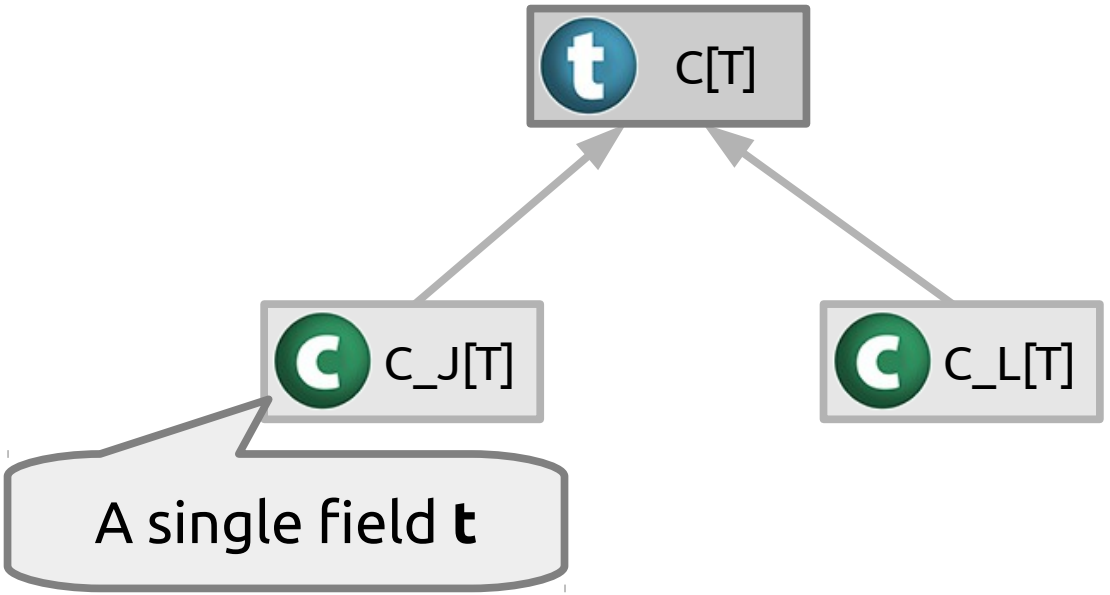

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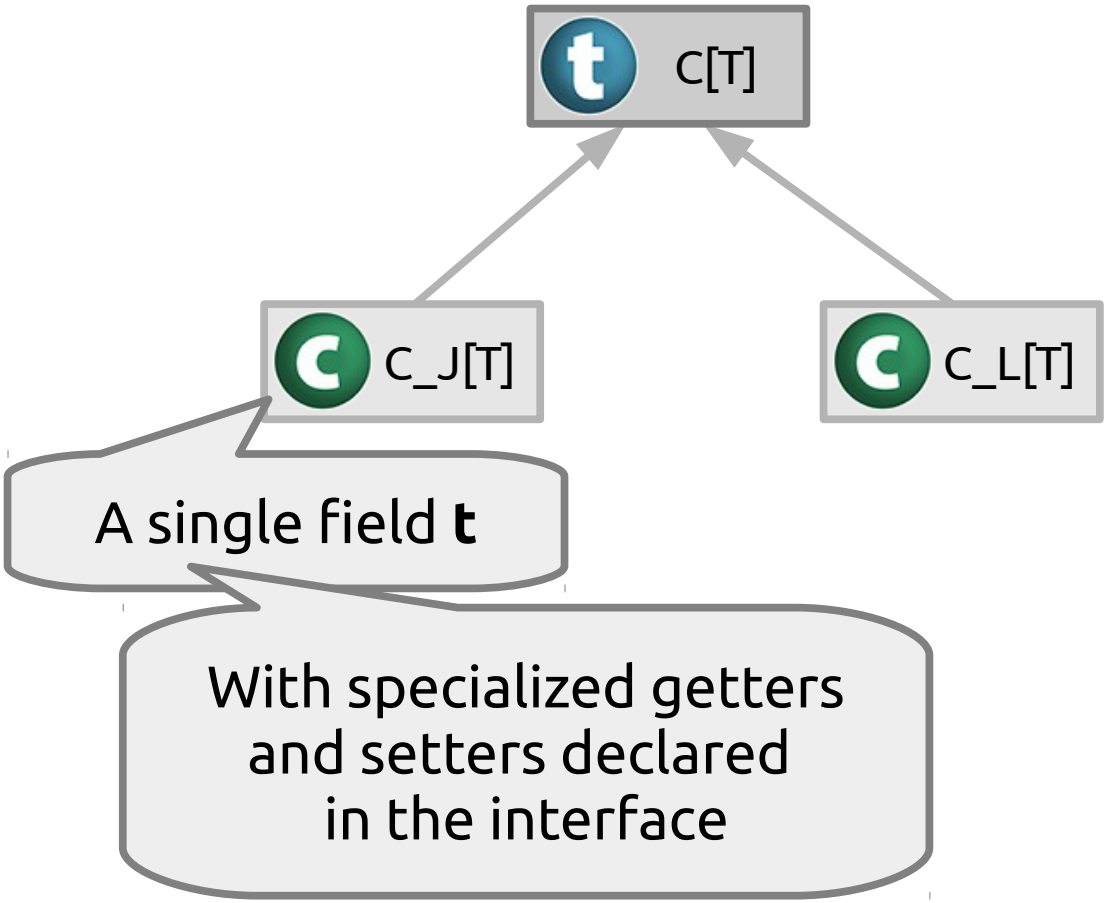

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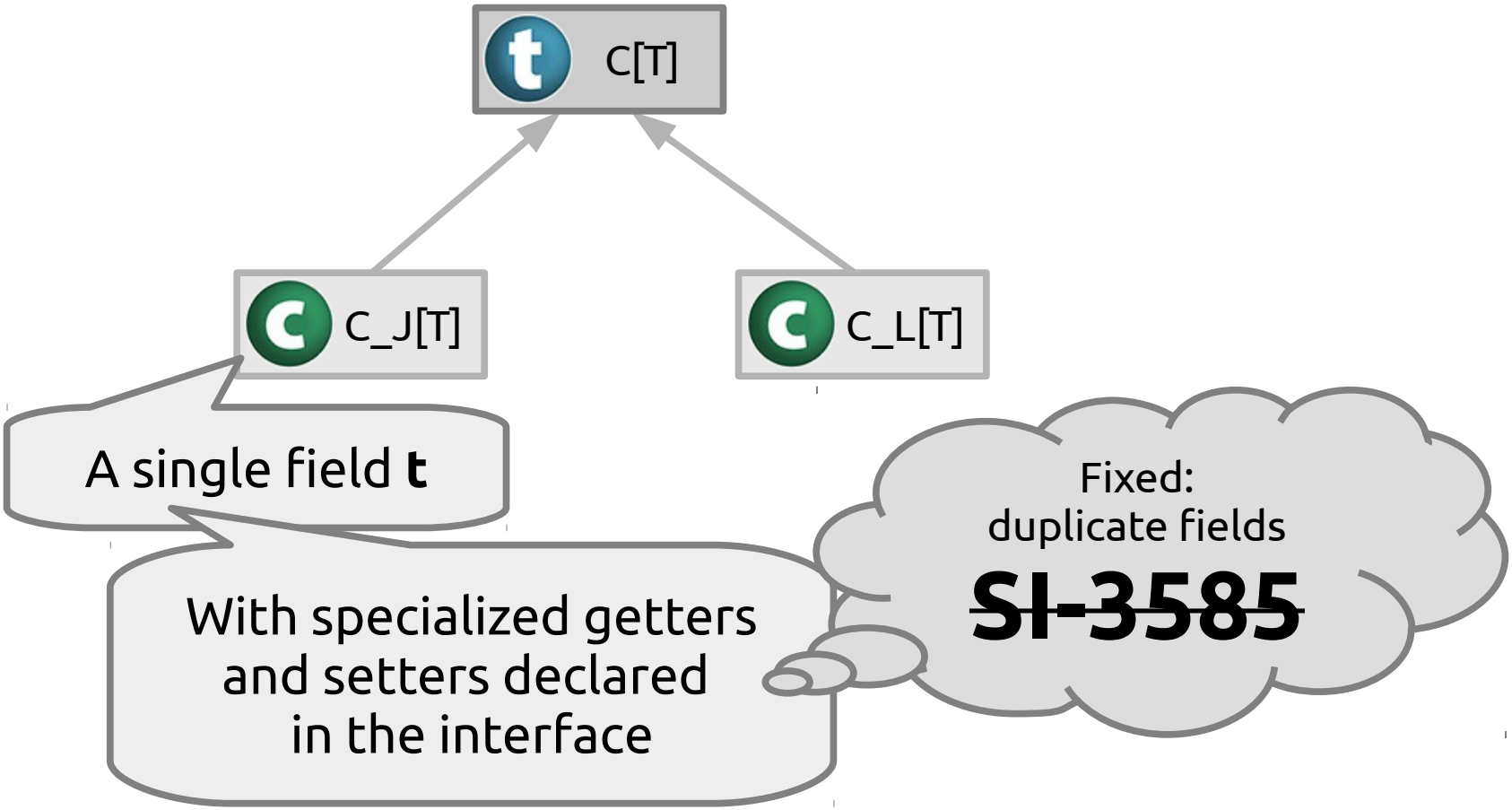

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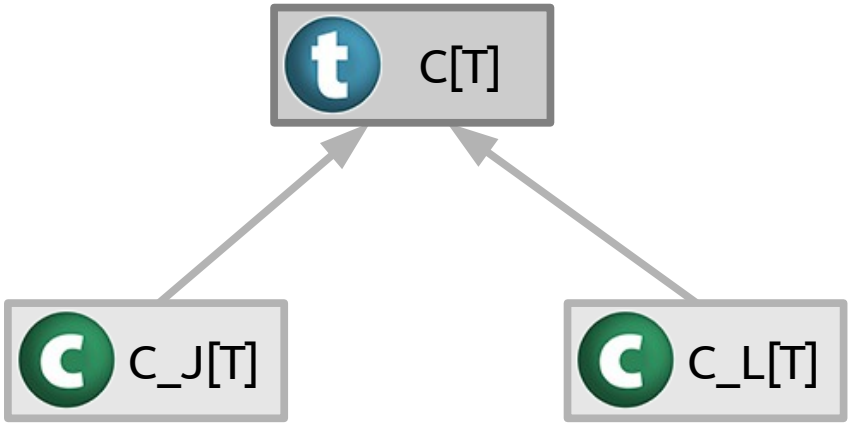

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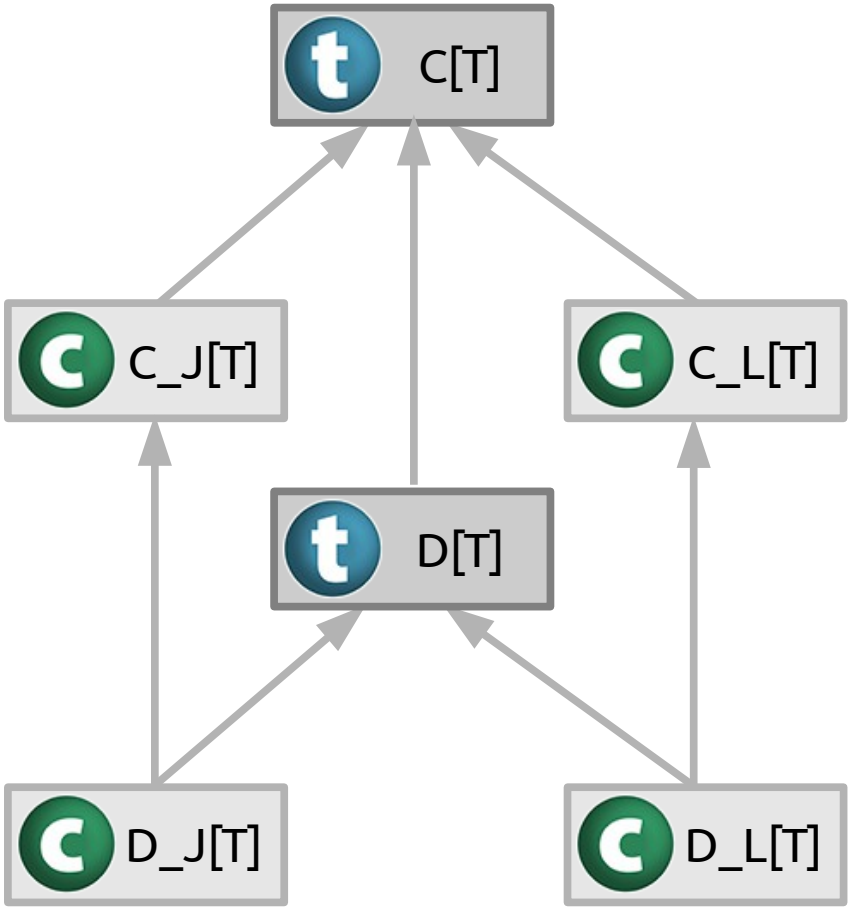

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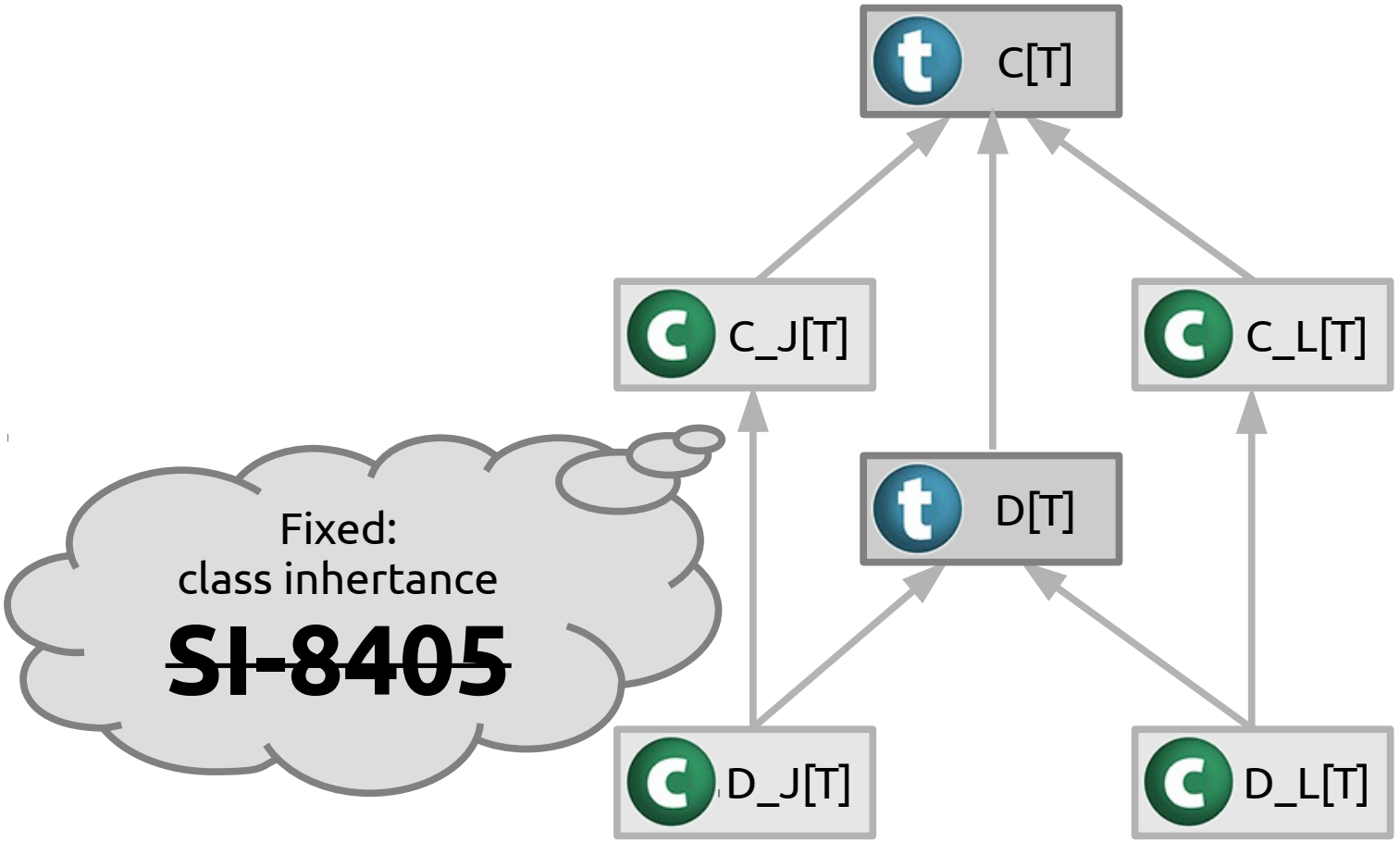

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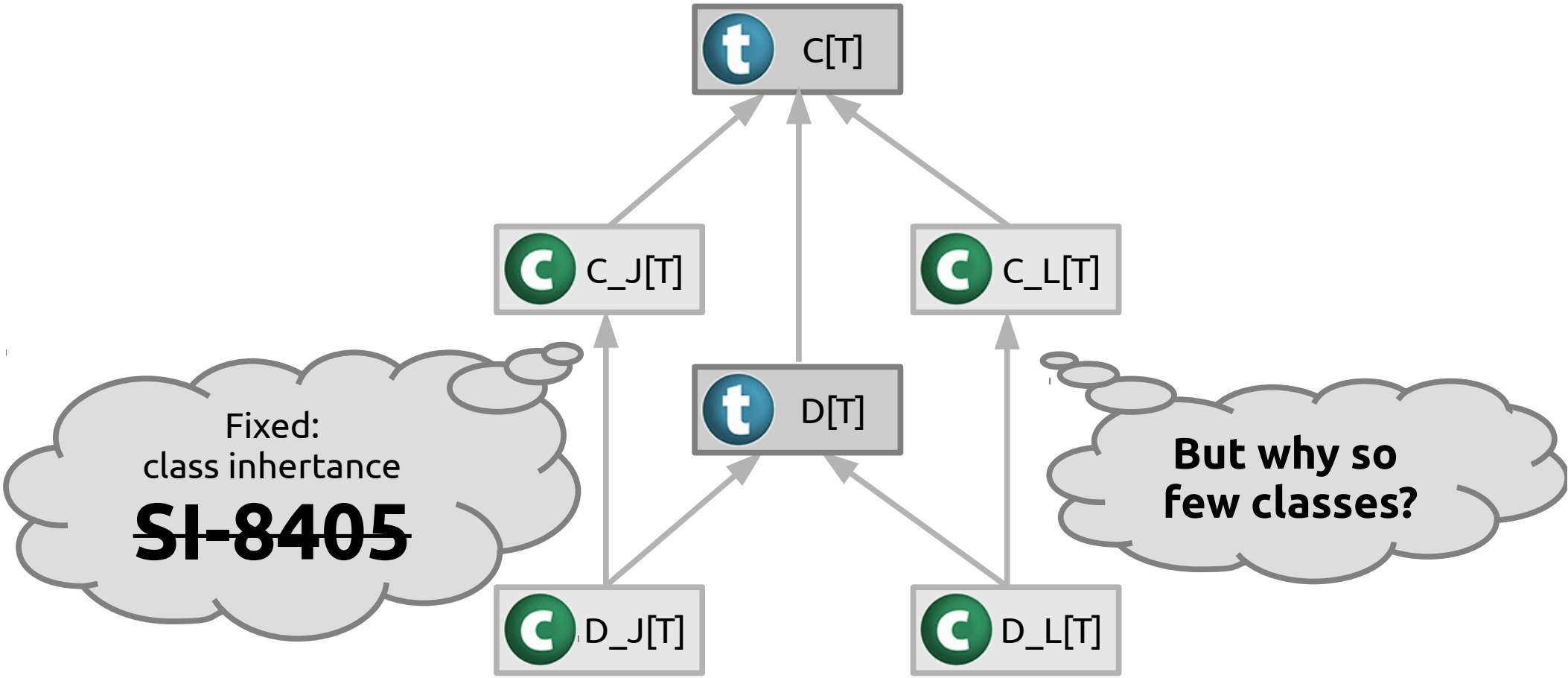

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- the limitations
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Where's the

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Still want to distribute it
via maven, not **via torrents**

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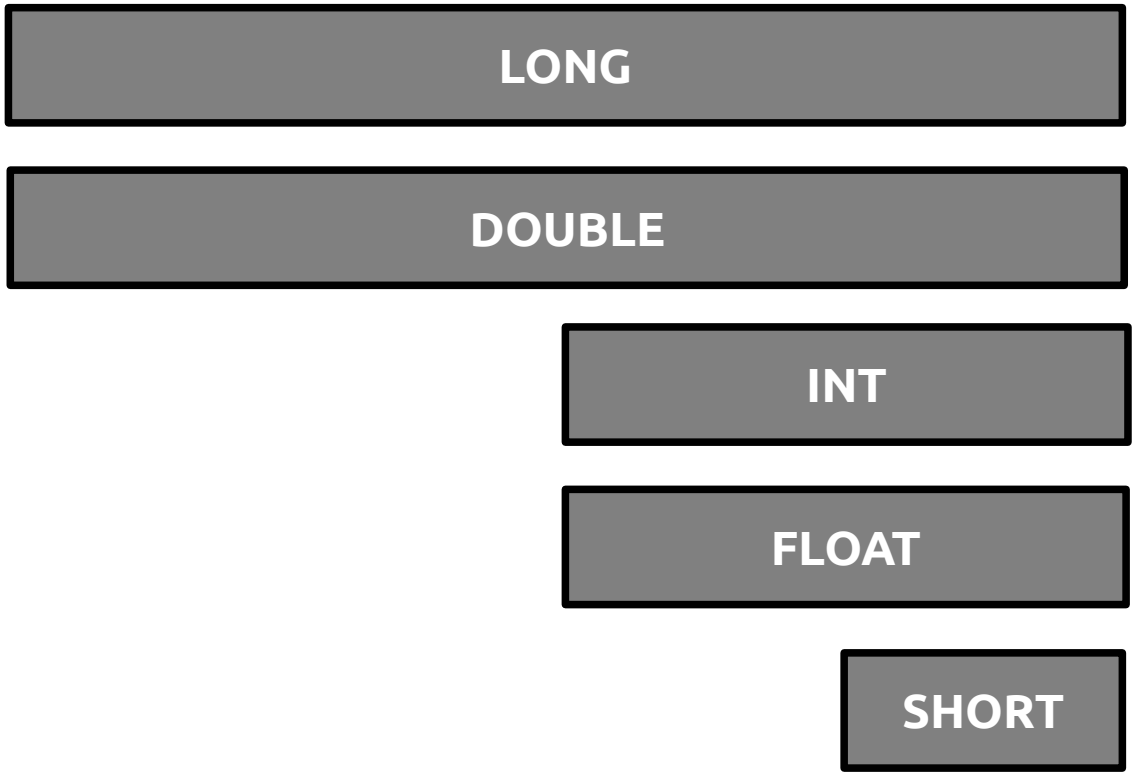

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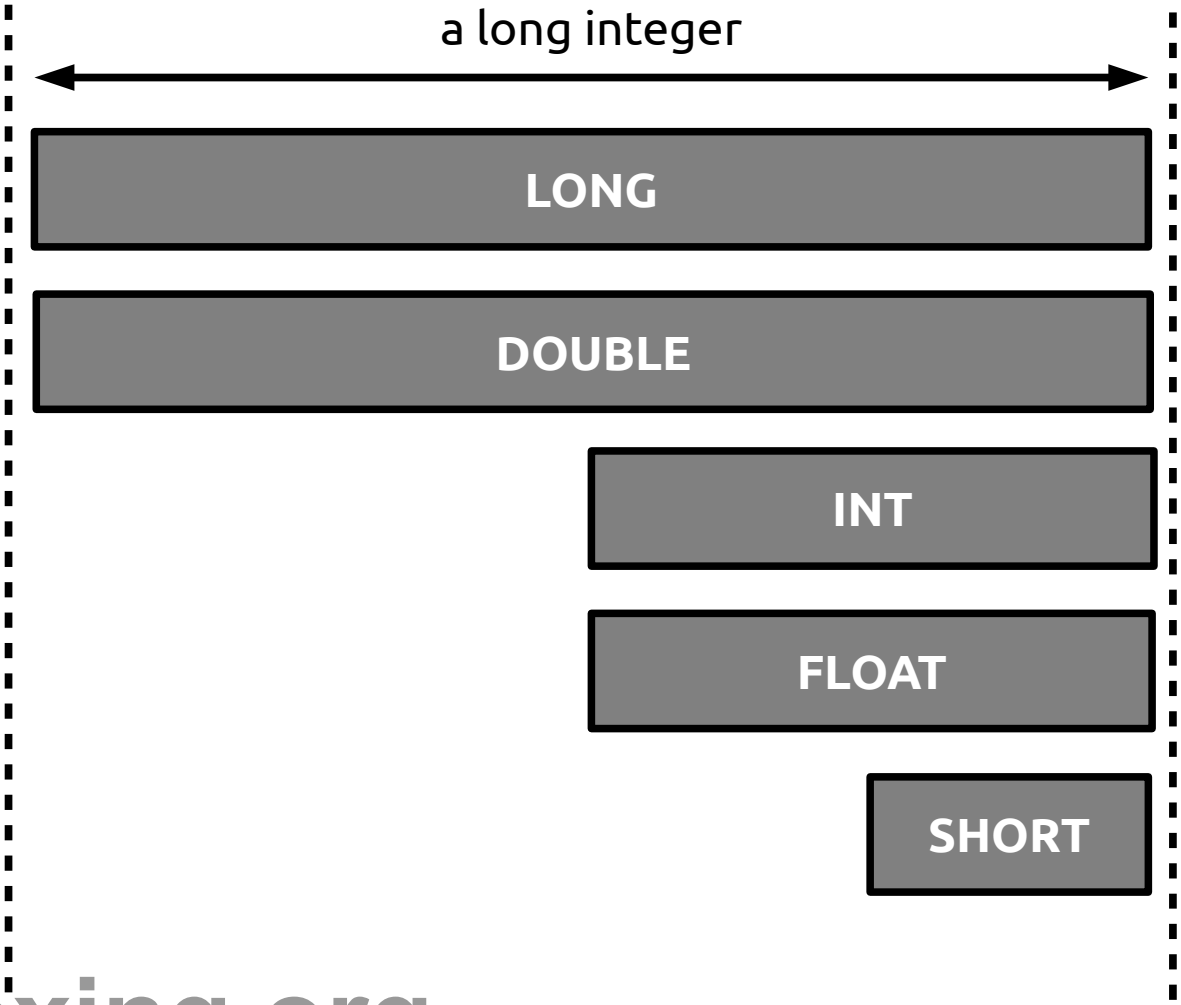

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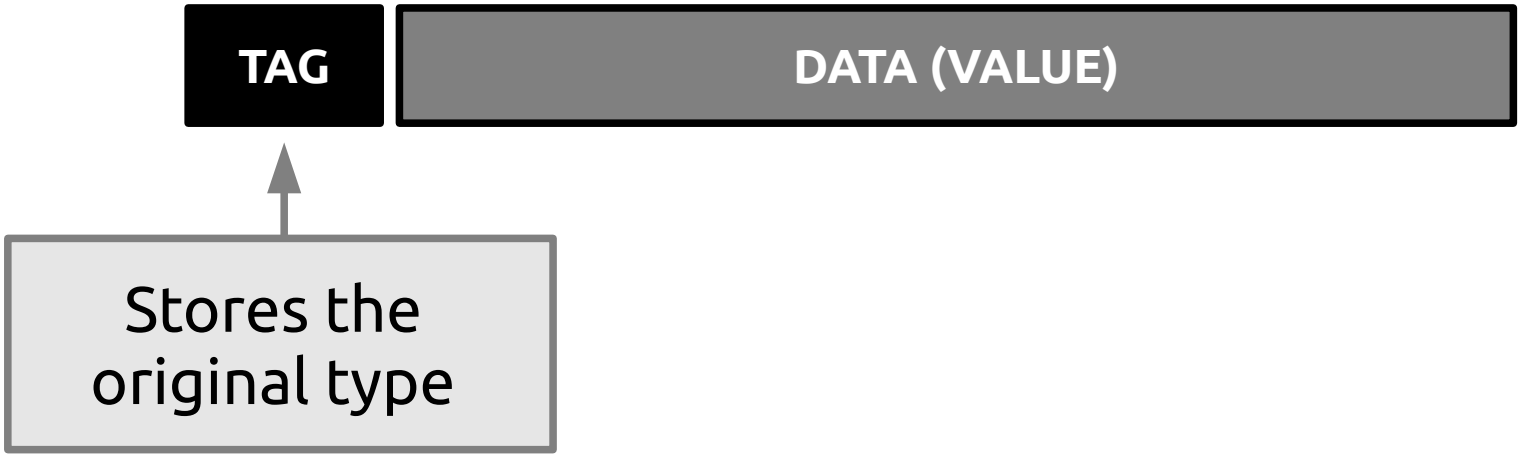

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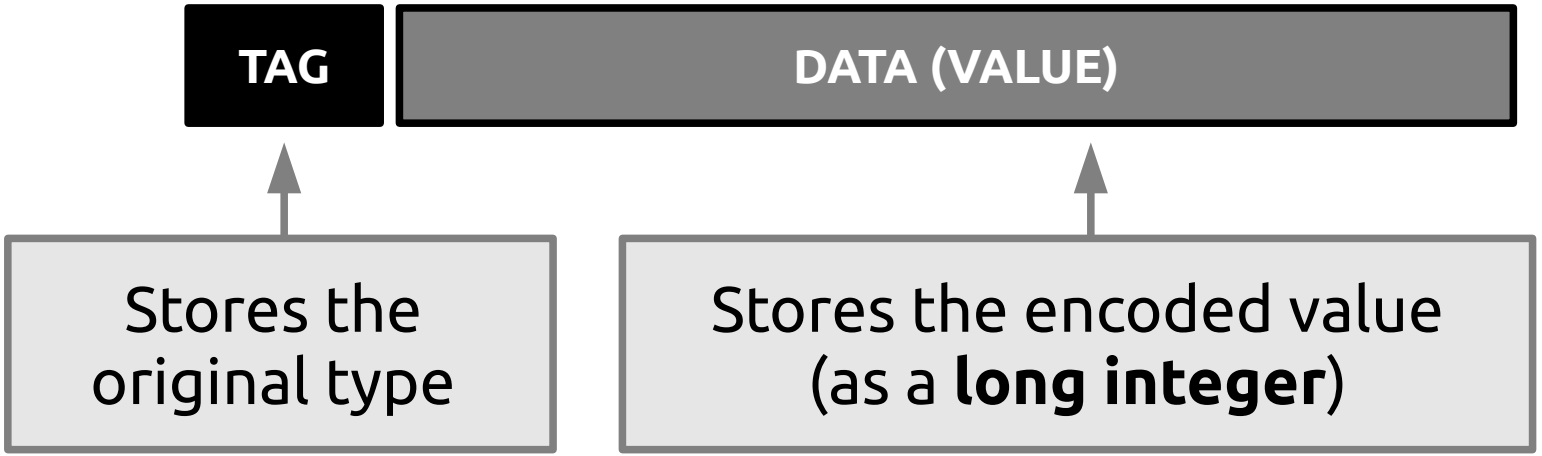

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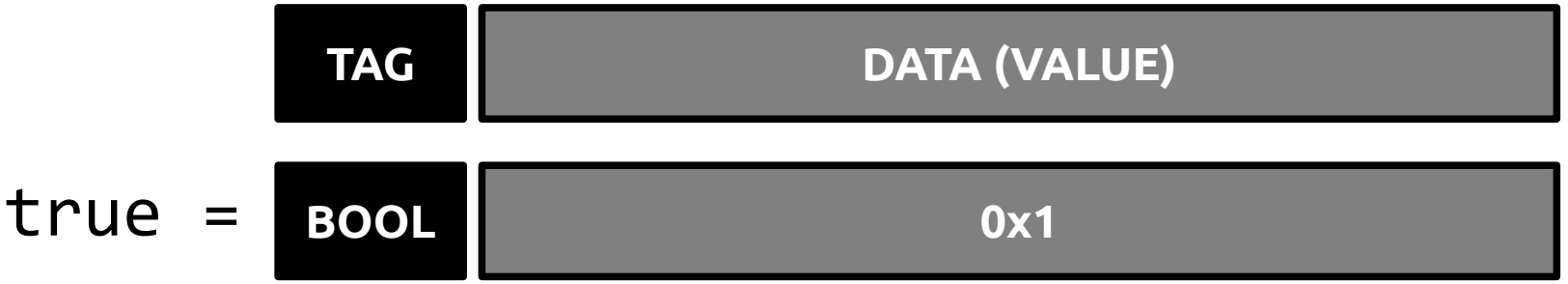

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	TAG	DATA (VALUE)
`true` =	BOOL	0x1
`42` =	INT	0x2A

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	TAG	DATA (VALUE)
`true` =	BOOL	0x1
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`5.0f` =	FLOAT	bit representation

And then the idea was born

it started from the **tagged union**

- somewhat similar to a boxed object

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Same benefits as for unboxed values

And then the idea was born

we can reduce the number of variants

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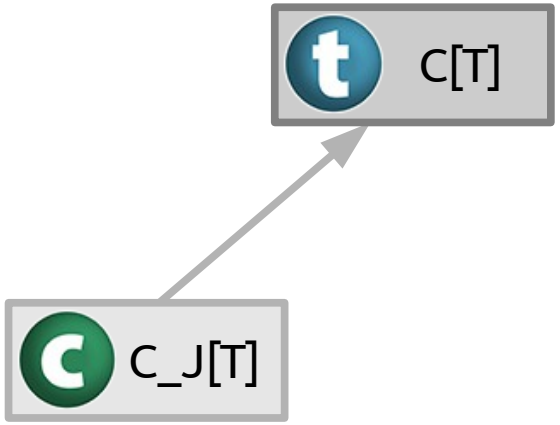

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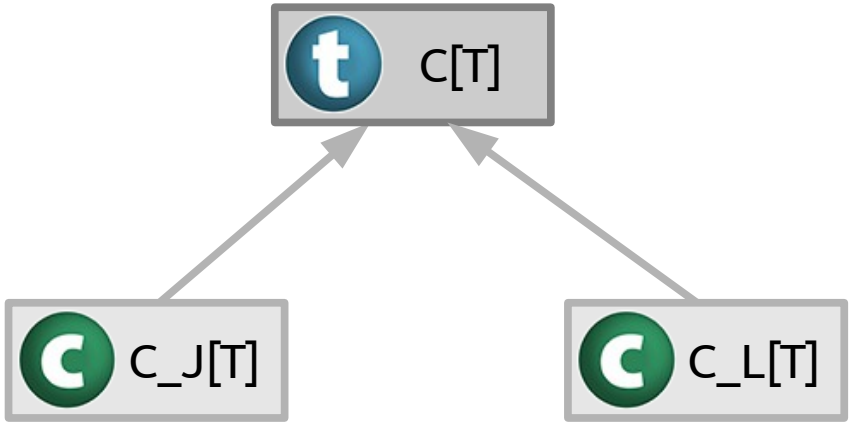

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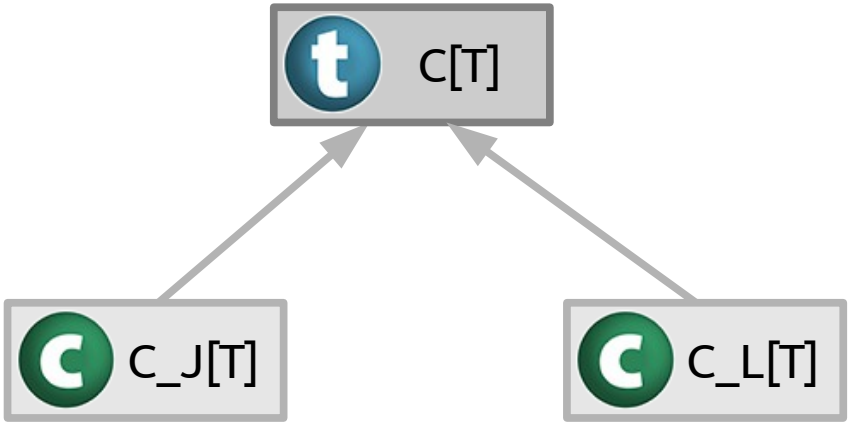

"From a low-level perspective, there are only values and pointers."

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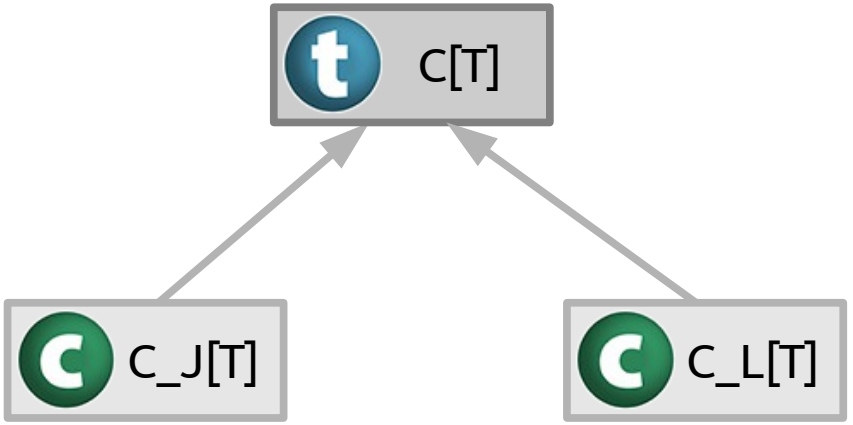

Let's take an example

"From a low-level perspective, there are only values and pointers."

Let's take

an example


```
def choice[@miniboxed T](t1: T,
                         t2: T): T =
  if (util.Random.nextBoolean())
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We'll have a version for primitive types

Let's take

an example


```
def choice_J[T](t1: ...,
                t2: ...): ... =
  if (util.Random.nextBoolean())
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  else
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```

Let's take
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def choice_J[T](t1: ...,
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But what's the signature?

Let's take

an example


```
def choice_J[T](t1: (Tag,Value),
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Let's take
an example


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This is naive tagged union

Let's take

an example

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And we even return it, despite the caller having passed it

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```

And we even return it, despite the caller having passed it

Insight: we're in a statically typed language, **use that**!

Let's take

an example


```
def choice_J[T](T_Tag: Tag, t1: Value,
                            t2: Value):Value=
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Let's take

an example

T_Tag corresponds to the type parameter

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Sort of a class tag

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```

Encoded as **Long**

Let's take

an example


```
def choice_J[T](T_Tag: Byte, t1: Long,
                              t2: Long): Long=
  if (util.Random.nextBoolean())
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```

So, back to the bytecode issue


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trait Function2[-T1, -T2, +R]
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- with specialization this produces **10^3 traits**

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But before we wrap this up

@miniboxed = @specialized

- the limitations
- bytecode bloat

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- the limitations
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before the benchmarks:
some internals

this is where it
gets complicated

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time for the
hardhats

Let's revisit

the example


```
def choice[@ miniboxed T](t1: T,
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  if (nextBoolean() && t1.hashCode != 13)
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Let's revisit

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def choice_J[T](T_Tag: Tag, t1: Long,
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t1.hashCode
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t1.hashCode
```

- how to translate this?

Let's revisit
the example


```
t1.hashCode
```

- how to translate this?
- when t1 is miniboxed?

Let's revisit

the example


```
scala> true.hashCode
res0: Int = 1231

scala> false.hashCode
res1: Int = 1237
```

Let's revisit
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scala> true.hashCode
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So calling hashCode on the Long won't work

Let's revisit

the example


```
minibox2box[T](T_Tag, t).hashCode
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  - execute the hashCode method

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Performance-wise

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- conversions
  - between minboxed and unboxed integer types
    - free on x64
  - between miniboxed and floating point types
    - low overhead (not free*)
  - between miniboxed and boxed values
    - avoided by @miniboxed!

* improved translation (thanks Rex!)

the last example
before the benchmarks

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```
def list[@miniboxed T](t1: T,
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  List[T](t1, t2)
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```

How to transform List[T]?

The last example

before the benchmarks


```
List[T]
```

what is List[T] when T is miniboxed?

The last example

before the benchmarks


```
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- for specialization:

  [T ← Int] List[T] => List[Int]

The last example

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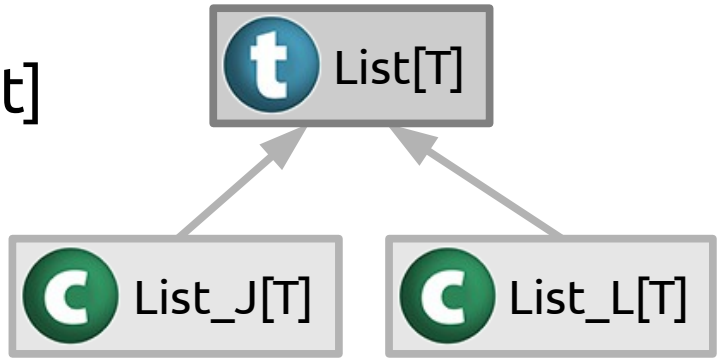

The last example
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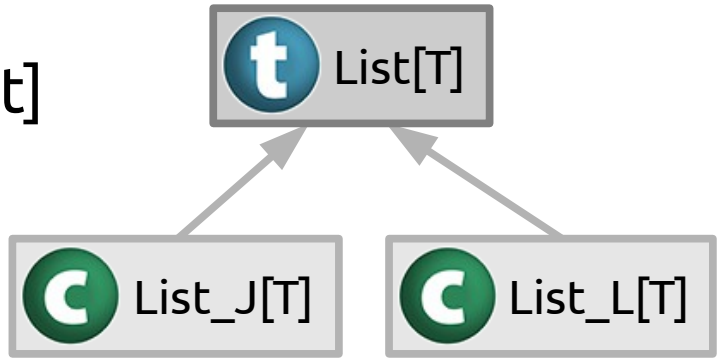

But List[T] is an interface,
we can still have an adapted
implementation class (List_J)

The last example

before the benchmarks


```
def list_J[T](T_Tag: Byte, t1: Long,
              t2: Long): List[T] =
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```
expected: T
found:    Long
```

The last example

before the benchmarks


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def list_J[T](T_Tag: Byte, t1: Long,
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def list_J[T](T_Tag: Byte, t1: Long,
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It turns out there's

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https://github.com/miniboxing/value-plugin

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https://github.com/miniboxing/value-plugin

But I won't go into the theory, that's another talk

Benchmarks

Linked List

Benchmarks

on the Scala library

- work with Aymeric Genet (github: @MelodyLucid)
- mock-up of Scala linked list
  - Function1 / Function2 / Tuple2
  - Traversable / TraversableLike
  - Iterator / Iterable / IterableLike
  - LinearSeqOptimized
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All the things you hate about the library are there!

Benchmarks

on the Scala library

- benchmark: Least Squares Method

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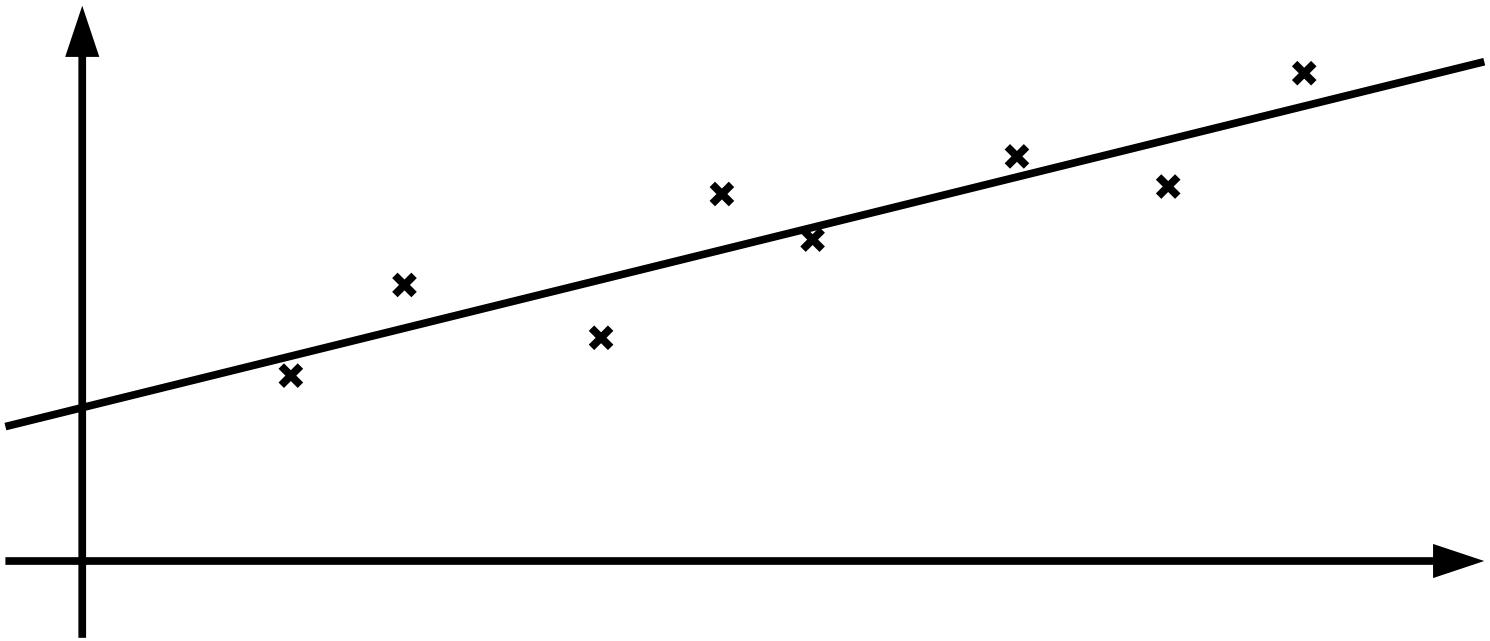
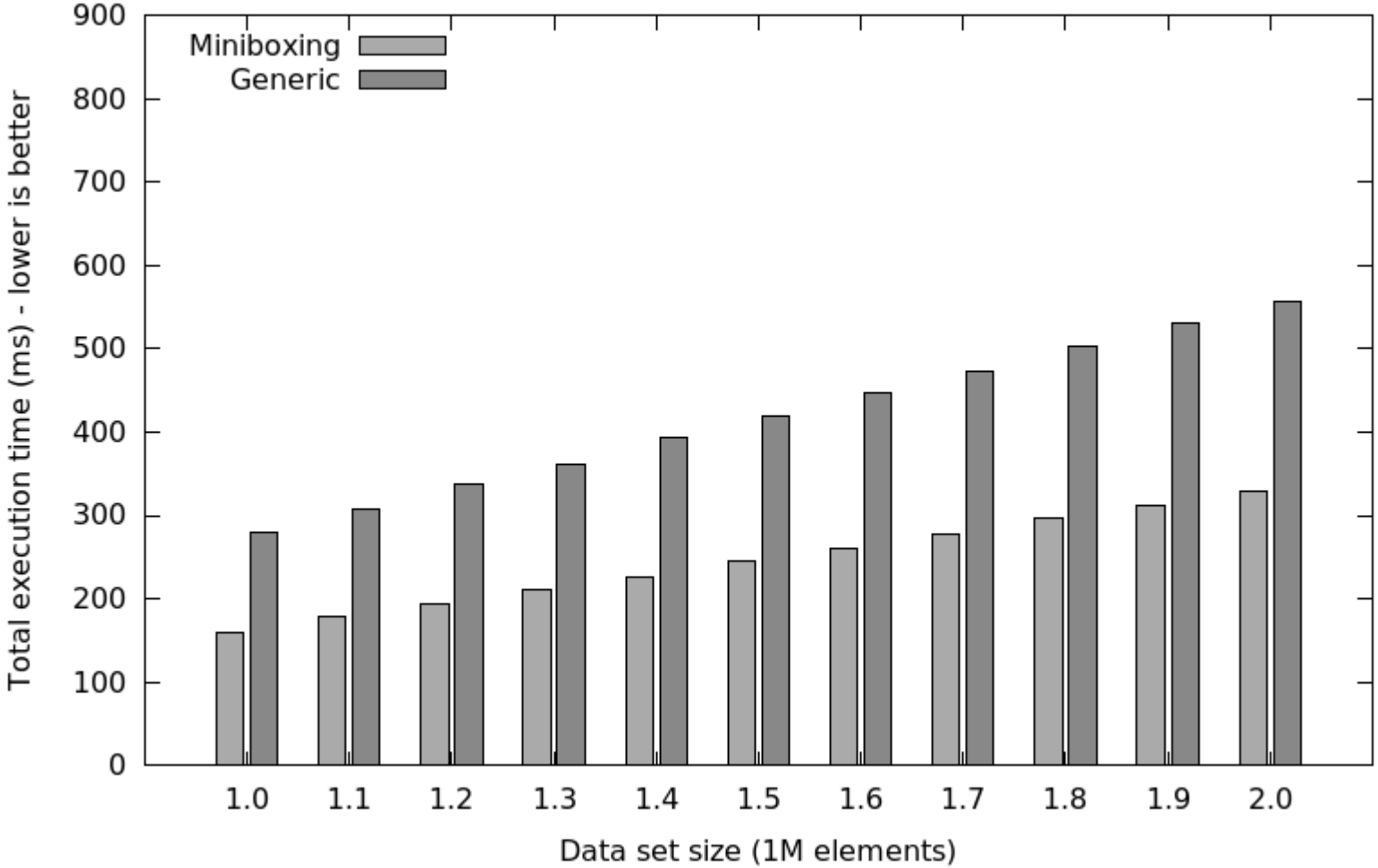
- benchmark: Least Squares Method



Benchmarks

on the Scala library (inf. heap)



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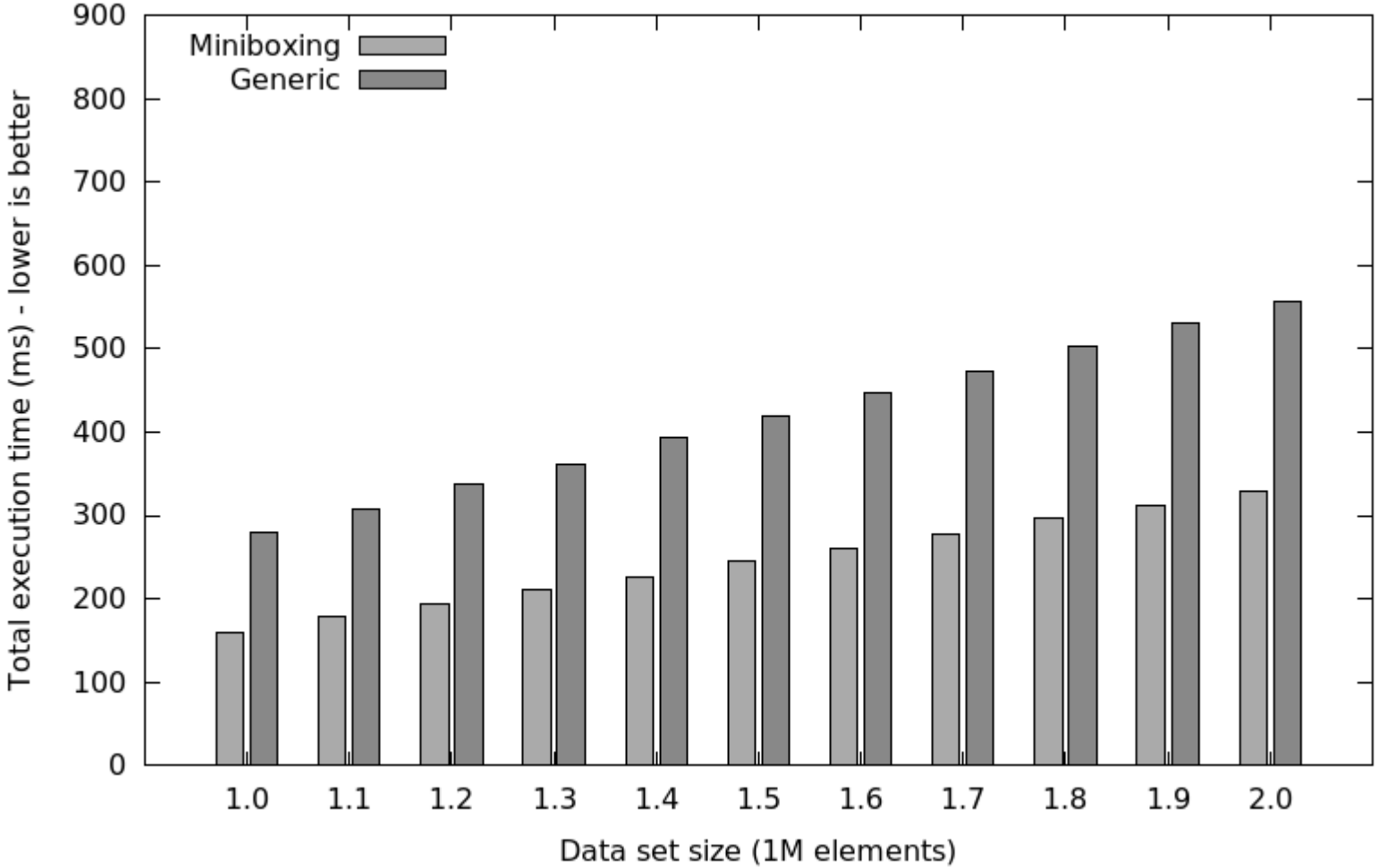
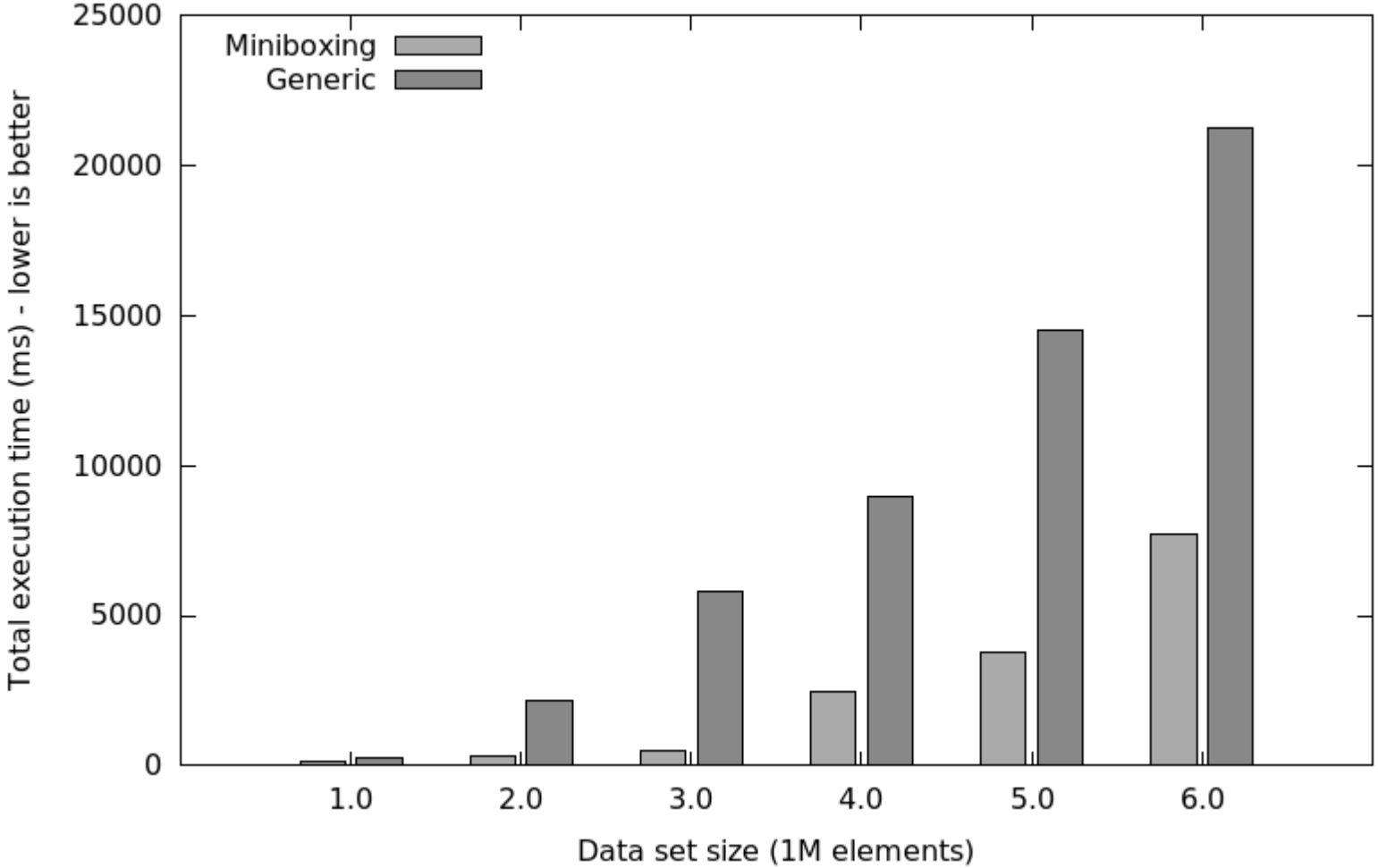


1.7x faster

Benchmarks

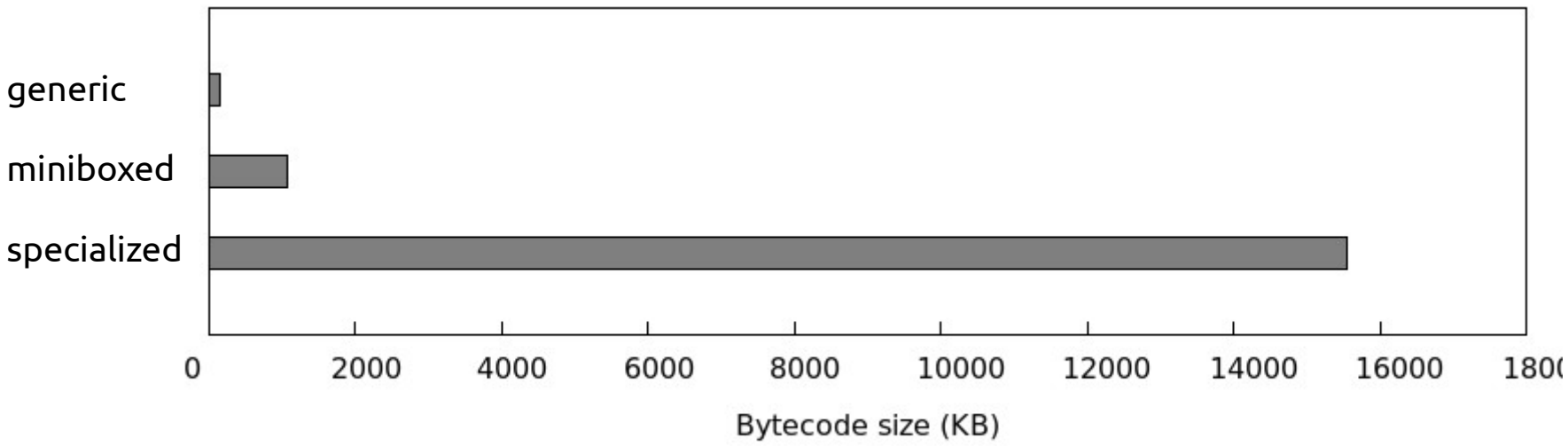
on the Scala library (with GC)



3x faster

Benchmarks

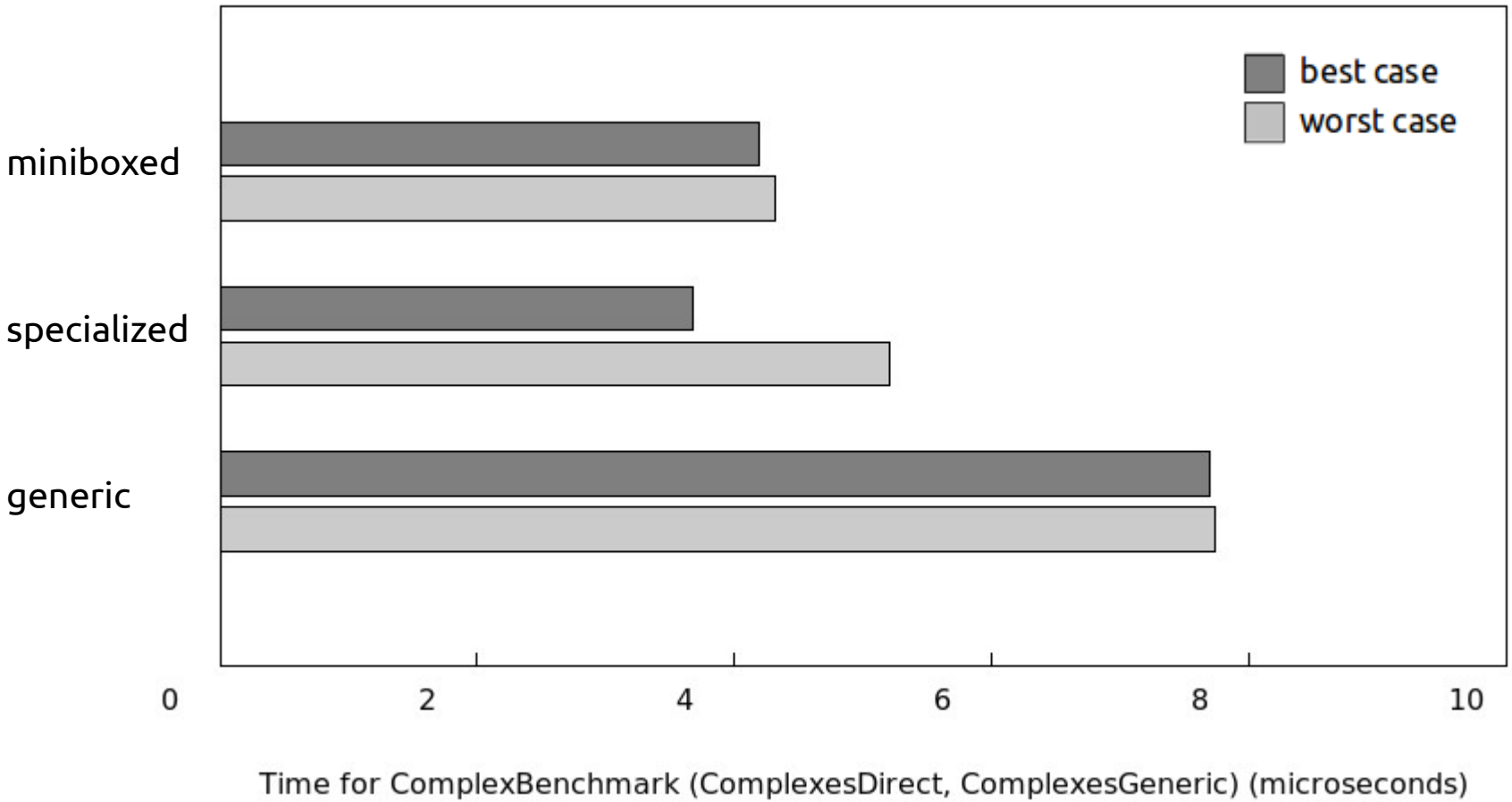
on the Scala library (bytecode)



non/spire

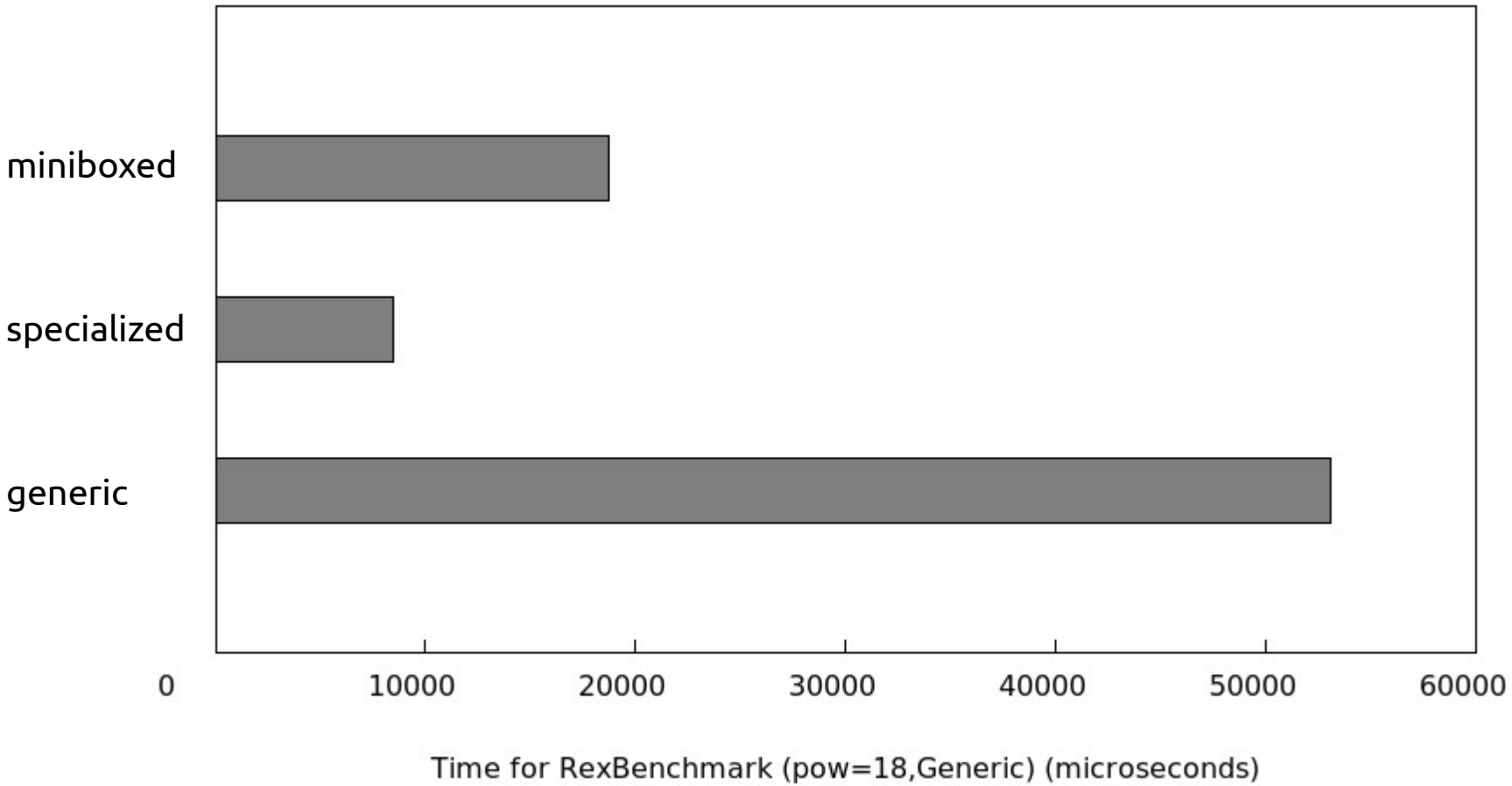
Benchmarks

on the Spire library (Complex)



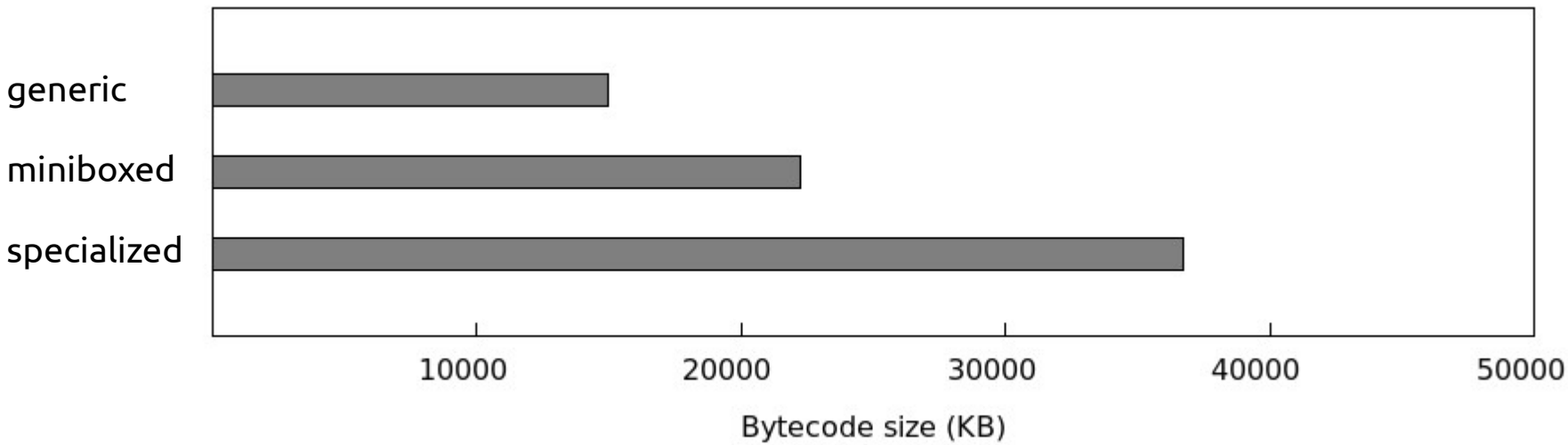
Benchmarks

on the Spire library (RexBench)



Benchmarks

on the Spire library (bytecode)



Benchmarks

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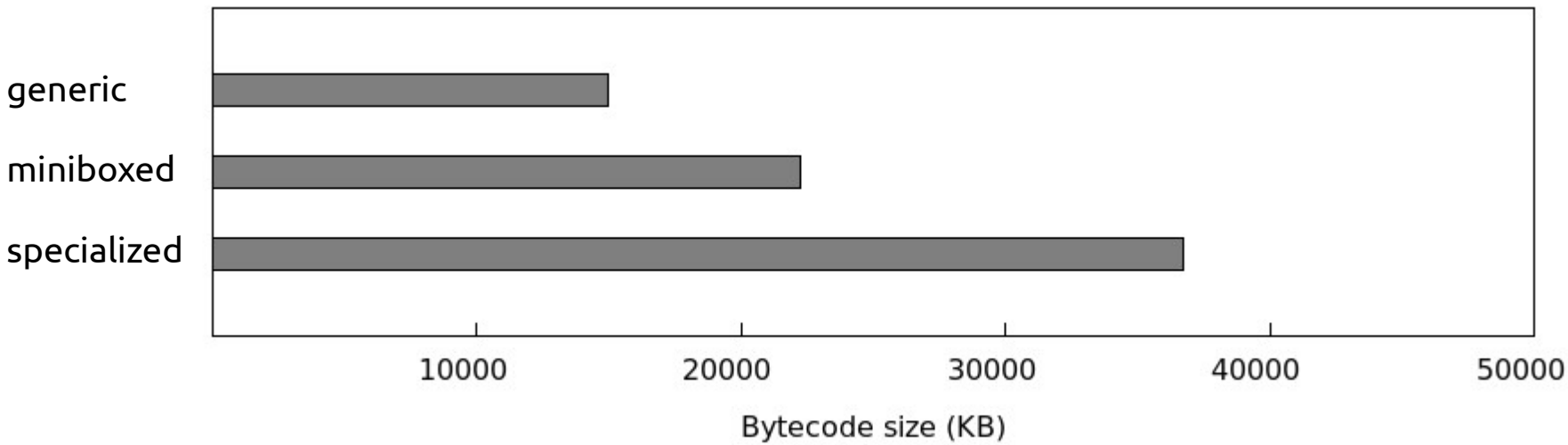

Spire is optimized for specialization

Credits

- Cristian Talau - developed the initial prototype, as a semester project
- Eugene Burmako - the value class plugin based on the LDL transformation
- Aymeric Genet - developing collection-like benchmarks for the miniboxing plugin
- Martin Odersky, for his patient guidance
- Iulian Dragos, for his work on specialization and many explanations
- Miguel Garcia, for his original insights that spawned the miniboxing idea
- Michel Schinz, for his wonderful comments and enlightening ACC course
- Andrew Myers and Roland Ducournau for the discussions we had and the feedback provided
- Heather Miller for the eye-opening discussions we had
- Vojin Jovanovic, Sandro Stucki, Manohar Jonalagedda and the whole LAMP laboratory in EPFL for the extraordinary atmosphere
- Adriaan Moors, for the miniboxing name which stuck :))
- Thierry Coppey, Vera Salvisberg and George Nithin, who patiently listened to many presentations and provided valuable feedback
- Grzegorz Kossakowski, for the many brainstorming sessions on specialization
- Erik Osheim, Tom Switzer and Rex Kerr for their guidance on the Scala community side
- OOPSLA paper and artifact reviewers, who reshaped the paper with their feedback
- Sandro, Vojin, Nada, Heather, Manohar - reviews and discussions on the LDL paper
- Hubert Plociniczak for the type notation in the LDL paper
- Denys Shabalin, Dmitry Petrashko for their patient reviews of the LDL paper

@miniboxed = @specialized

- the limitations
- bytecode bloat

for Scala collections!

visit scala-miniboxing.org!