Storage Strategies for Collections in Dynamically Typed Languages


Carl Friedrich Bolz


Lukas Diekmann


Laurence Tratt

KING'S College LONDON

Software Development Team

2013-08-24

Collections in dynamically typed languages are **slow**

Why is that?

Referencing arbitrary types

Referencing arbitrary types

↓

Needs **common representation** on heap

Memory usage in dynamically typed languages

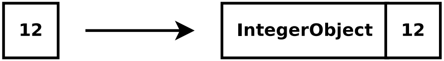
Referencing arbitrary types

↓

Needs **common representation** on heap

↓

Solution: **Boxing**



Example

Statically typed integer vs dynamically typed integer

Language	Words
C	
PyPy	

Example

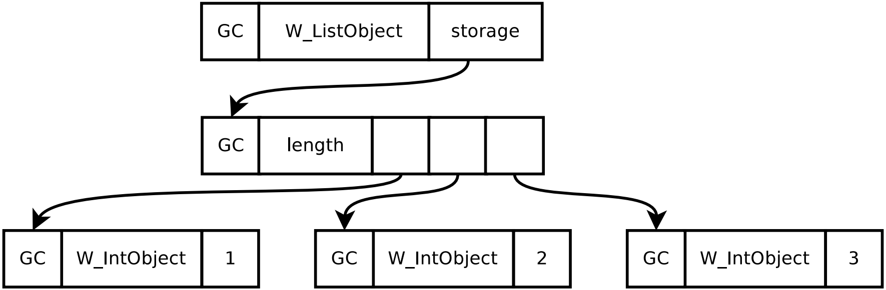
Statically typed integer vs dynamically typed integer

Language	Words
C	1
PyPy	

Statically typed integer vs dynamically typed integer

Language	Words
C	1
PyPy	3

Worse in collections




```
>>> list = [1,2,3]
```

Worse in collections

A list with 1,000,000 integers

Language	Memory
C	
PyPy	

Worse in collections

A list with 1,000,000 integers

Language	Memory
C	3.8 MiB
PyPy	

Worse in collections

A list with 1,000,000 integers

Language	Memory
C	3.8 MiB
PyPy	15.3 MiB

A way out?

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.
- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

A way out?

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.
- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

A way out?

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.
- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

And now?

And now?

Storage strategies

Storage strategies

Split up collection into **strategy** and **storage**

Strategy
Takes over collections functionality

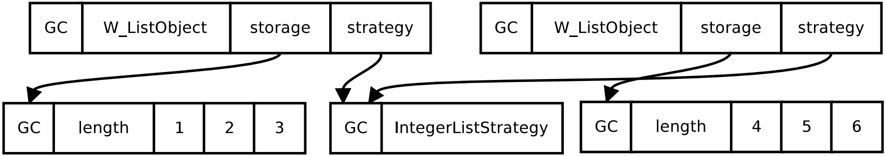
Strategy

Takes over collections functionality

Storage

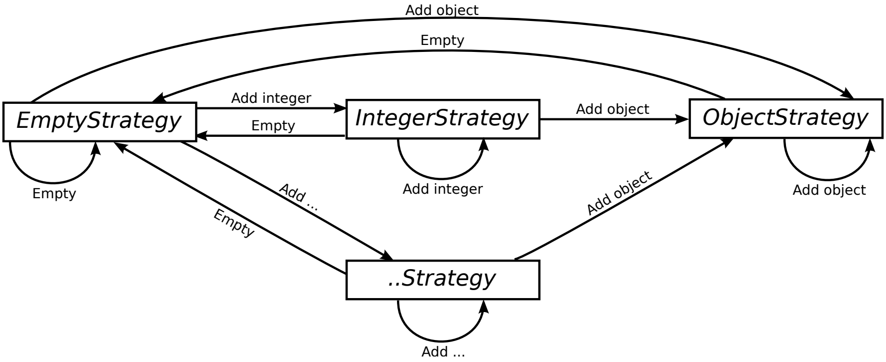
Contains *unboxed* data types

Storage strategies




```
l1 = [1,2,3]
l2 = [4,5,6]
```

Storage strategy life cycle



Implementation

```
class W_ListObject(W_Object):
  def __init__(self):
    self.strategy = EmptyListStrategy()
    self.lstorage = None

  def append(self, w_item):
    self.strategy.append(self, w_item)

@singleton
class ListStrategy(object):
  def append(self, w_list, w_item):
    raise NotImplementedError("abstract")

@singleton
class EmptyListStrategy(ListStrategy):
  def append(self, w_list, w_item):
    if is_boxed_int(w_item):
      w_list.strategy = IntegerListStrategy()
      w_list.lstorage = new_empty_int_list()
    elif ...:
      ...
    else:
      w_list.strategy = ObjectListStrategy()
      w_list.lstorage = new_empty_object_list()
    w_list.append(w_item)
```

```
@singleton
class IntegerListStrategy(ListStrategy):
  def append(self,  w_list, w_item):
    if is_boxed_int(w_item):
      u_int = unbox_int(w_item)
      w_list.lstorage.append_int(u_int)
      return
    self.switch_to_object_strategy(w_list)
    w_list.append(w_item)

  def switch_to_object_strategy(self, w_list):
    lstorage = new_empty_object_list()
    for i in w_list.lstorage:
      lstorage.append_obj(box_int(i))
    w_list.strategy = ObjectListStrategy()
    w_list.lstorage = lstorage

@singleton
class ObjectListStrategy(ListStrategy):
  def append(self,  w_list, w_item):
    w_list.lstorage.append_obj(w_item)
```

Unboxed data types enable several optimisations.

Start with a predefined strategy.

```
"string".split("i")
```

Copy strategy from other collection

```
set([1,2,3])
```

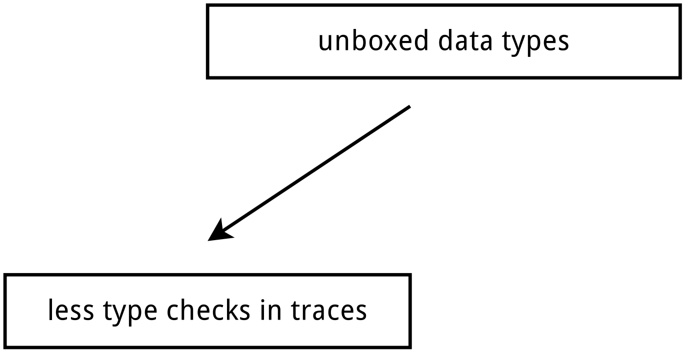
Add fast paths when comparing objects of different types.

`contains, difference, issubset`

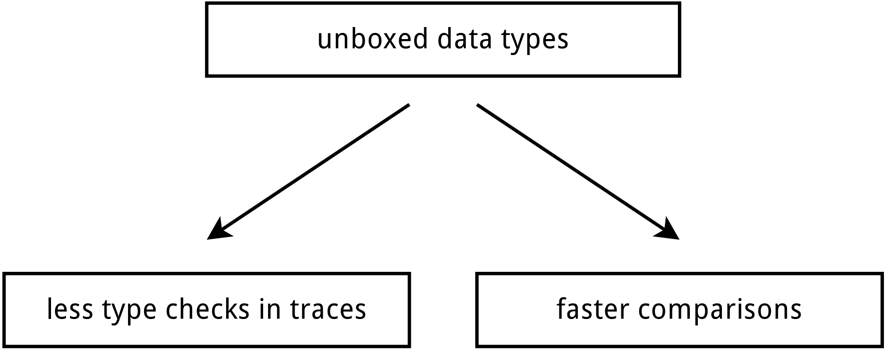
RangeListStrategy: Calculates elements on the fly.

```
range(1000)
```

unboxed data types


unboxed data types
less type checks in traces

JIT interaction



Evaluation

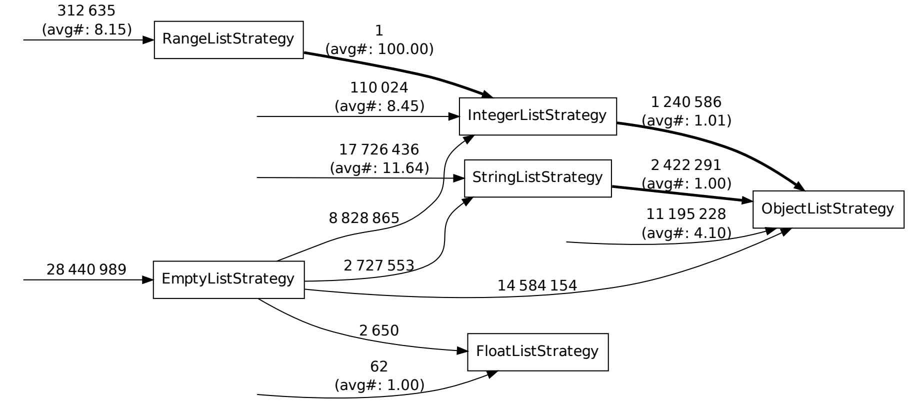
Methodology

- Classic performance benchmarks
- Real world applications
- Experiments downloadable at soft-dev.org

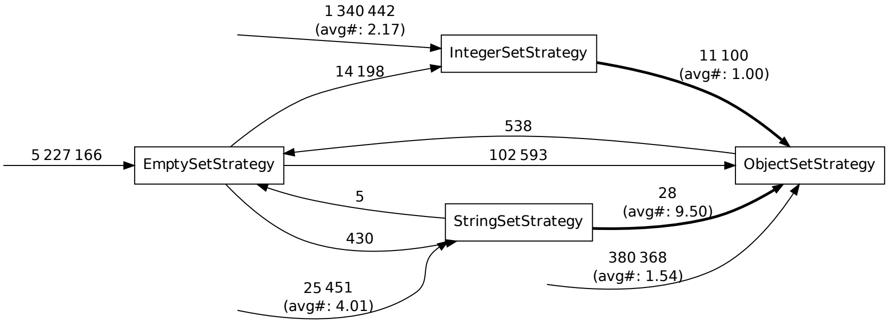
Validating hypotheses

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.
- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

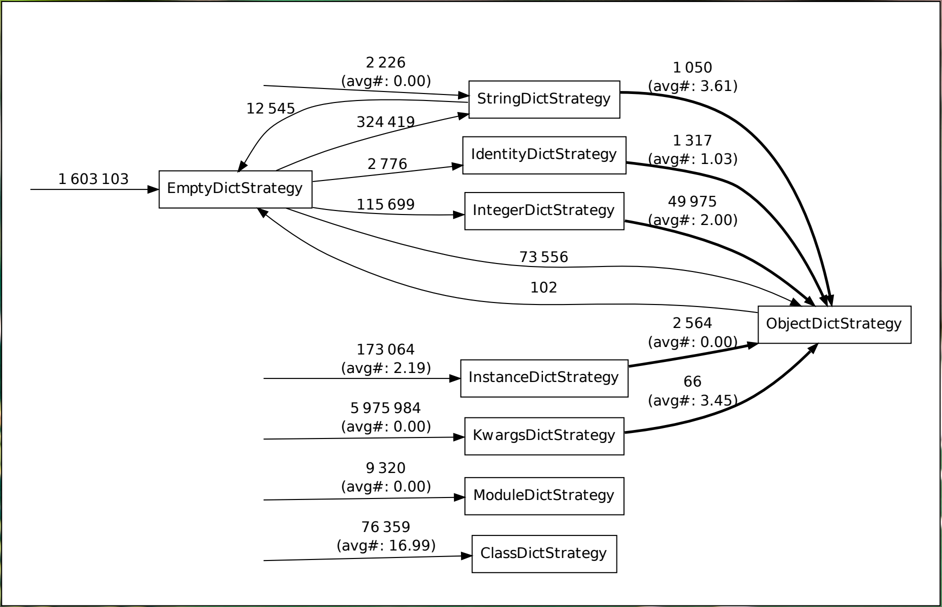
List transitions



Set transitions



Dict transitions



Validating hypotheses

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.
- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

Validating hypotheses

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.

STRONG

- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

- **H1** It is **uncommon** for a homogeneously typed collection storing objects of primitive types to later type dehomogenise.

STRONG

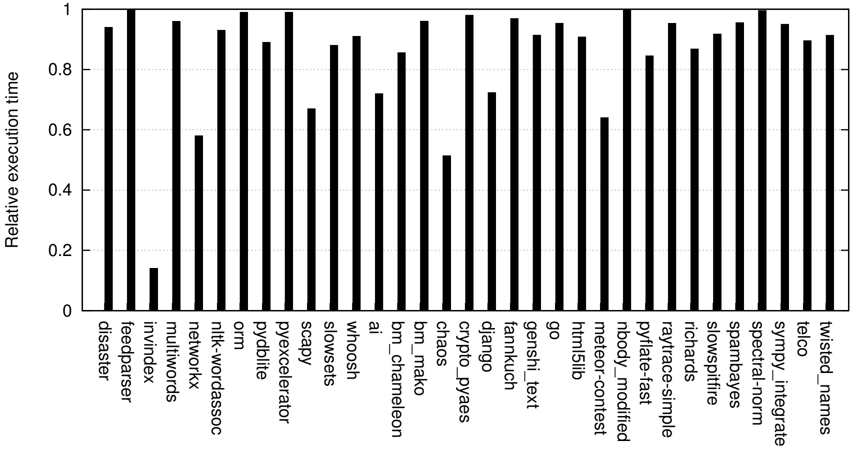
- **H2** When a previously homogeneously typed collection type dehomogenises, the transition happens after only a **small number of elements** have been added.

CONCLUSIVE

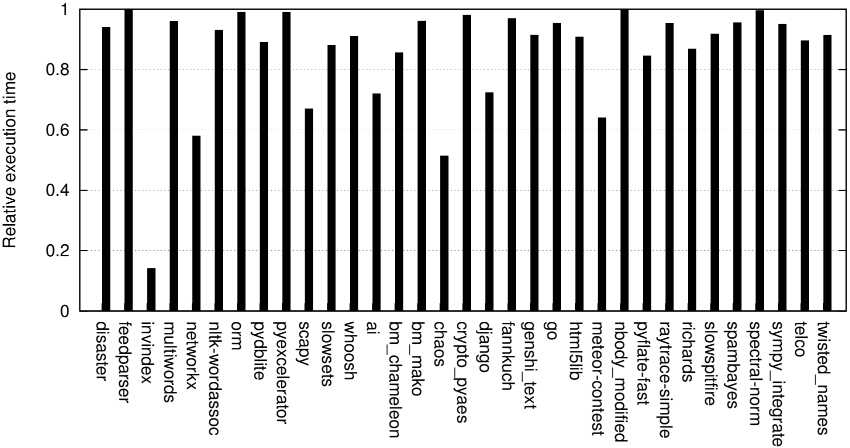
Speed benchmarks

- Executed 35 times
- Skip first 5 results containing JIT warmup

Speed benchmarks



Speed benchmarks

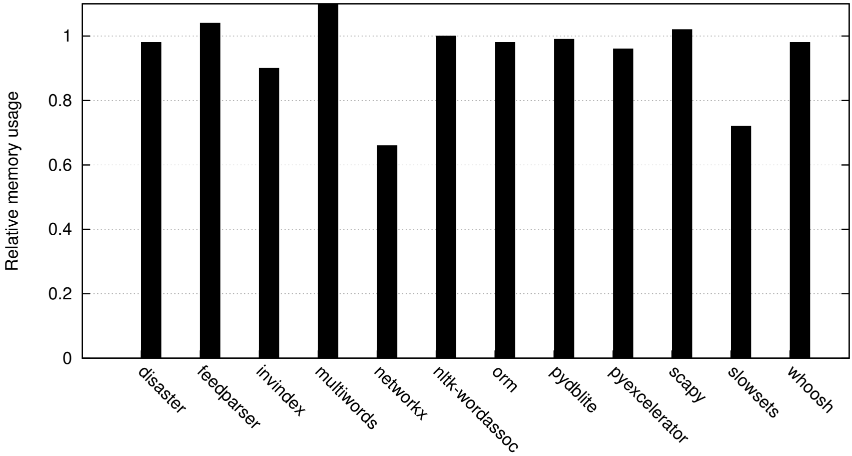


Performance increase of $\sim$18%

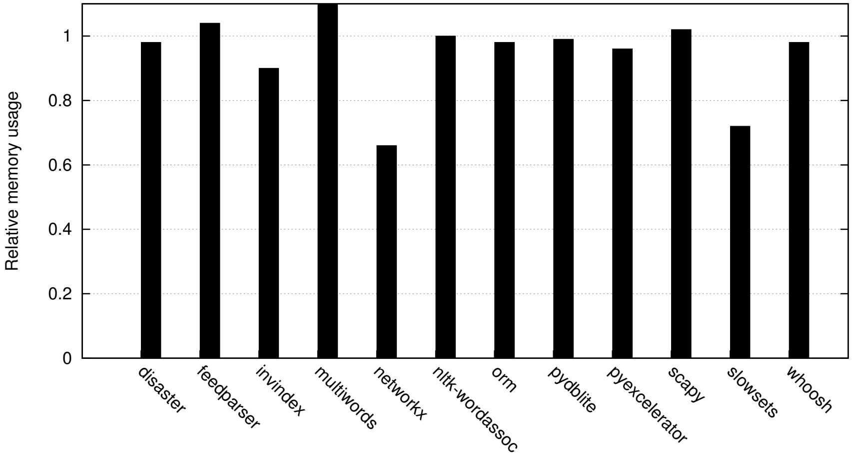
Memory benchmarks

- Memory usage via probes
- At probably maximum point of maximal usage

Memory benchmarks



Memory benchmarks



Memory decrease of $\sim$6%

Summary

Summary

- simple to implement

Summary

- simple to implement
- only $\sim$1500 LoC

Summary

- simple to implement
- only $\sim$1500 LoC
- good performance boost: $\sim$18%

Summary

- simple to implement
- only ∼1500 LoC
- good performance boost: ∼18%
- minor memory reduction: ∼6%

Thank you for listening

`http://soft-dev.org/`