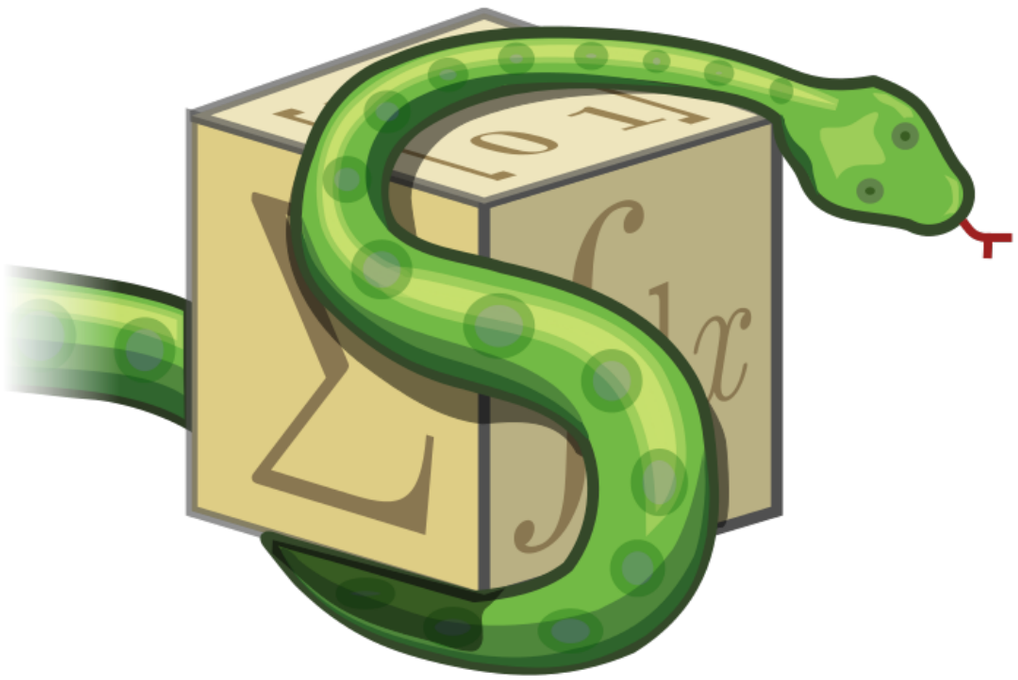
Lets Talk About GIL

@aktech

Who am I?

Loves everything which is free and open!

Loves everything which is free and open!
including Software



SymPy

```
>>> x = symbols('x')
>>> solveset(sin(x) - 1, domain=S.Reals)
```

$$\left\{2n\pi + \frac{\pi}{2} \mid n \in \mathbb{Z}\right\}$$

```
In [1]: from sympy import this
The Zen of SymPy

Unevaluated is better than evaluated.
The user interface matters.
Printing matters.
Pure Python can be fast enough.
If it's too slow, its (probably) your fault.
Documentation matters.
Correctness is more important than speed.
Push it in now and improve upon it later.
Coverage by testing matters.
Smart tests are better than random tests.
But random tests sometimes find what your smartest test missed.
The Python way is probably the right way.
Community is more important than code.
```

Try in your browser

http://live.sympy.org/

Google Summer of Code

Google Summer of Code

Student application deadline
March 27 16:00 UTC

The Telegraph

Process

an instance of a program running in a computer.

Thread

smallest sequence of programmed instructions

Thread

light weight and share memory.

Strength of Threads

Strength of Threads

shared state

"Everyone has everything"

- Raymond Hettinger

Weakness of Threads

Weakness of Threads

shared state

"Everyone can access everything"

Weakness of Threads

shared state

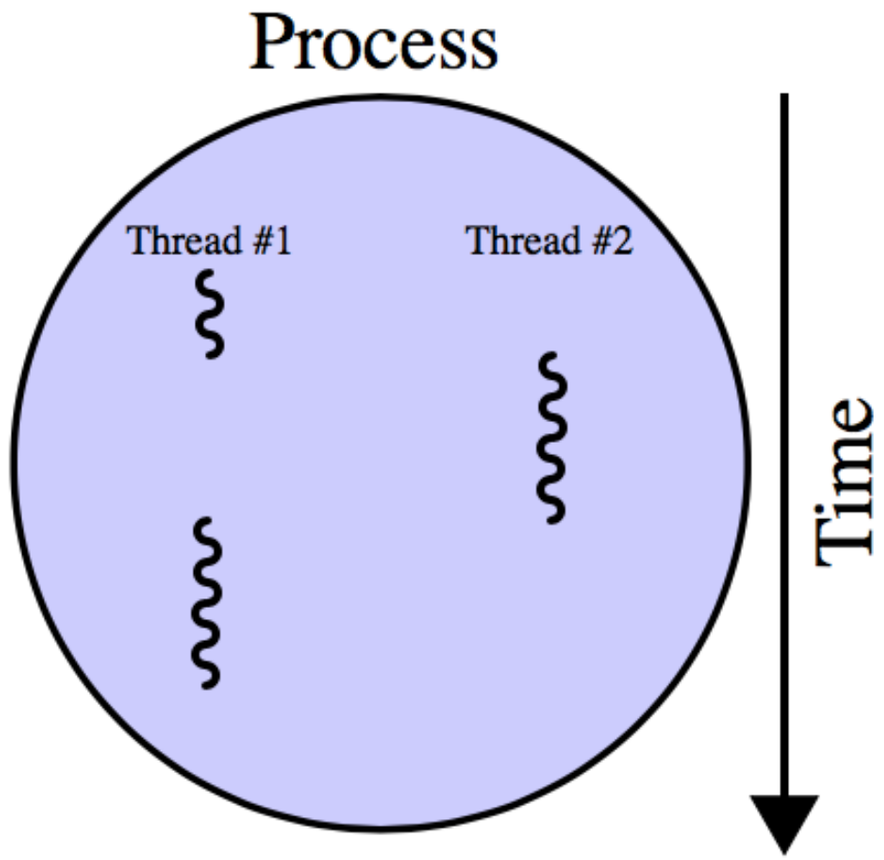
"Everyone can access everything"

Simultaneously!

Multithreading

The ability of a central processing unit (CPU) or a single core in a multi-core processor to execute multiple **threads concurrently**.

Multithreading



Why Multithreading?

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- Keep a Process Responsive

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- Keep a Process Responsive
- Keep a Processor Busy

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- Keep a Process Responsive
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- Keep Multiple Processors Busy

Why Multithreading?

- Keep a Process Responsive
- Keep a Processor Busy
- Keep Multiple Processors Busy
- Save Time

Multithreading in C++

Lets see an Example!

Multithreading in Python

Threading module in Python

Defining by Class

```
import time
import threading

class CustomThread(threading.Thread):
    def __init__(self, **kwargs):
        threading.Thread.__init__(self)
        self.param = kwargs.get('foo')

    def run(self):
        # This code executes in the Thread
```

Threading module in Python

functions as threads

```
def countdown(count):
      while count > 0:
          count -= 1
          time.sleep(5)

t1 = threading.Thread(target=countdown, args=(10,))
t1.start()
```

Lets See An Example

A Trivial Example

Lets do all the work **without** Threading

```
TOTAL_WORK = 10000000

def countdown(count):
    while count > 0:
        count -= 1

start = time.time()
countdown(TOTAL_WORK)  # Single Thread Execution
print(end - start)
```

- An Example by David Beazley

A Trivial Example

Lets do all the work **with** Threading

```
TOTAL_WORK = 10000000

def countdown(count):
     while count > 0:
          count -= 1

thread1 = threading.Thread(target=countdown, args=(TOTAL_WORK/2,))
thread2 = threading.Thread(target=countdown, args=(TOTAL_WORK/2,))

start = time.time()
thread1.start(); thread2.start()
thread1.join(); thread2.join()
end = time.time()

print(end - start)
```

Which one would be Faster?

All the work done sequentially ?

or

All the work divided in Two Threads?

All the work done sequentially took:
0.632690191269

All the work divided in Two Threads took:
0.91114282608

If **two people** divide a work, shouldn't it be faster than a **single person** doing all the work?

Lets Talk About GIL Now!

Global Interpreter Lock

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- The GIL ensures that only one thread runs in the interpreter at once.

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Global Interpreter Lock

- The GIL ensures that only one thread runs in the interpreter at once.
- So, any time a thread is forced to wait, other "ready" threads get their chance to run.
- Whenever a thread runs, it holds the GIL

Processes

- I/O Bound:

  processes which are associated with input/output based activity like reading from files,etc.

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- I/O Bound:

  processes which are associated with input/output based activity like reading from files,etc.

- CPU Bound

  processes which spends the majority of its time simply using the CPU (doing calculations)

GIL Behaviour

For I/O Bound:

GIL is released on blocking I/O

GIL Behaviour

For CPU Bound:

Interpreter periodically performs a “check”,
every 100 interpreter "ticks"

Before Python 3.2

Tick?

- Roughly stated, a tick corresponds to a **Python bytecode operation**.
- For the most part that's true, however there are certain bytecode instructions that do not qualify as whole ticks.
- Ticks are **uninterruptible**. e.g. `>>> x in range(10^6)`
- The interpreter will not thread switch in the middle of a tick.

Why GIL?

Why GIL?

- Simplified implementation
- Easy to write C Extensions
- No Deadlocks!
- Works for I/O Bound processes!

Memory Management in Python

Reference Counting

`sys.getrefcount`

Reference Counting

`Py_INCREF()`

`Py_DECREF()`

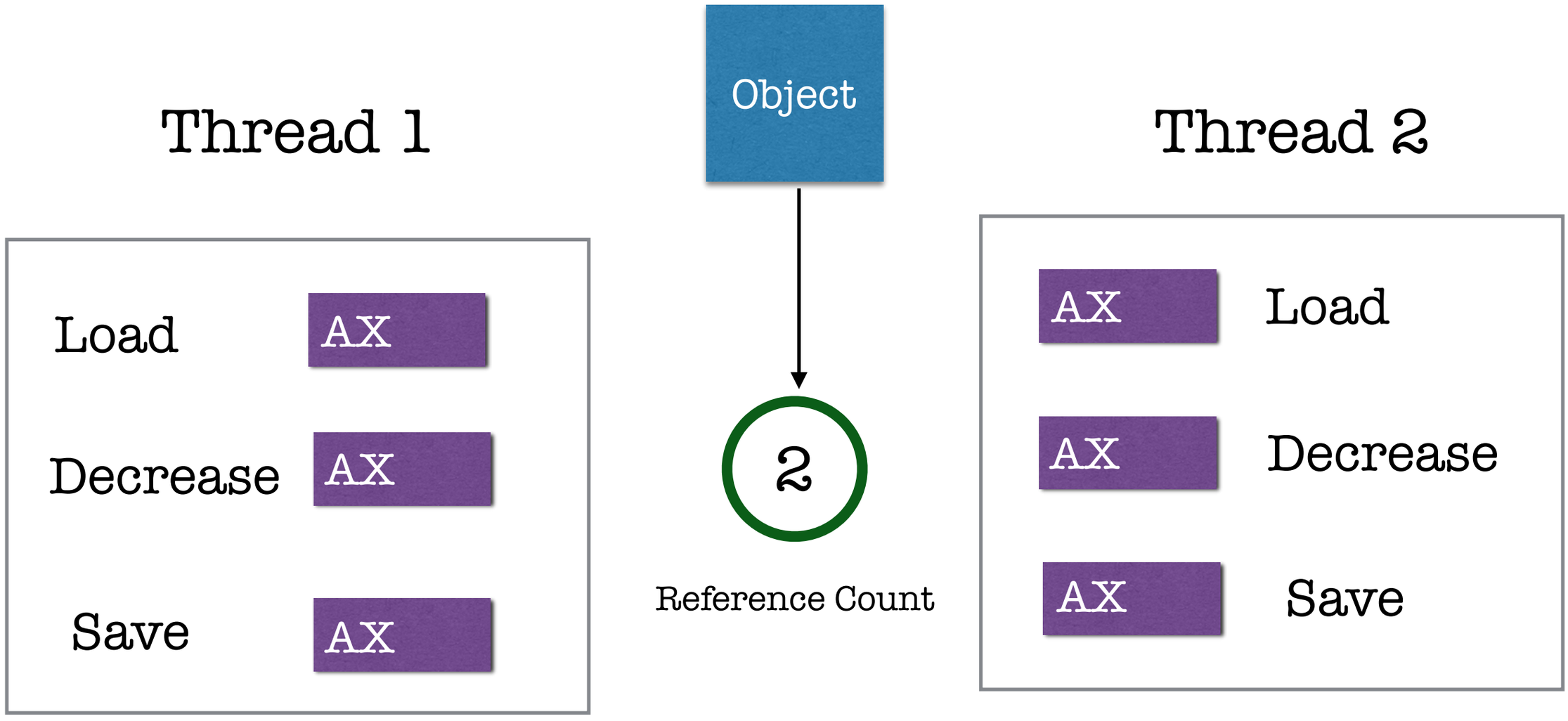
Methods in Python/C API

Reference Counting With Threads

Lets See an Example!

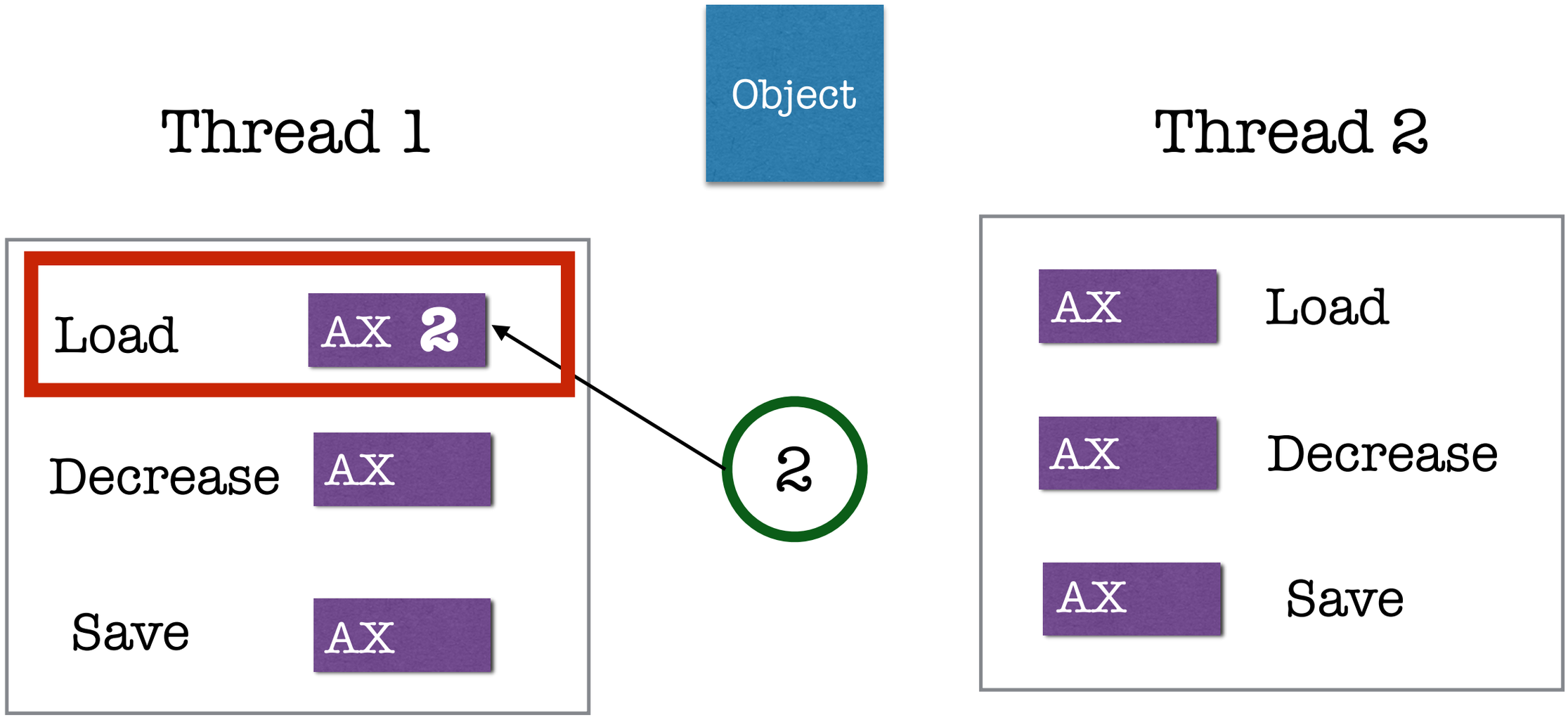
Py_DECREF()

Reference Counting With Threads



AX stands Accumulator Register: used in arithmetic operations

Reference Counting With Threads



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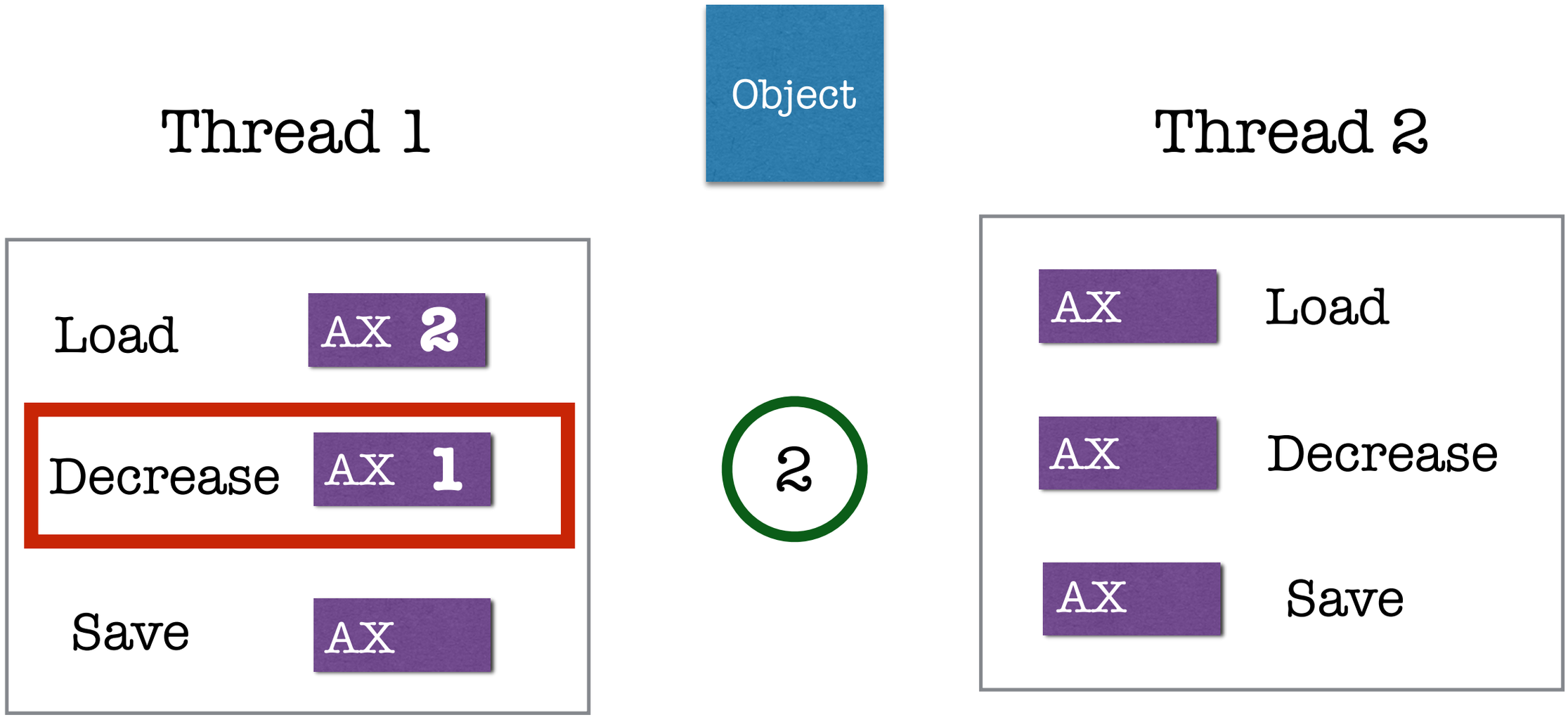

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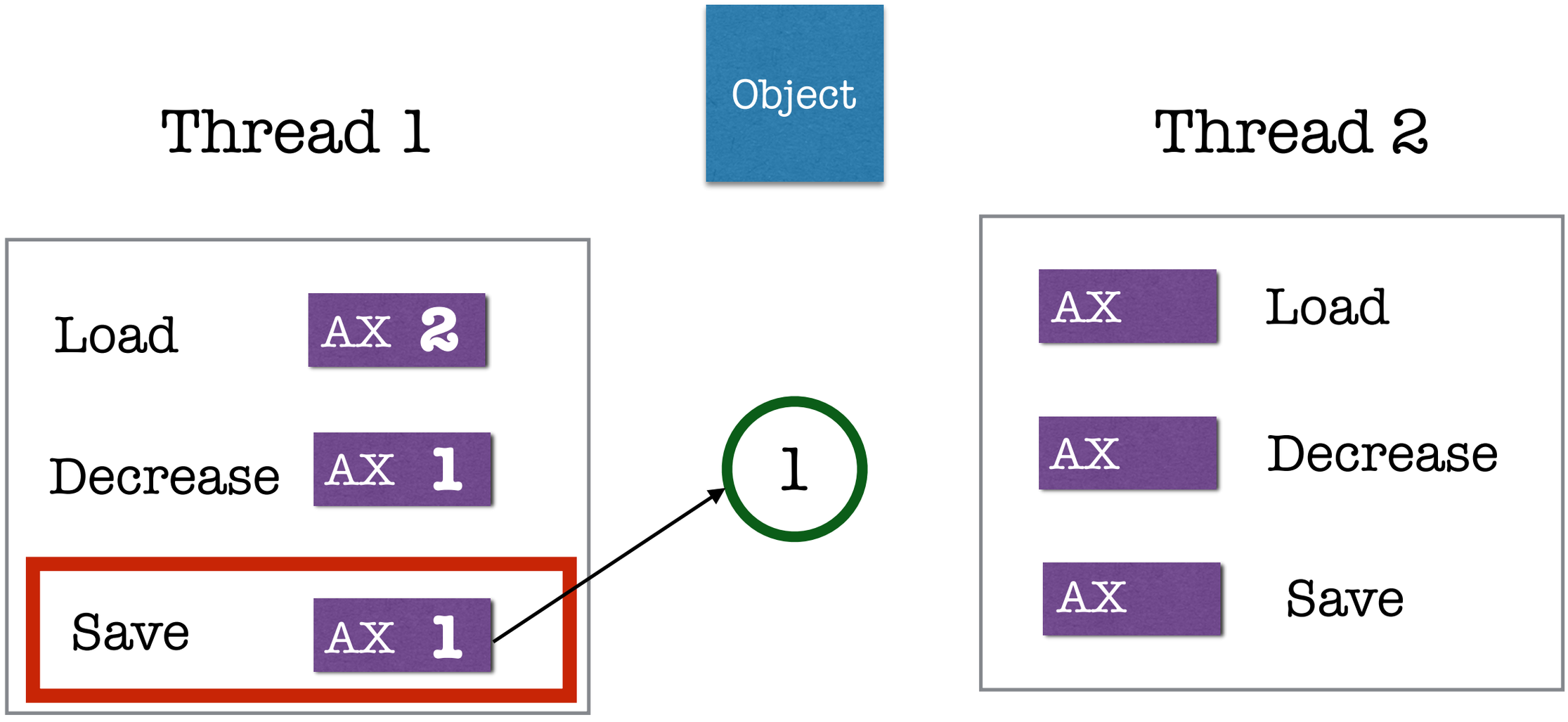

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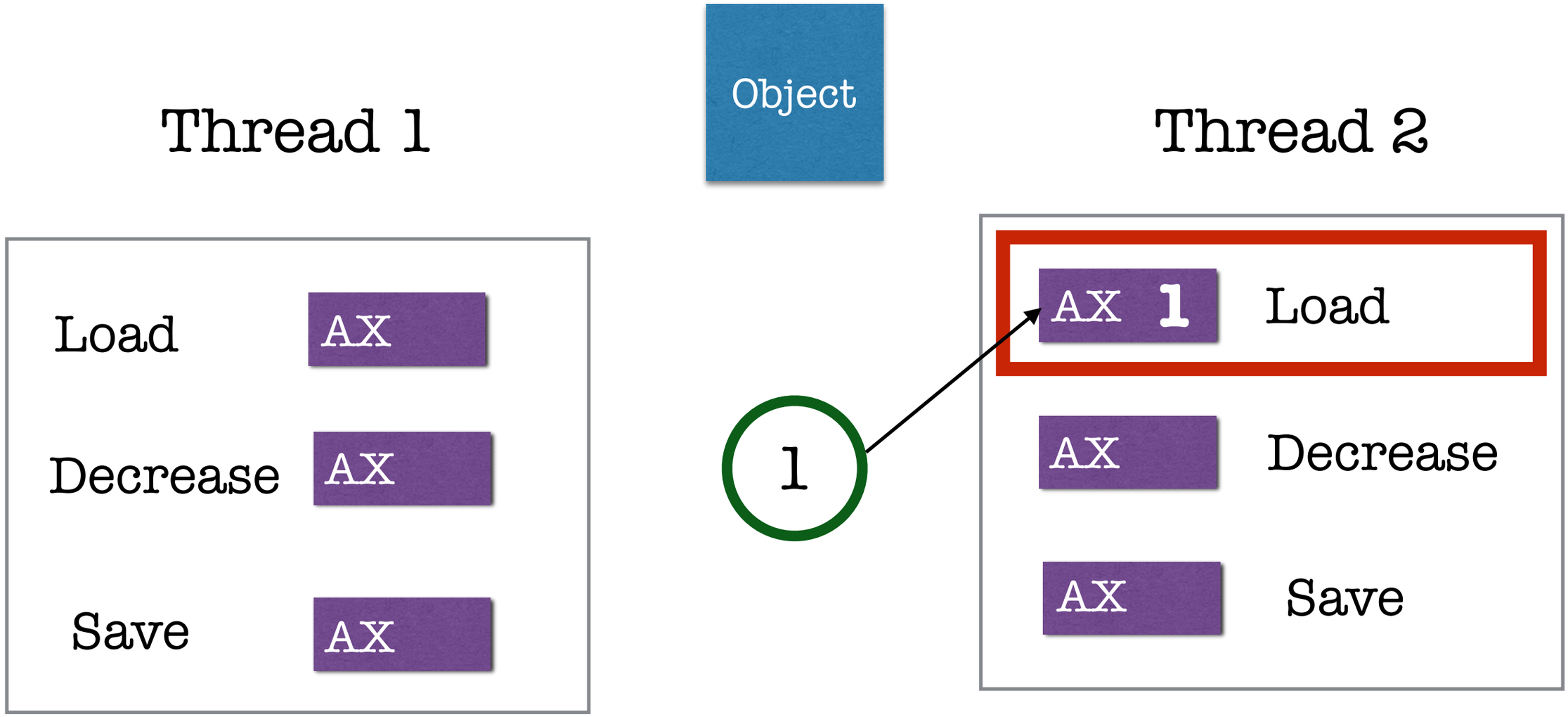

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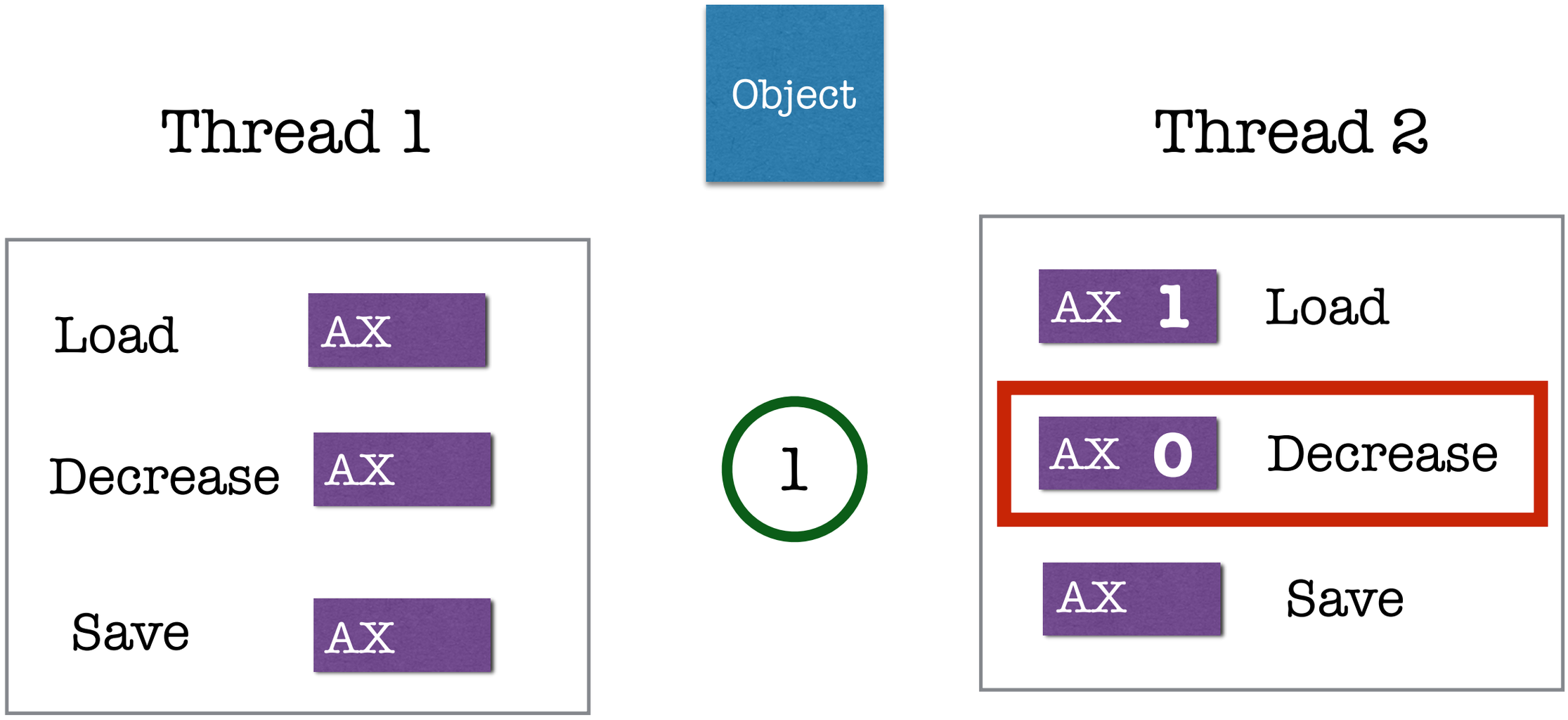

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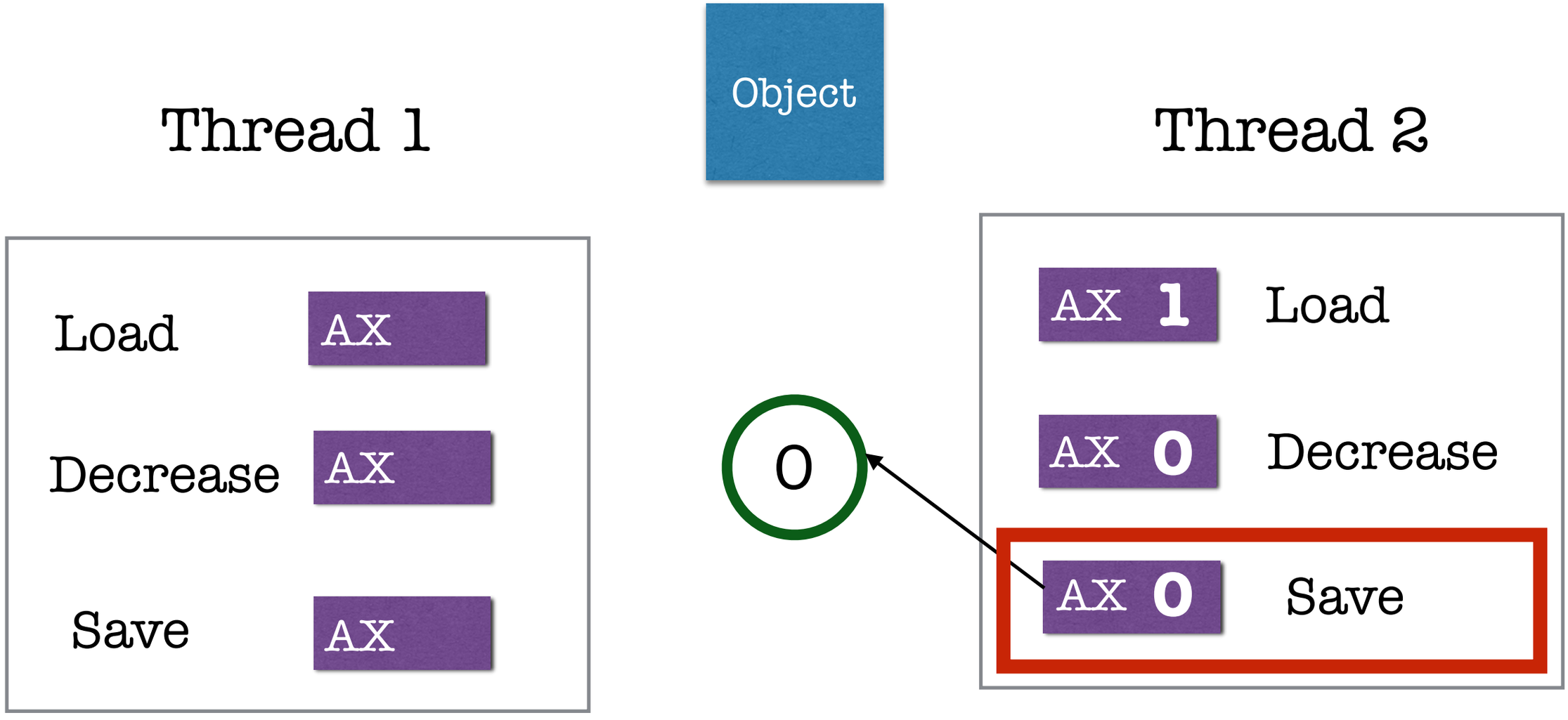

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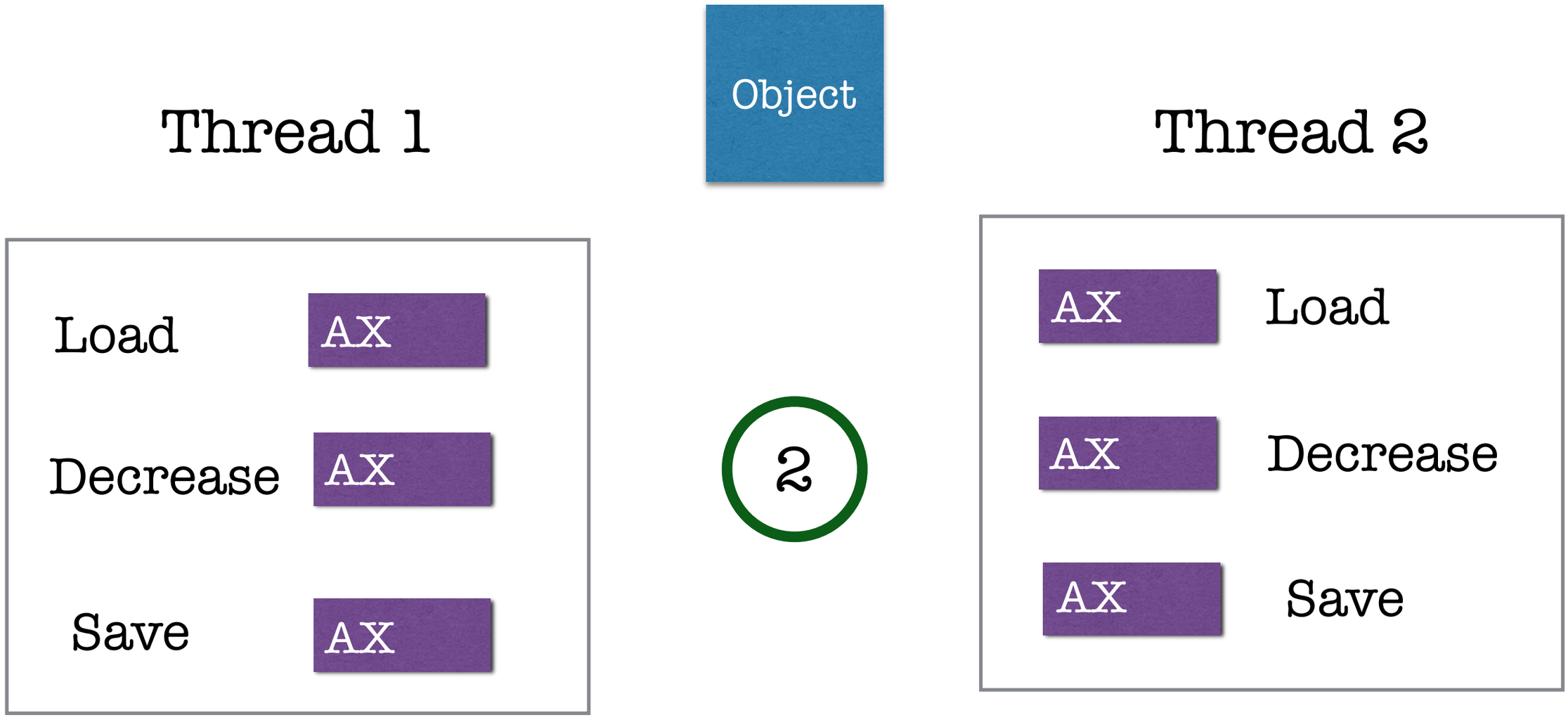

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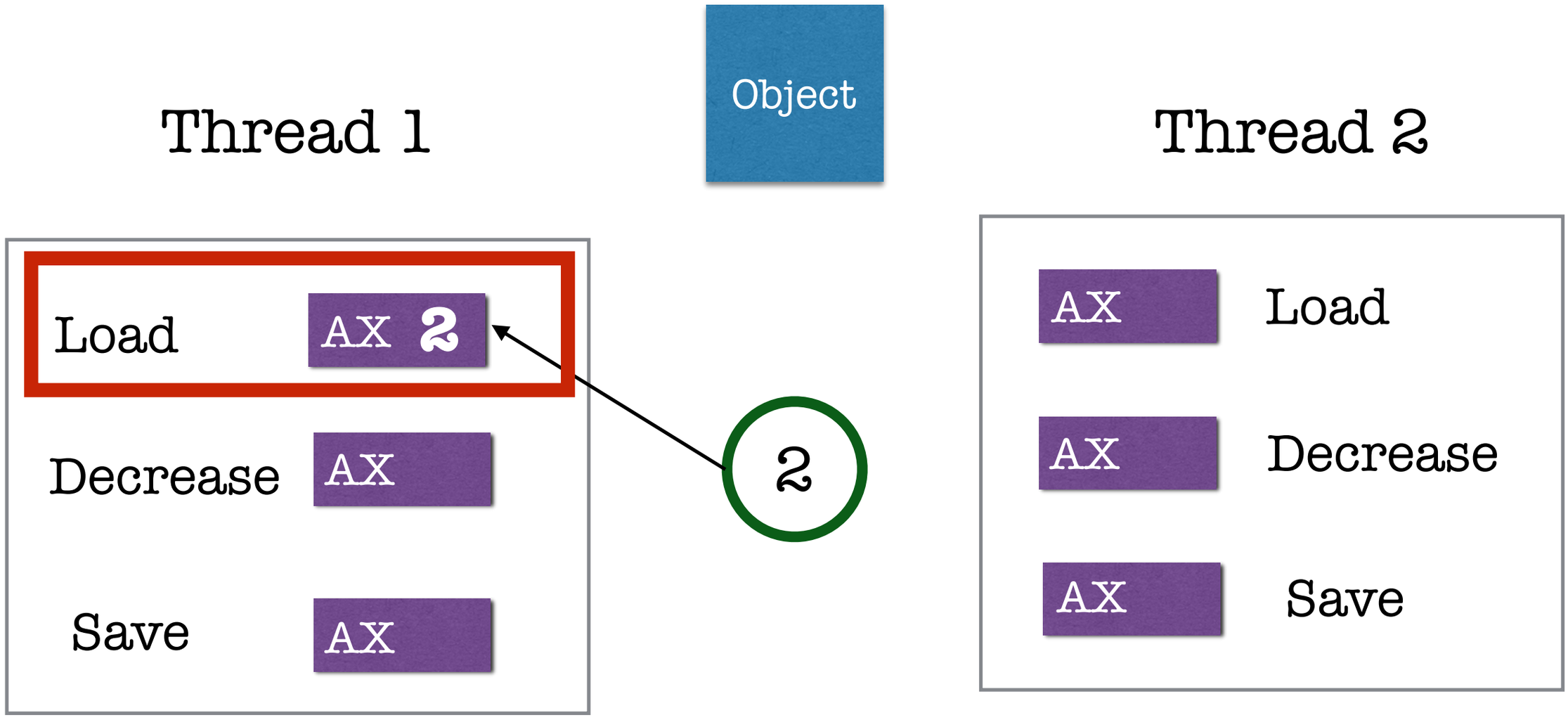

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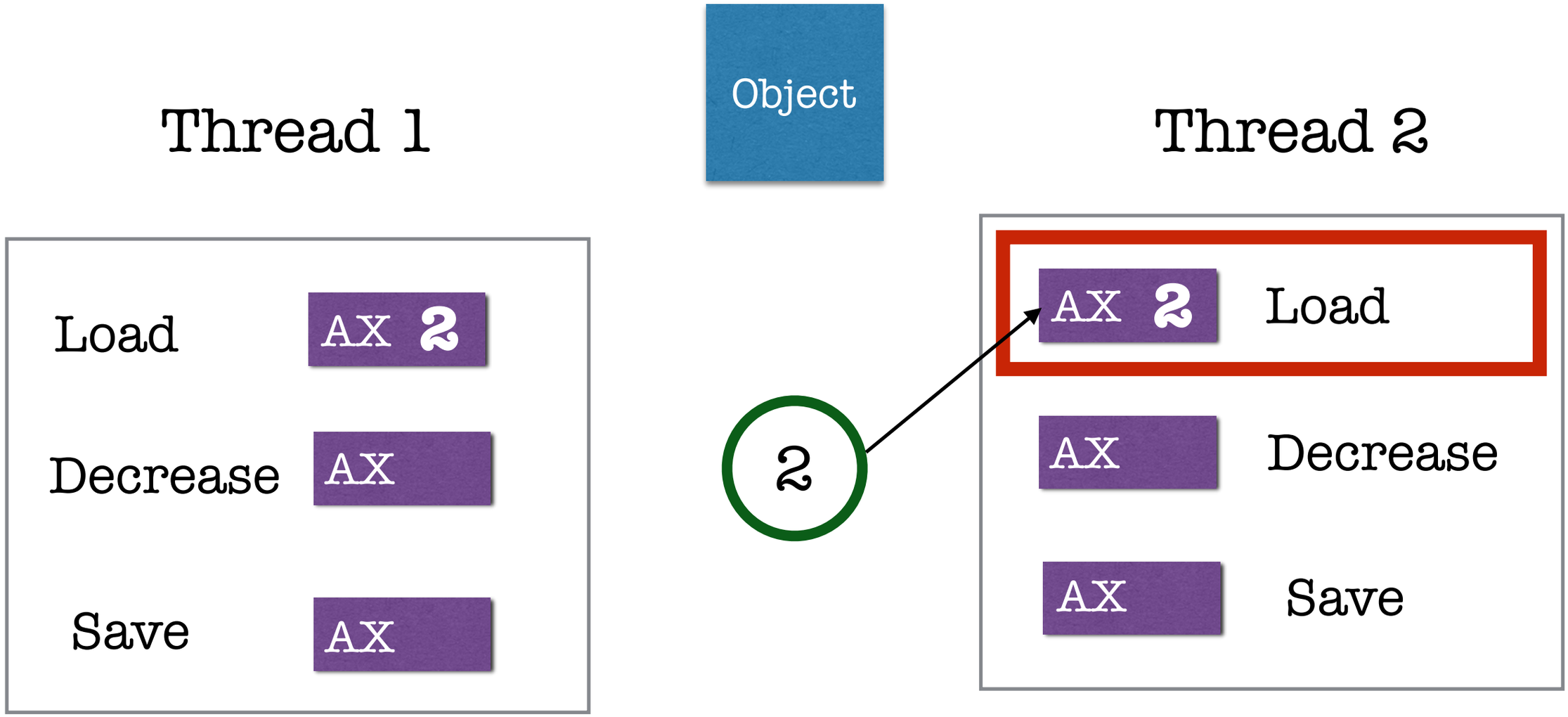

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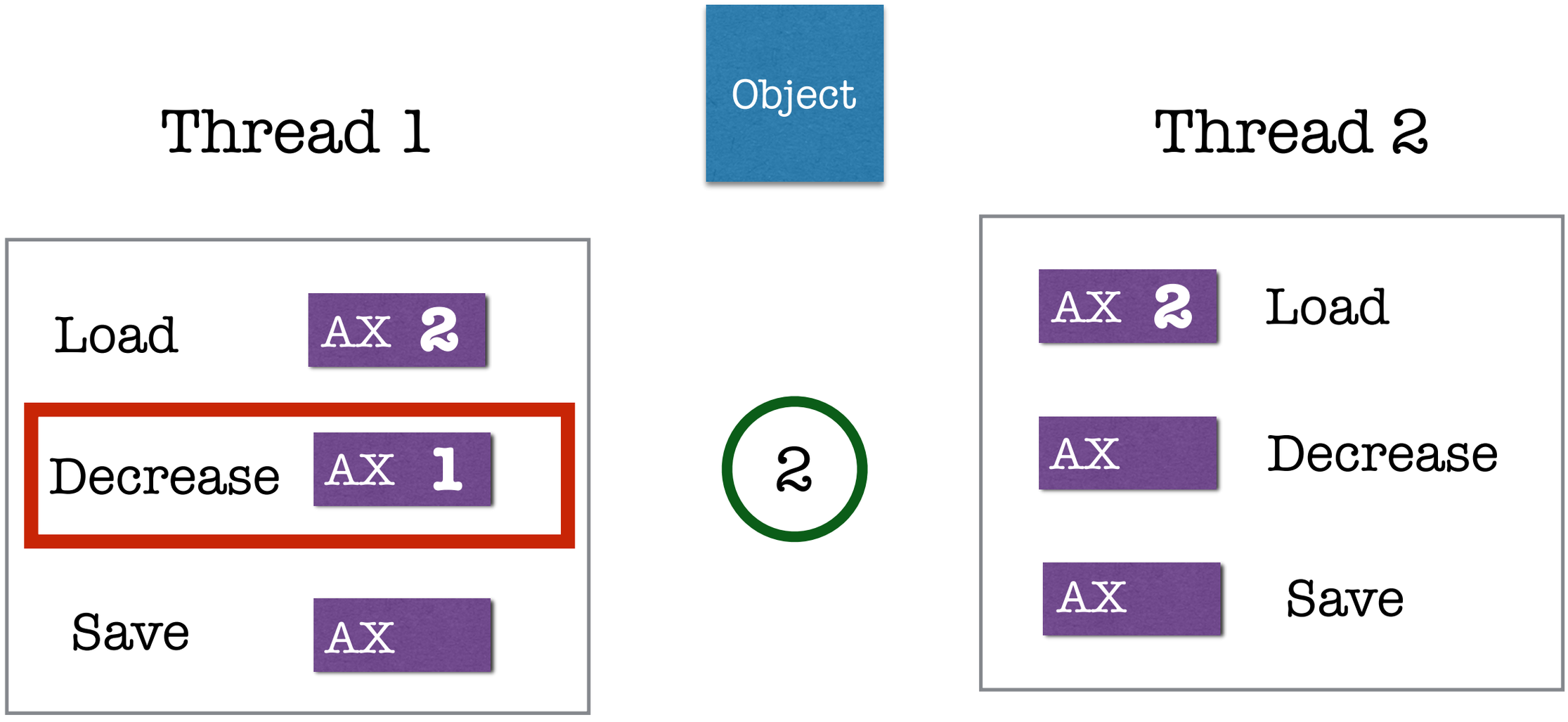

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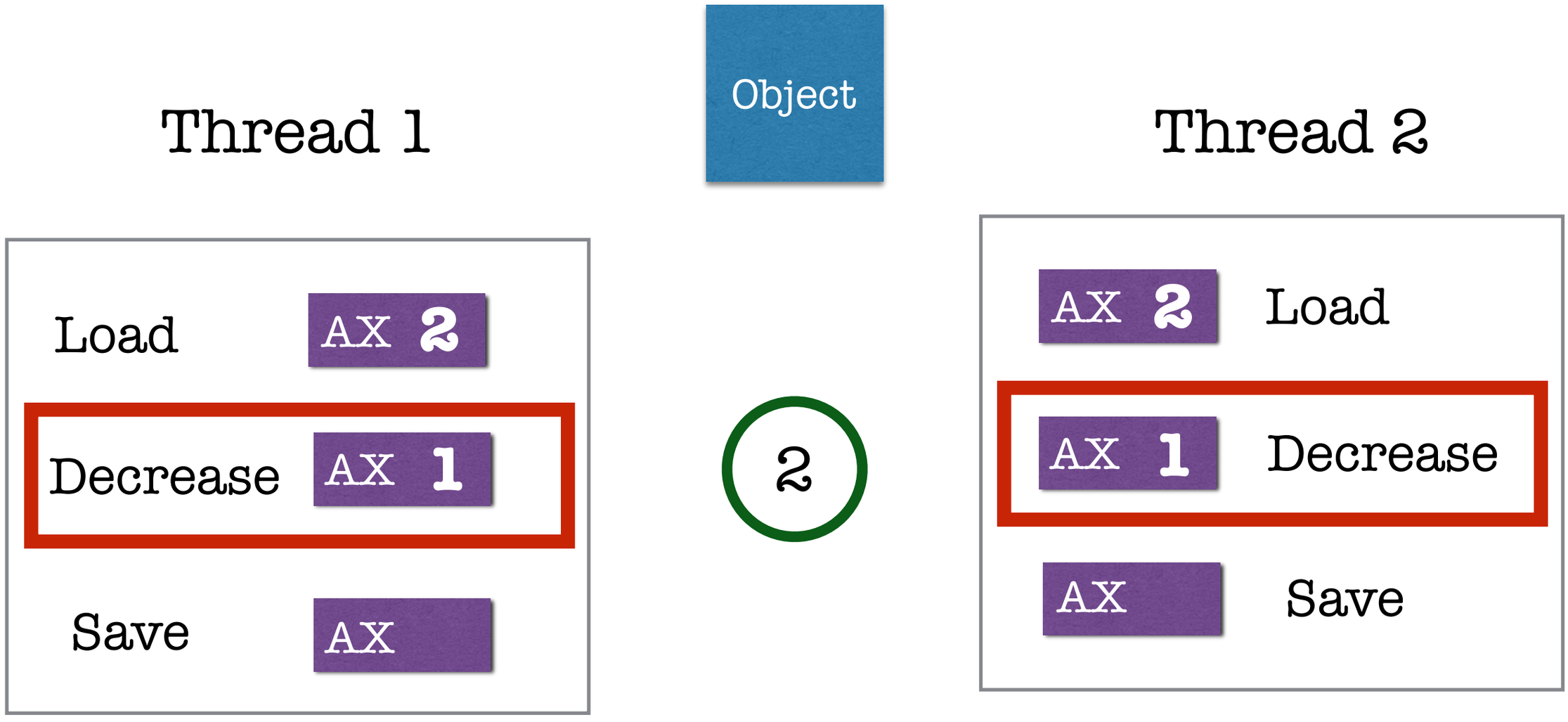

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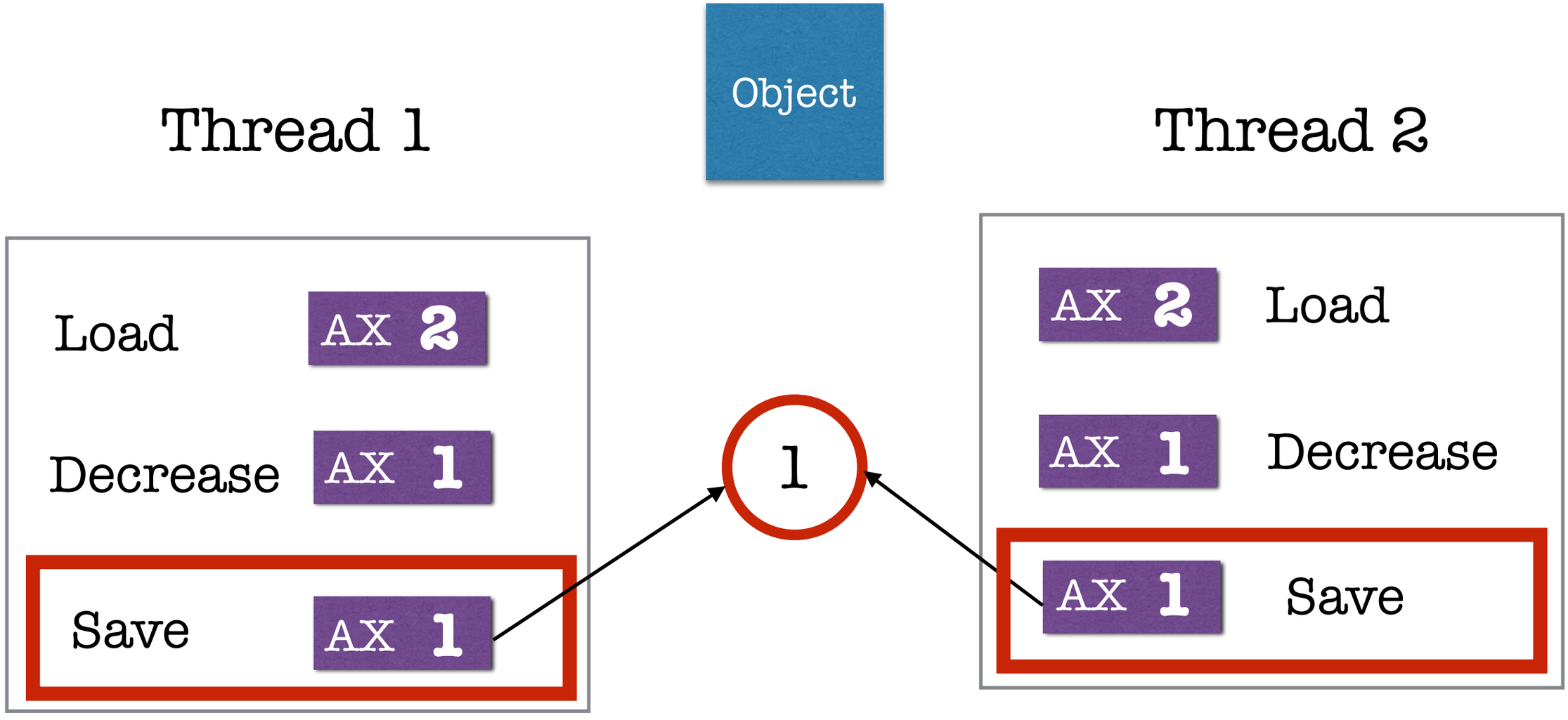
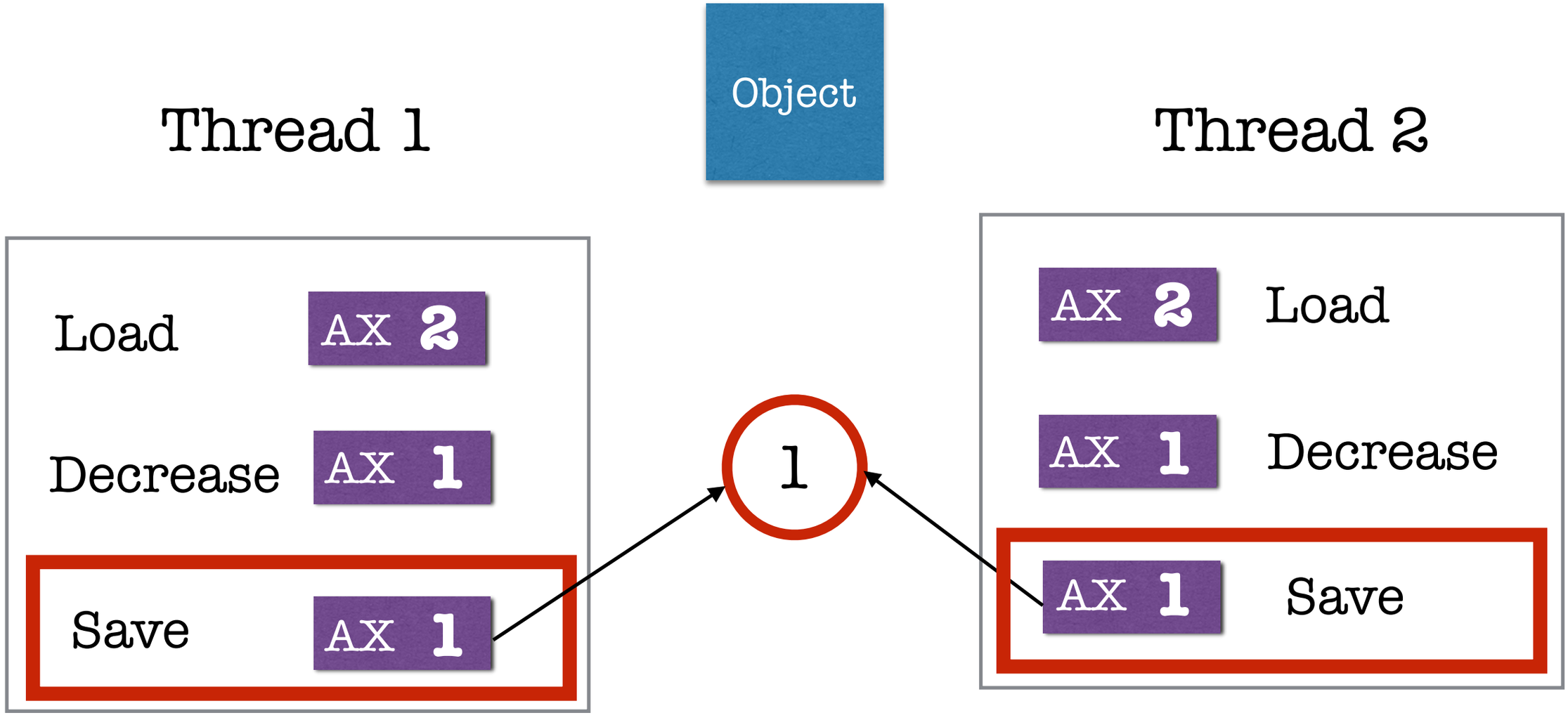


Should have been 0, isn't it?

Reference Counting With Threads



Memory Leak!

Utilising Multiple Cores

alternative approaches

Utilising Multiple Cores

Utilising Multiple Cores

- Process based concurrency

Utilising Multiple Cores

- Process based concurrency
- C Extensions

Utilising Multiple Cores

- Process based concurrency
- C Extensions
- Cython

C-Extensions

Extending Python with C or C++

C-Extensions

Releasing the GIL from extension code

Save the thread state in a local variable.

Release the GIL

... Do some blocking I/O operation ...

Reacquire the GIL

Restore the thread state from the local variable.

C-Extensions

`Py_BEGIN_ALLOW_THREADS`

..Don't Talk to CPython Interpreter..

`Py_END_ALLOW_THREADS`

C-Extensions

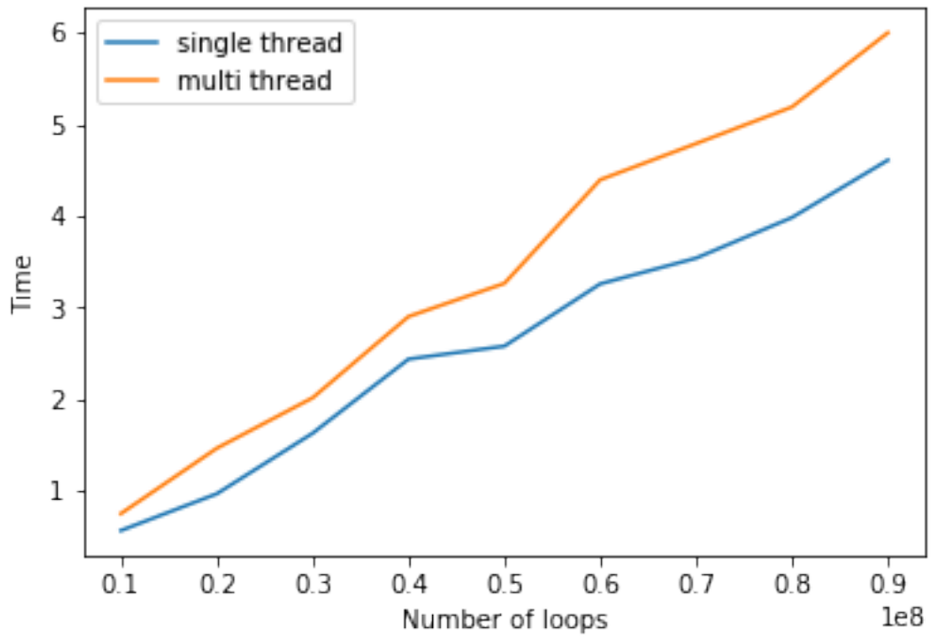
Example Demo

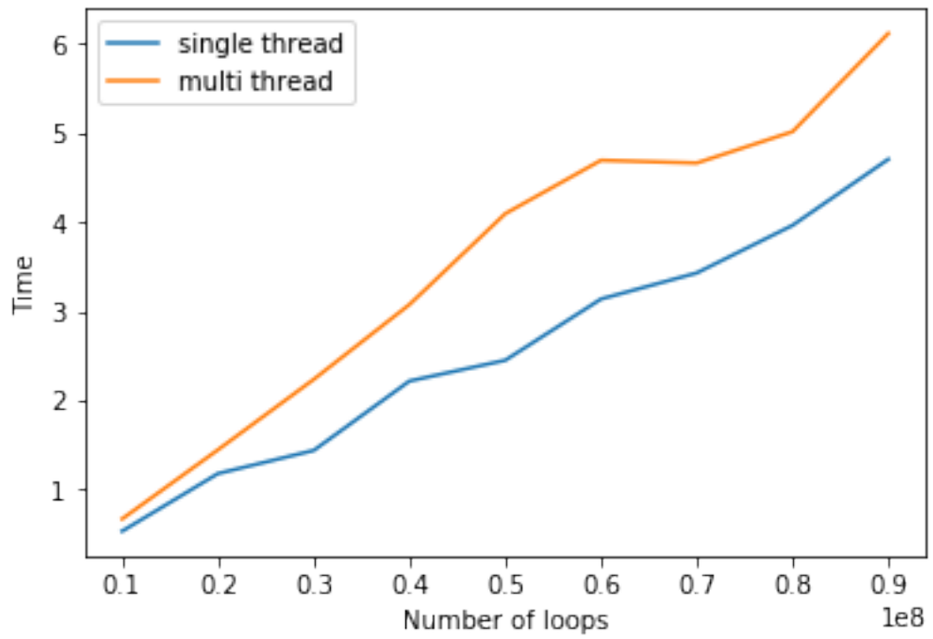
Threading in Python

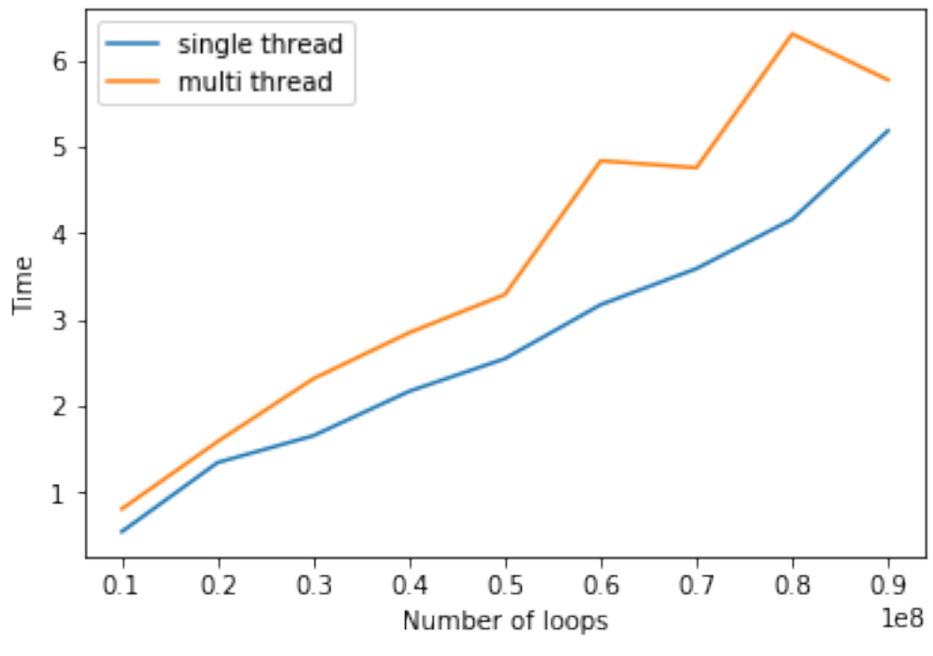
Lets see some Visualisations

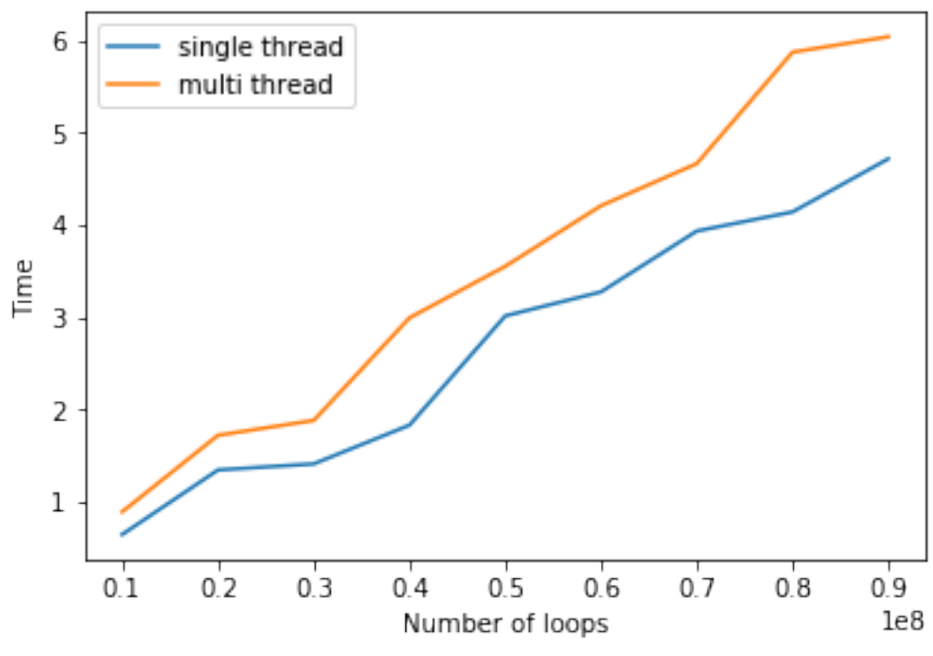
Benchmarked on:
MacBook Air (13-inch, Early 2015)
1.6 GHz Intel Core i5
4 GB 1600 MHz DDR3

Threading in Python









Threading with C-Extensions

Lets see some Visualisations

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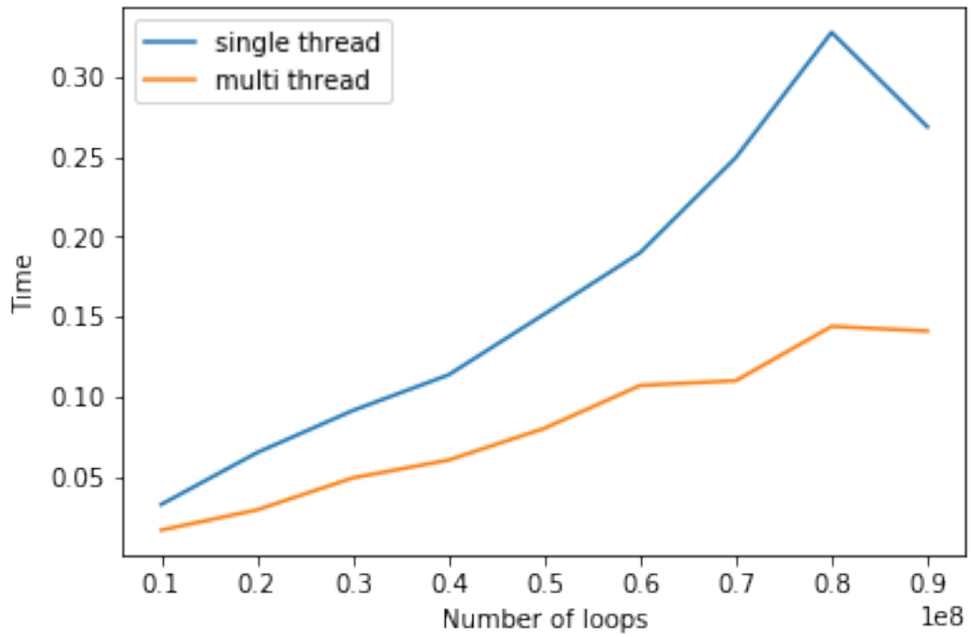
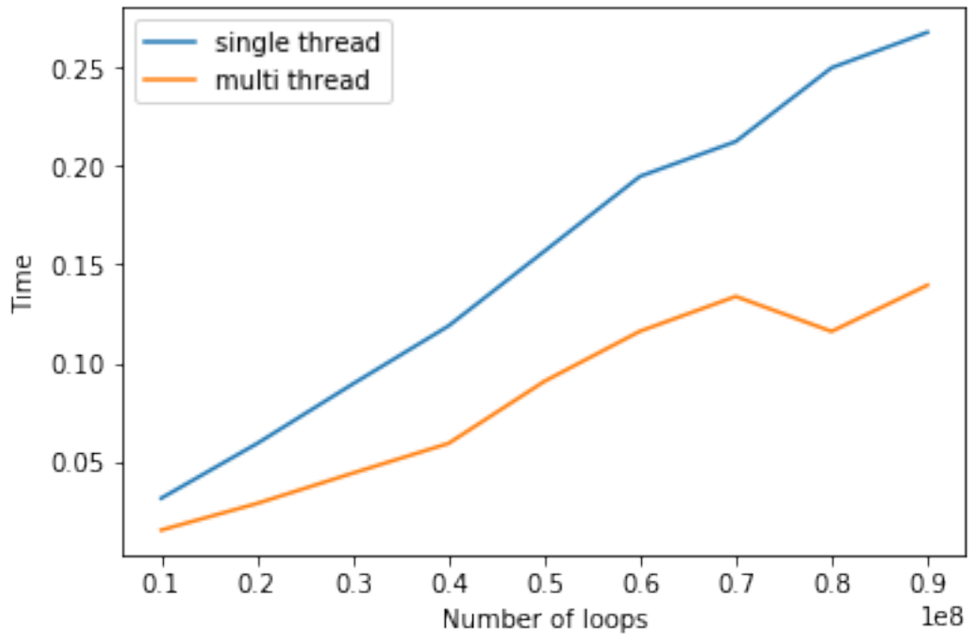
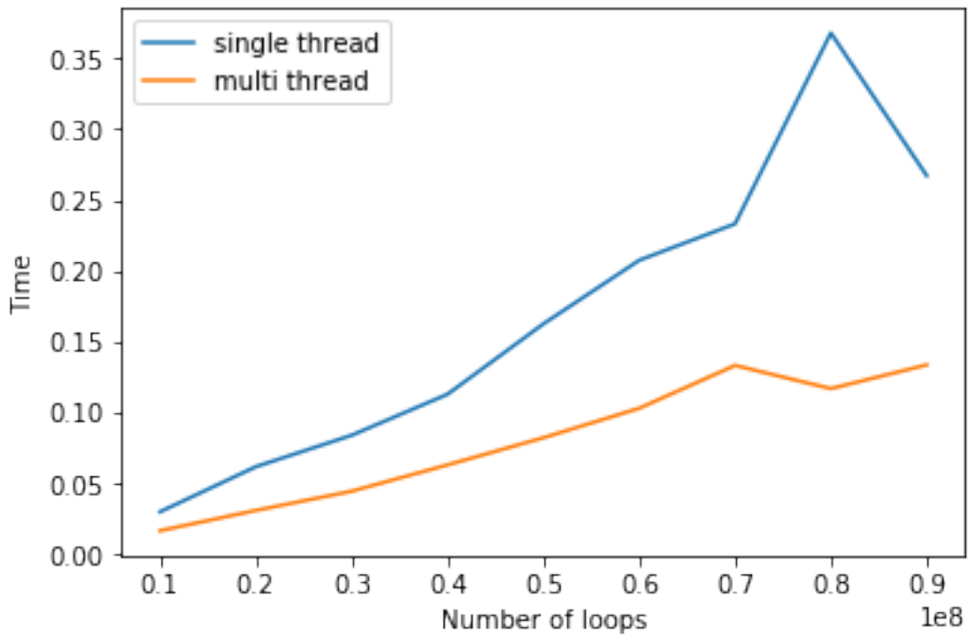
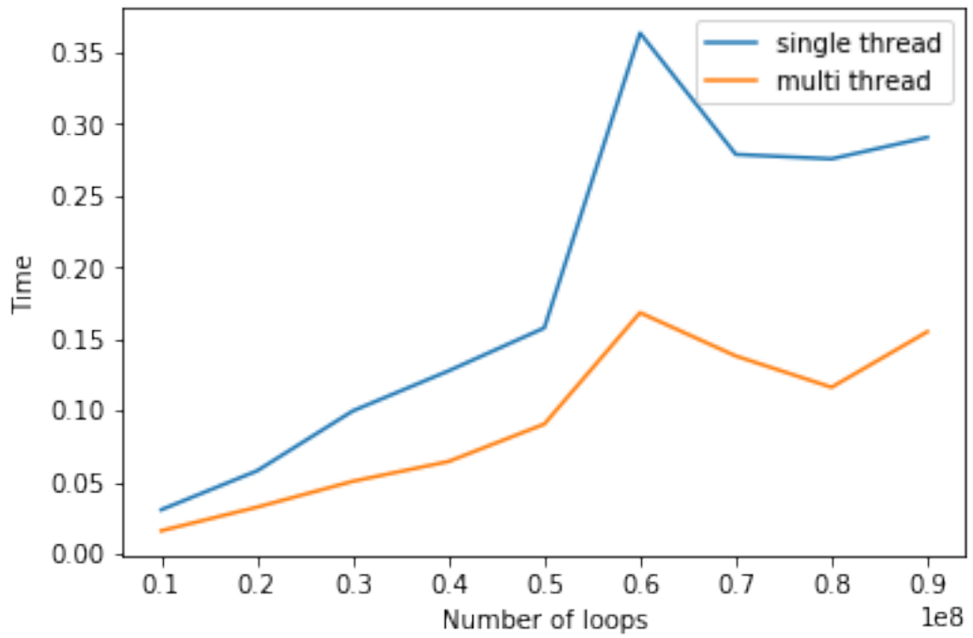
Threading with C-Extensions









Guido on GIL

I'd welcome a set of patches into Py3k only if:

- performance for a **single-threaded** program and
- for a multi-threaded but **I/O-bound** program

does NOT decrease.

The Famous GIL Removal Patch

The Famous GIL Patch of Greg

Idea: Each thread has to isolate its interpreter state and not rely on C global variables.

- moved into a **per-thread data structure**.

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The Famous GIL Patch of Greg

Idea: Each thread has to isolate its interpreter state and not rely on C global variables.

- moved into a **per-thread data structure**.
- patch introduces a **global reference-counting mutex lock**
- Mutable builtins such as lists and dicts need their **own locking** to synchronise modifications.

The Famous GIL Patch of Greg

patch made the performance of single-threaded applications much worse

The Famous GIL Patch of Greg

patch made the performance of single-threaded applications much worse

so much so that the patch couldn't be adopted.

The New Gil

The New Gil

by Antoine Pitrou

Since Python 3.2

The New Gil

Earlier:“ticks" based

Now: time based

The New Gil

Benefits:

- new GIL allows a thread to run for 5ms regardless of other threads
- Eliminates the Battle for GIL
- Eliminates Excessive Thrashing/Context Switching

References:

https://docs.python.org/3/whatsnew/3.2.html#multi-threading
https://mail.python.org/pipermail/python-dev/2009-October/093321.html

References

- http://www.dabeaz.com/GIL/
- Larry Hastings - Python's Infamous GIL
- Brett canon on GIL
- Nick Coghlan’s utilising multiple cores
- Raymond Hettinger on Concurrency
- Python C API docs

Thank You!

Github: @aktech **Twitter**: @**i**aktech

http://iamit.in