Introduction to Non-Blocking Algorithms

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Concurrent Non-Blocking Algorithms

- Concurrent: Several threads can execute the algorithms simultaneously.
- Blocking algorithms: Algorithms for which processes may isolate or block part of the data-structure to access it without interference. May cause deadlocks.
- Non-blocking algorithms: They ensure that the data-structure is always accessible to all processes. Independent from other halted/delayed processes.

Compare and swap (CAS)

- **Atomic** instruction available on most processors.
- Most common building block for non-blocking algorithms.
- Available in Java
  AtomicInteger.compareAndSet(int,int) -> bool

- If the memory is equal to some expected value (compare) then set the memory to a new value.

- Intel:
  cmpxchg r/m, r (needs lock prefix)

  if eax == r then r/m = r, ZF=0
  else eax = r/m, ZF=1

Other Atomic Instructions (Intel)

- Increment.
  (lock inc r/m)
- Decrement.
  (lock dec r/m)
- Exchange.
  (xchg r/m, r)
- Fetch and add.
  (lock xadd r/m, r)
- They can be used to implement simple and efficient synchronizations primitives.

Non-Blocking Algorithms

- The key:
  - Try to compute speculatively.
  - CAS before committing the result.
  - Retry if CAS fails.

- Good practice:
  - Work with a state-machine.
  - Every state must be consistent.
  - States = committed (intermediate) results.

Non-Blocking Counter

Standard blocking algorithm

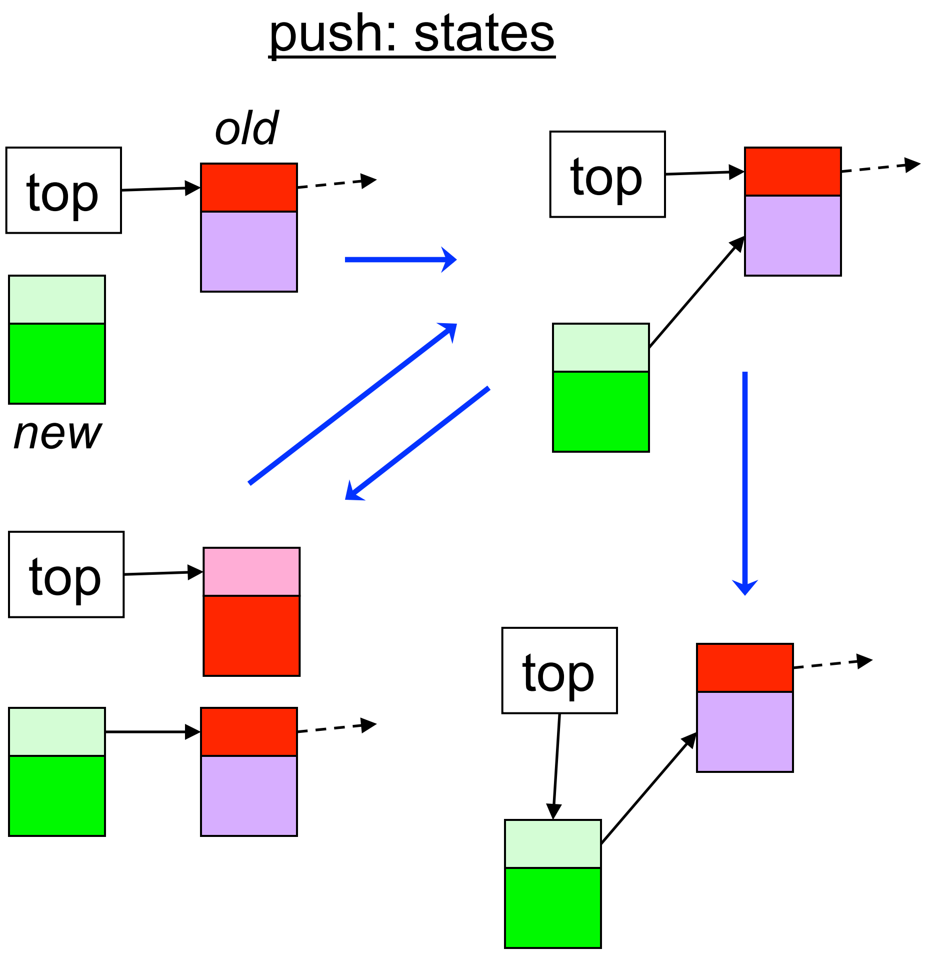
```
proc inc(A)
lock
  tmp = A
  tmp = tmp+1
  A = tmp
unlock
end
```

Non-blocking algorithm

```
proc inc(A)
do
  tmp = A
while not CAS(A, tmp, tmp+1)
end
```

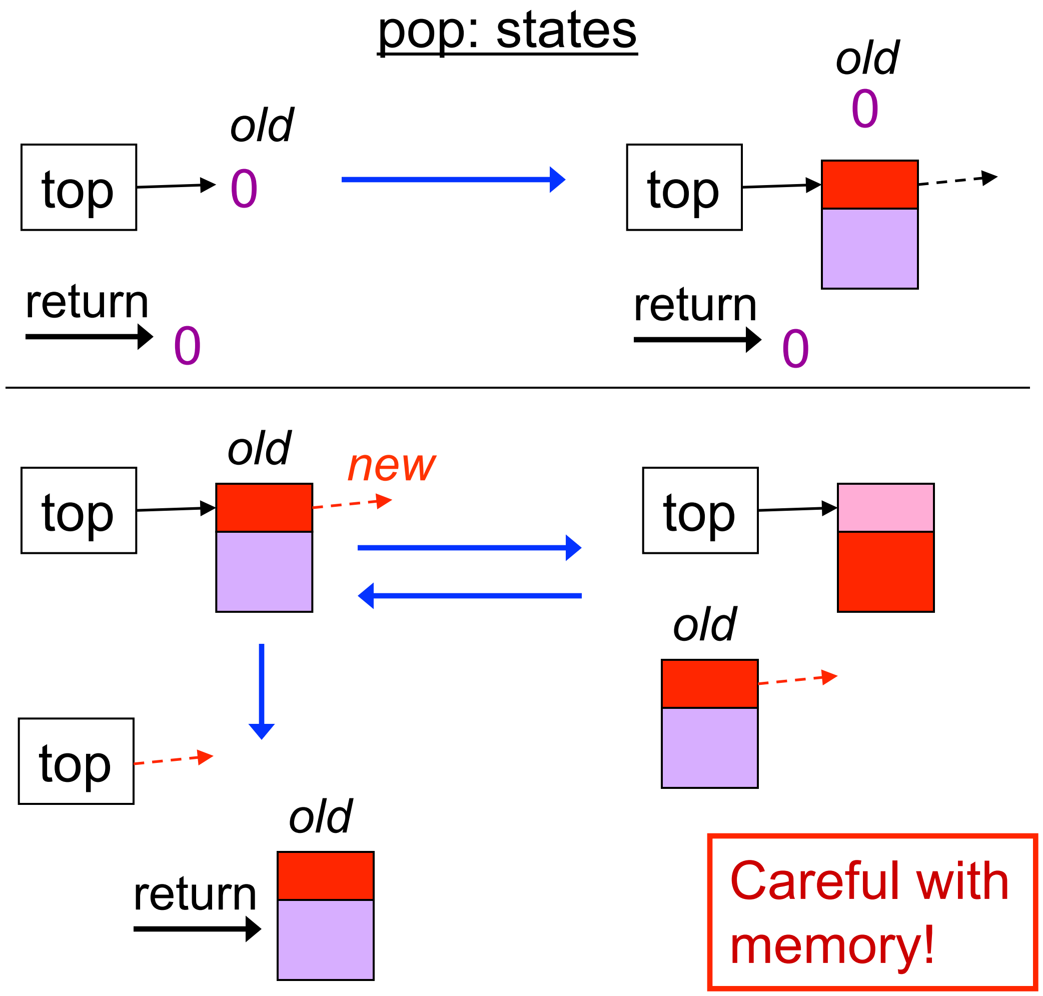
Non-Blocking Stack [Treiber's Algorithm]

```
proc push(new)
do
  old = top
  new.next = old
while not CAS(top, old, new)
end

proc pop
do
  old = top
  return null if old == null
  new = old.next
while not CAS(top, old, new)
return old
end
```



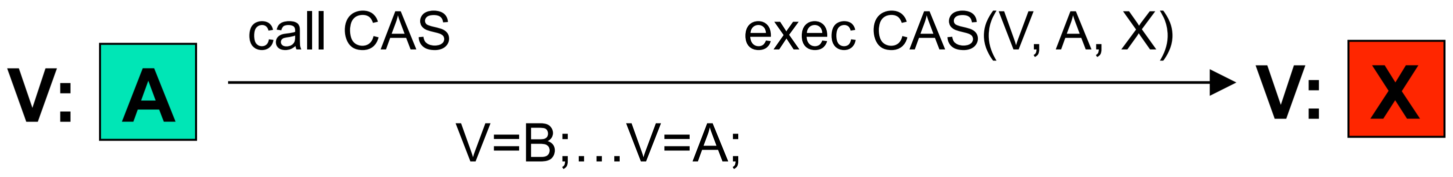
Non-Blocking Stack [Treiber's Algorithm]

```
proc push(new)
do
  old = top
  new.next = old
while not CAS(top, old, new)
end

proc pop
do
  old = top
  return null if old == null
  new = old.next
while not CAS(top, old, new)
return old
end
```



The ABA Problem

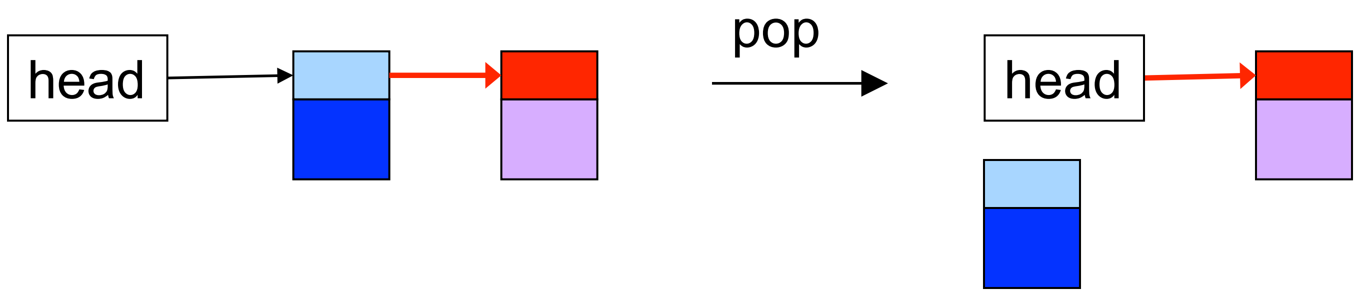
- Suppose that the value of V is A.
- Try a CAS to change A to X.
- Another thread can change A to B and back to A.
- The CAS won't see it and will succeed.
- Usual solution: Add a version number to V.



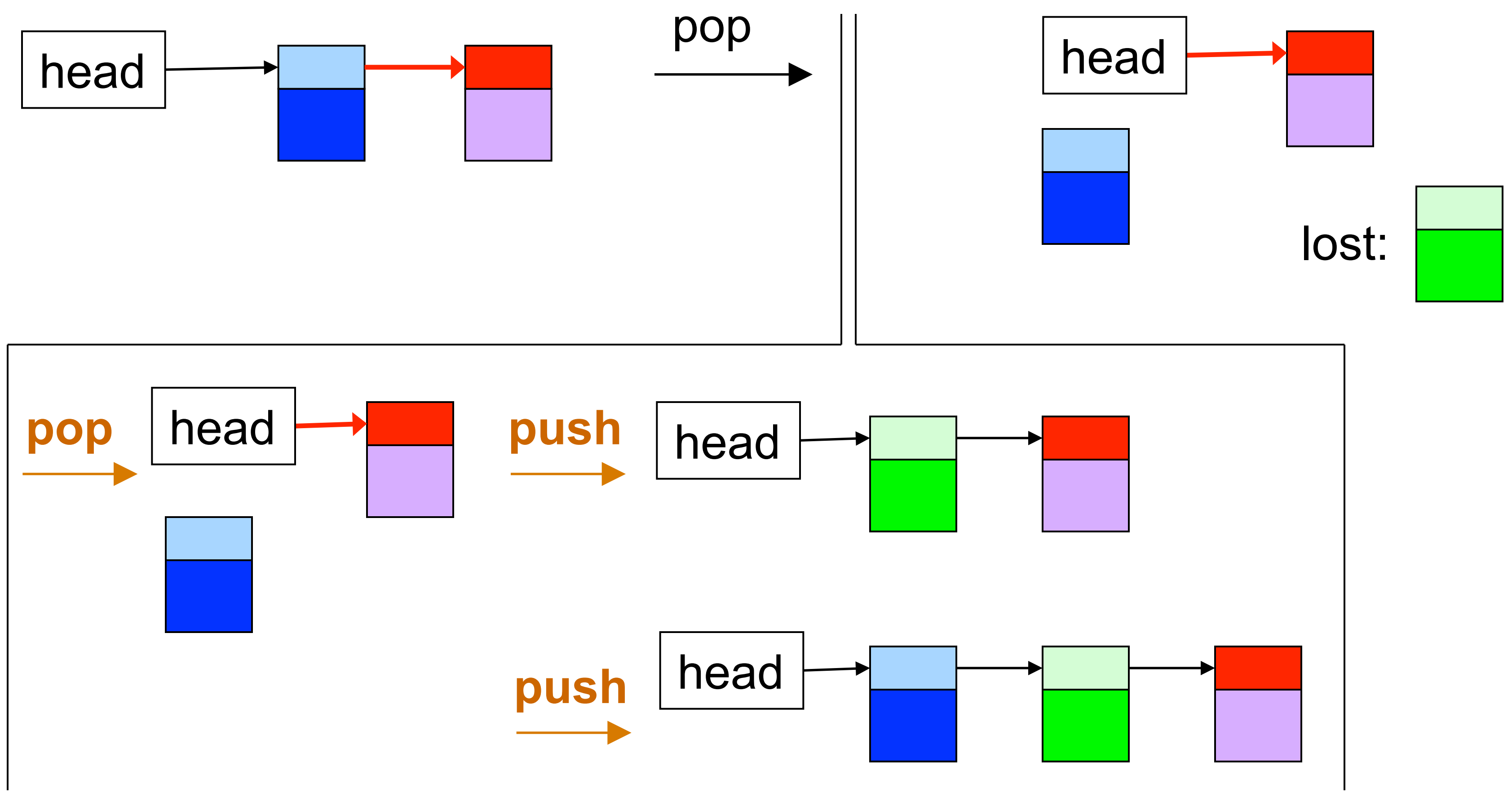
The ABA problem

- Some algorithms may suffer from it.
- Example: Linked list.

Expected behavior



The ABA problem



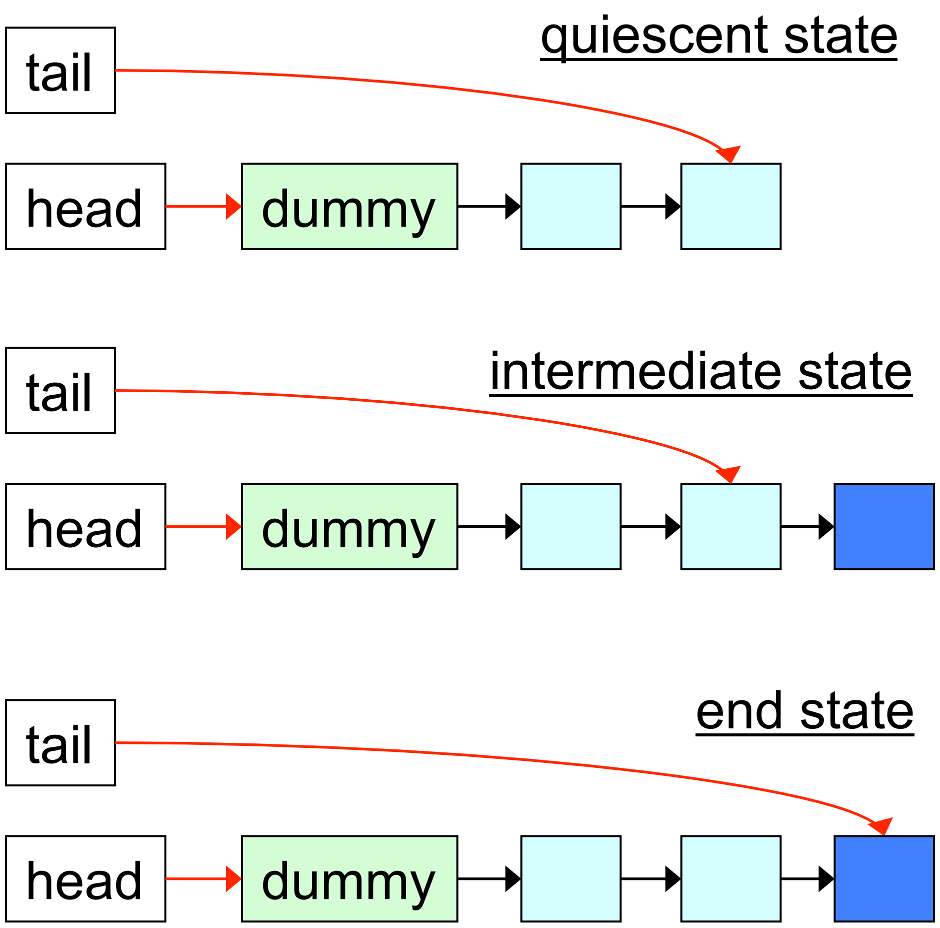
Fixes

- Reference counter (implicit in Java).
  - Allocation/de-allocation problems.
- Version number.
  - ABA problems.

Insertion in a Queue [Michael-Scott's Algorithm]

```
proc put(new)
do
    last = tail
    nxt = last.next
    if last == tail
        if nxt == null
            if CAS(last.next, null, new)
                CAS(tail, last, new)
                break
            fi
        else
            CAS(tail, last, nxt)
        fi
    fi
loop
end
```

ABA problem: use tags.


quiescent state
tail
head
dummy
intermediate state
tail
head
dummy
end state
tail
head
dummy