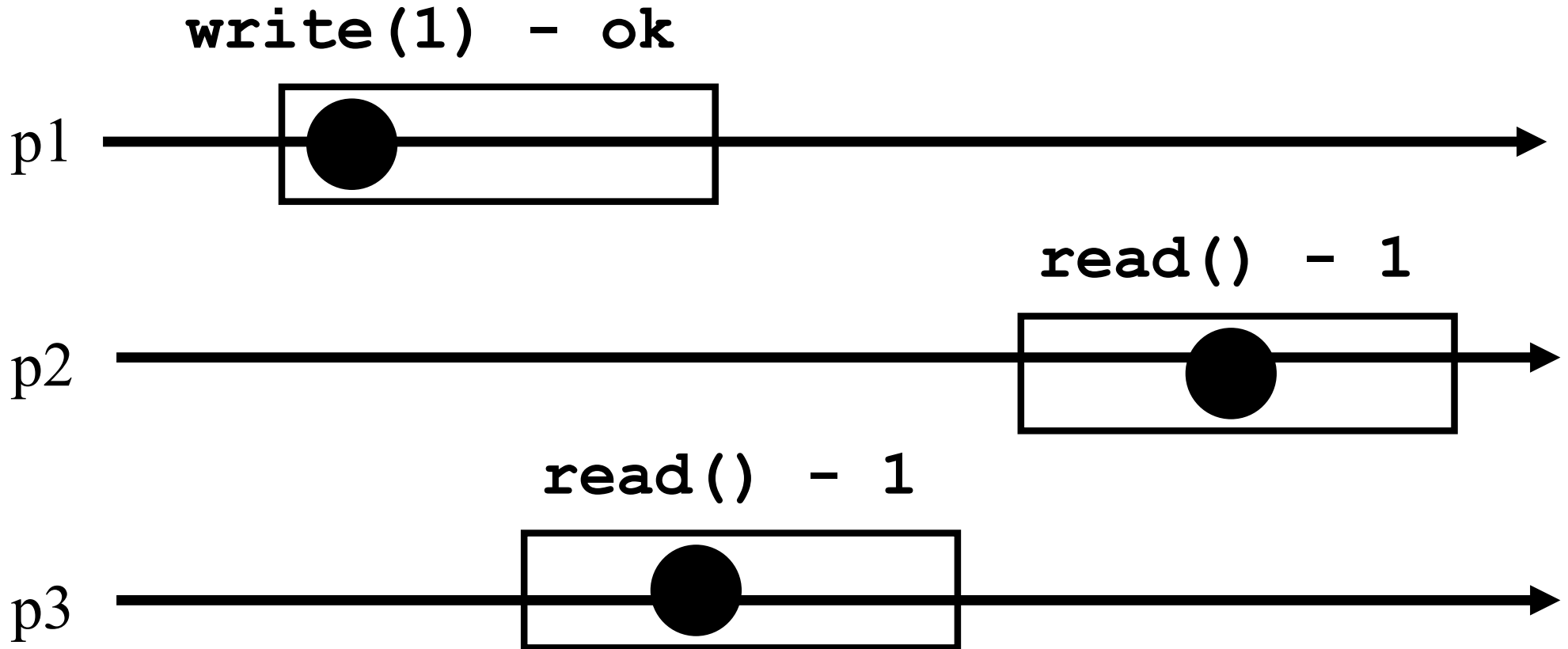


The Power of Registers

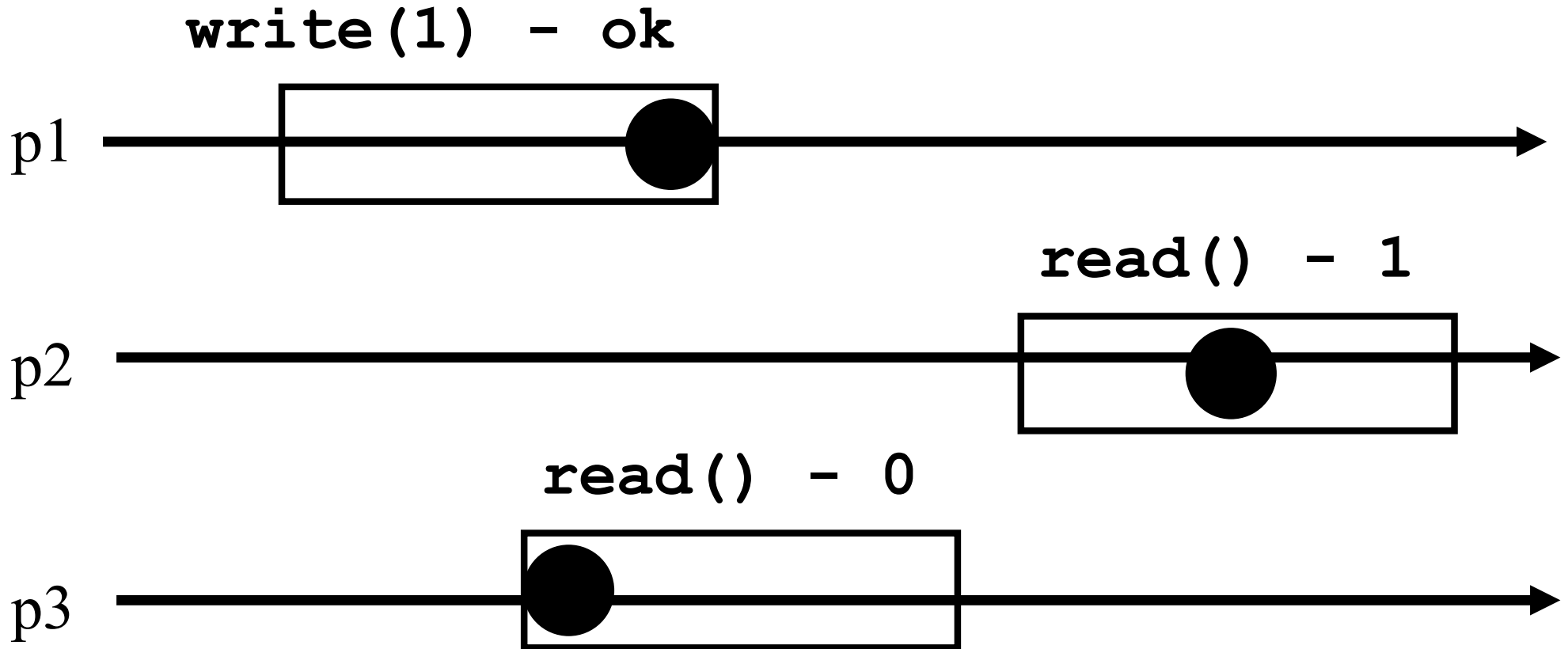
Prof R. Guerraoui
Distributed Programming Laboratory



Atomic execution



Atomic execution



Registers

- **Question 1:** what objects can we implement with registers?
- Question 2: what objects we cannot implement?

Wait-free implementations of atomic objects

- An object is defined by its sequential specification; i.e., by how its operations should be implemented when there is no concurrency: being **atomic** means preserving the sequential semantics
- Implementations should be ***wait-free***: every process that invokes an operation eventually gets a reply (unless the process crashes)

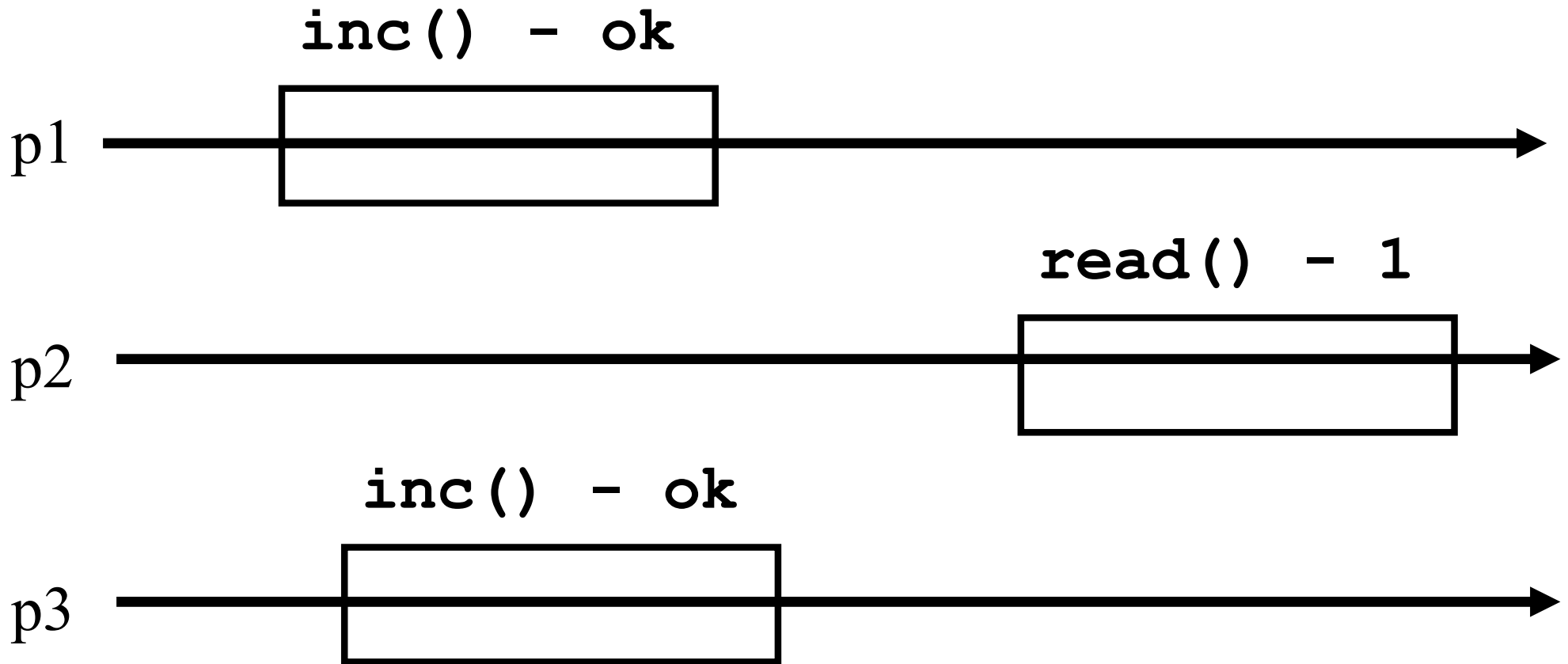
Counter (sequential spec)

- A ***counter*** has two operations ***inc()*** and ***read()*** and maintains an integer *x* *init to 0*
- ***read():***
 - return(x)
- ***inc():***
 - $x := x + 1;$
 - return(ok)

Naive implementation

- The processes share one register Reg
- ***read():***
 - return(Reg.read())
- ***inc():***
 - temp:= Reg.read()+1;
 - Reg.write(temp);
 - return(ok)

Atomic execution?



Atomic implementation

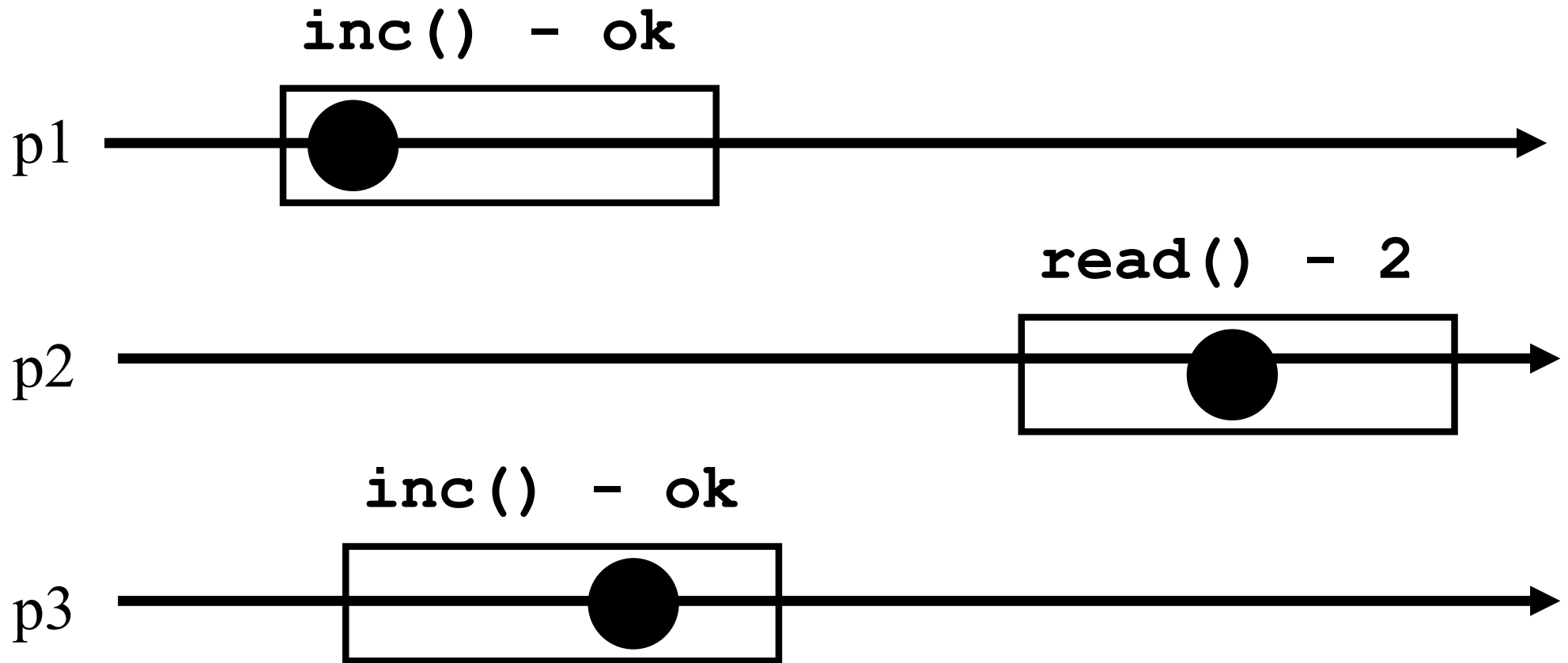
- The processes share an array of registers
Reg[1,...,N]
- ***inc()***:
 - Reg[i].write(Reg[i].read() + 1);
 - return(ok)

Atomic implementation

read():

- sum := 0;***
- for j = 1 to n do***
 - sum := sum + Reg[j].read();***
- return(sum)***

Atomic execution?



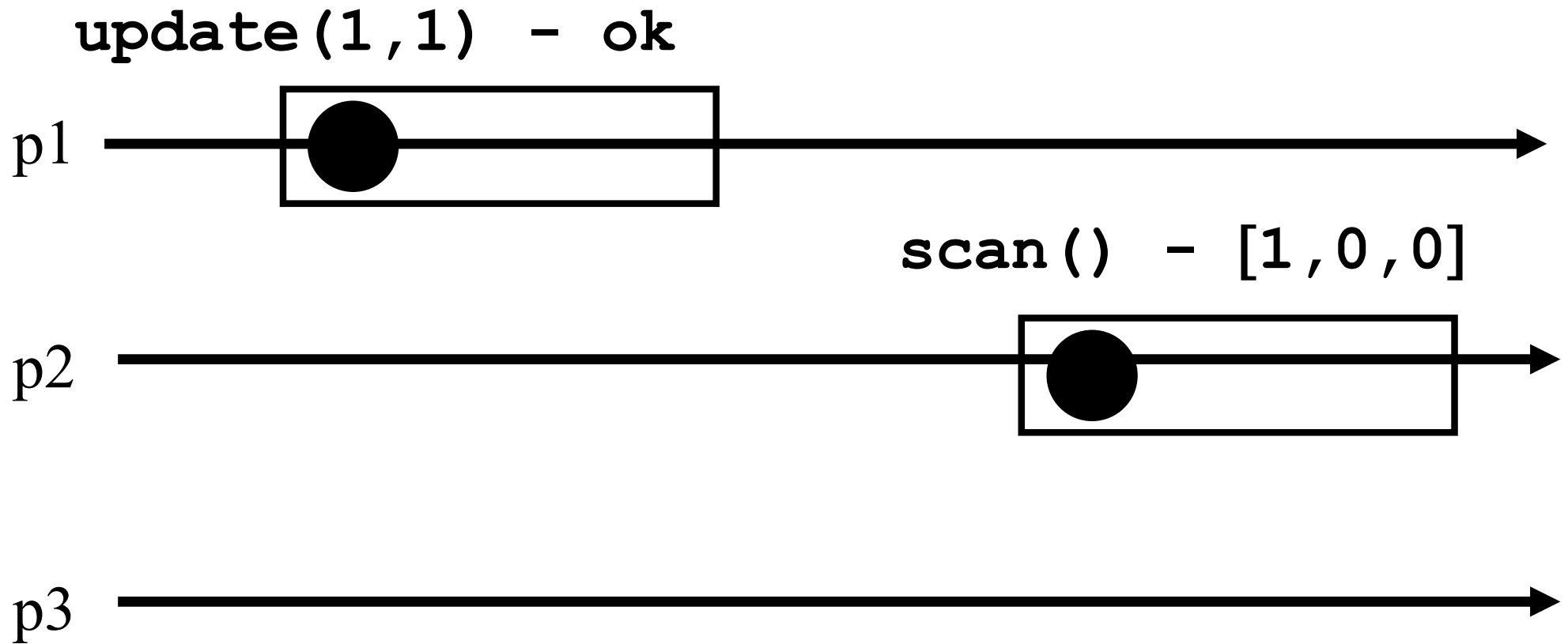
Snapshot (sequential spec)

- A ***snapshot*** has operations ***update()*** and ***scan()*** and maintains an array x of size N
- ***scan()***:
 - return(x)
- ***update(i,v)***:
 - $x[i] := v$;
 - return(ok)

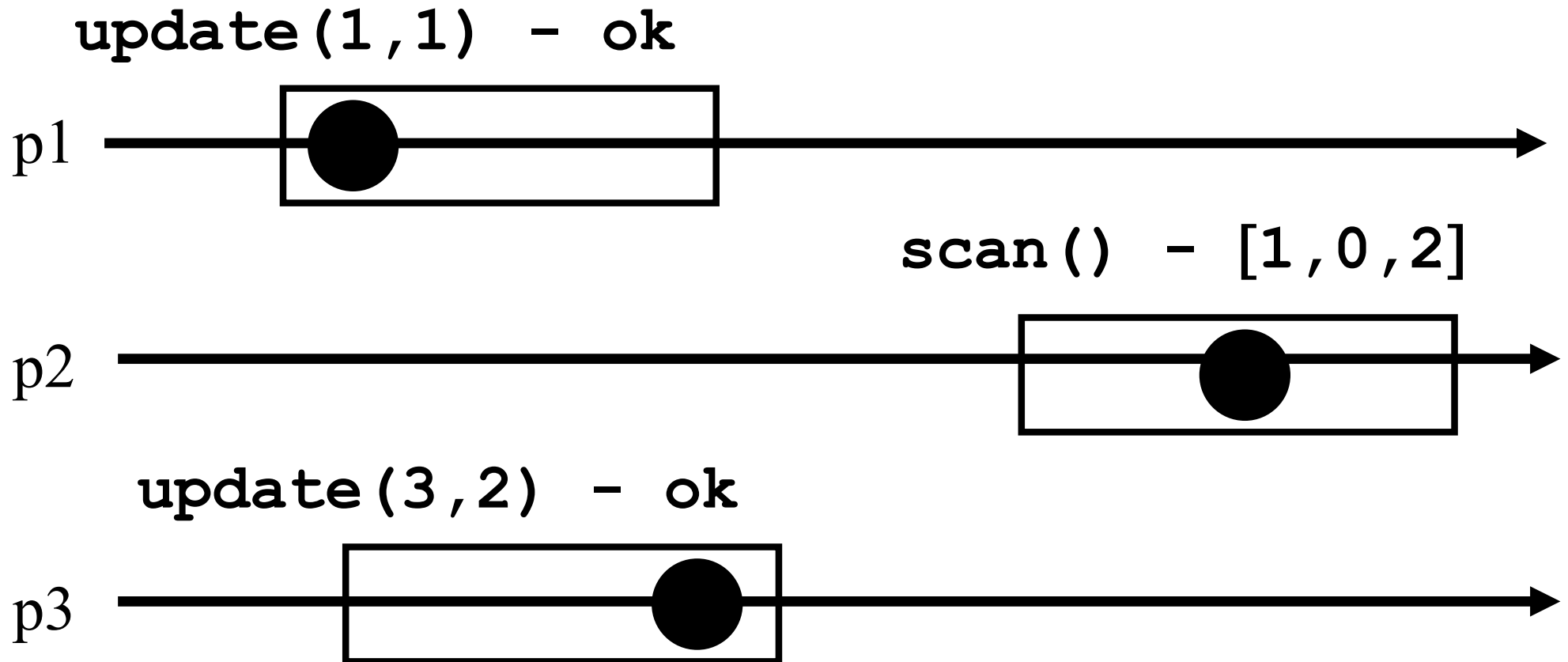
Naive implementation

- The processes share one array of N registers
Reg[1,...,N]
- ***scan()***:
 - for j = 1 to N do
 - x[j] := Reg[j].read();
 - return(x)
- ***update(i,v)***:
 - Reg[i].write(v); return(ok)

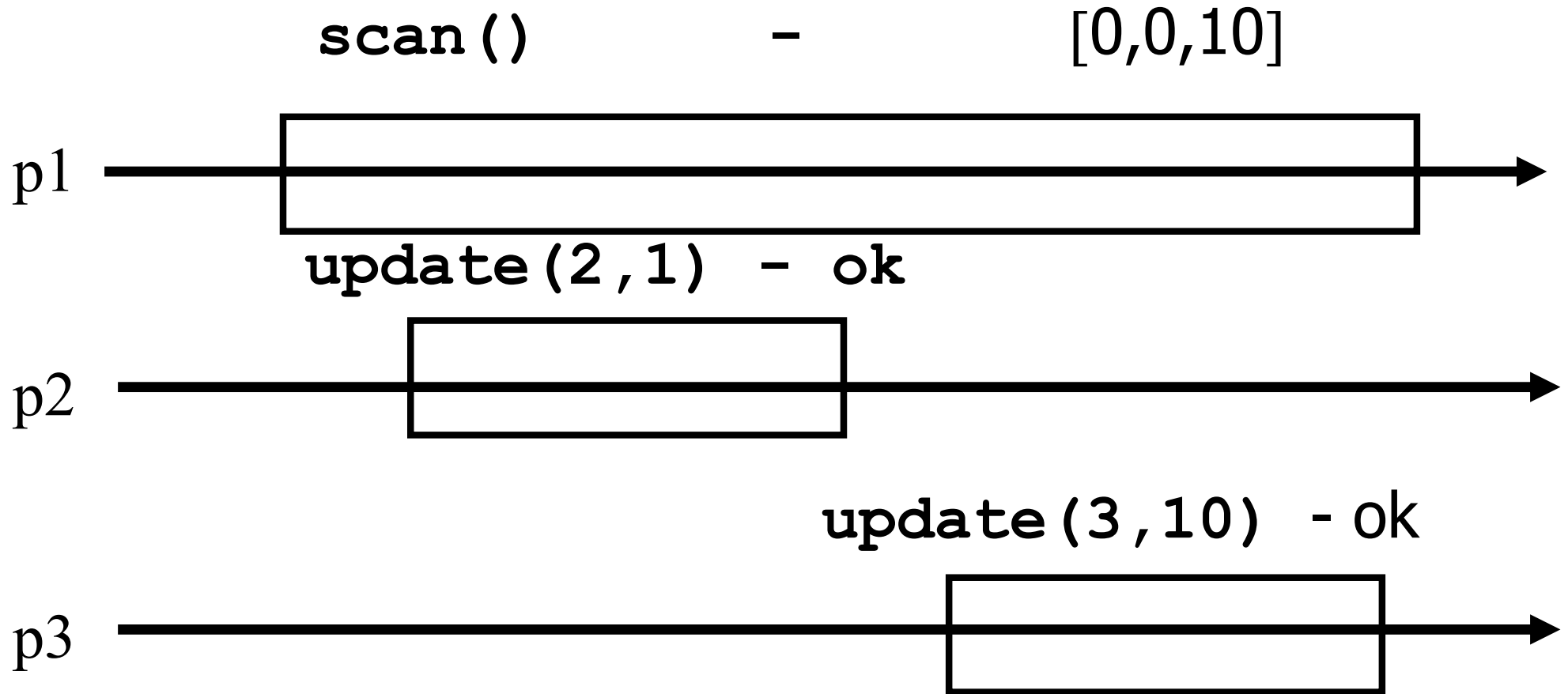
Atomic execution?



Atomic execution?



Atomic execution?



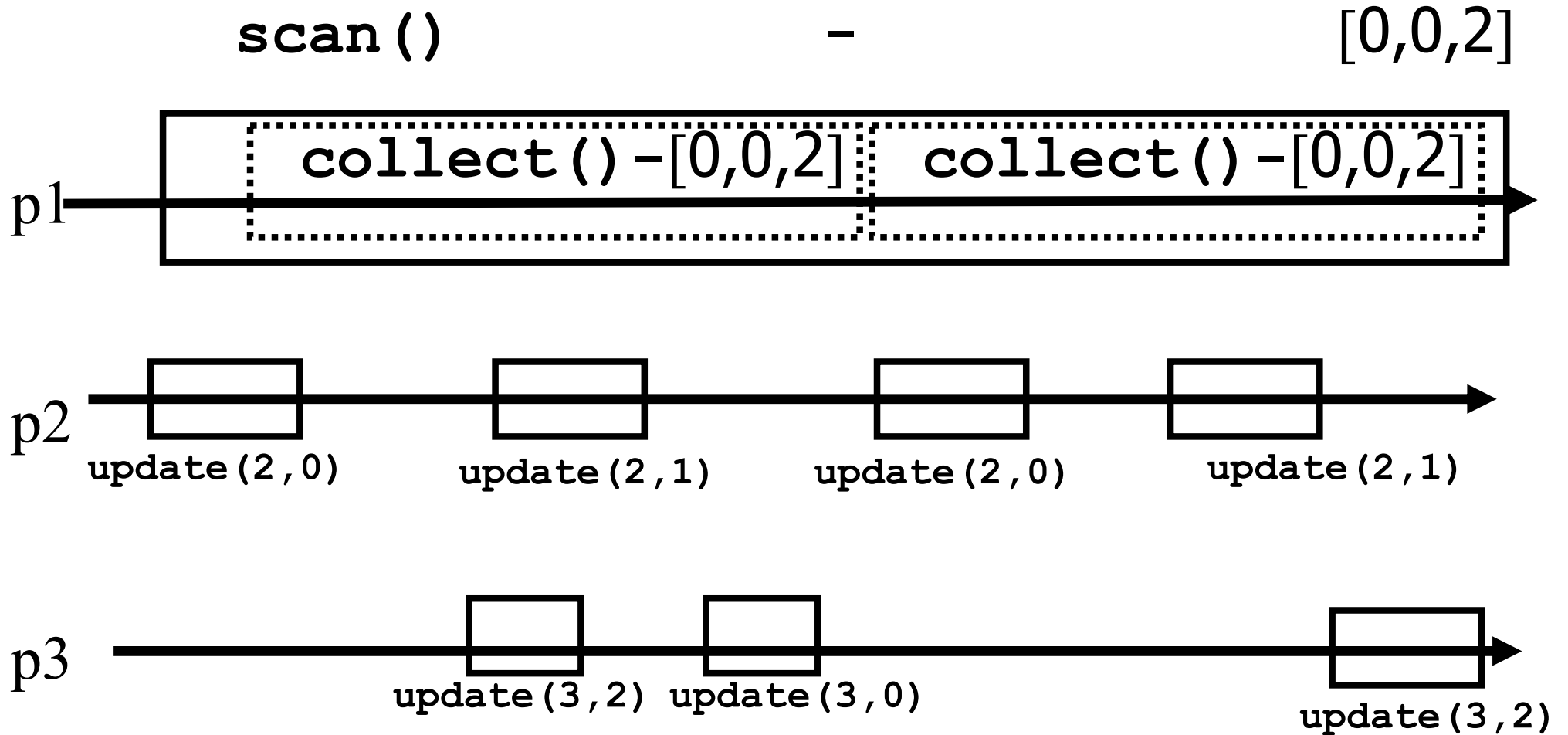
Non-atomic vs atomic snapshot

- What we implement here is some kind of ***regular*** snapshot:
 - A ***scan*** returns, for every index of the snapshot, the last written values or the value of any concurrent update
 - We call it ***collect***

Key idea for atomicity

- To ***scan***, a process keeps reading the entire snapshot (i.e., it ***collect***), until two results are the **same**
- This means that the snapshot did not change, and it is safe to return without violating atomicity

Same value vs. Same timestamp



Enforcing atomicity

- The processes share one array of N registers $\text{Reg}[1, \dots, N]$; each contains a value and a timestamp
- We use the following operation for modularity
- ***collect()***:
 - for $j = 1$ to N do
 - $x[j] := \text{Reg}[j].\text{read}()$;
 - return(x)

Enforcing atomicity (cont'd)

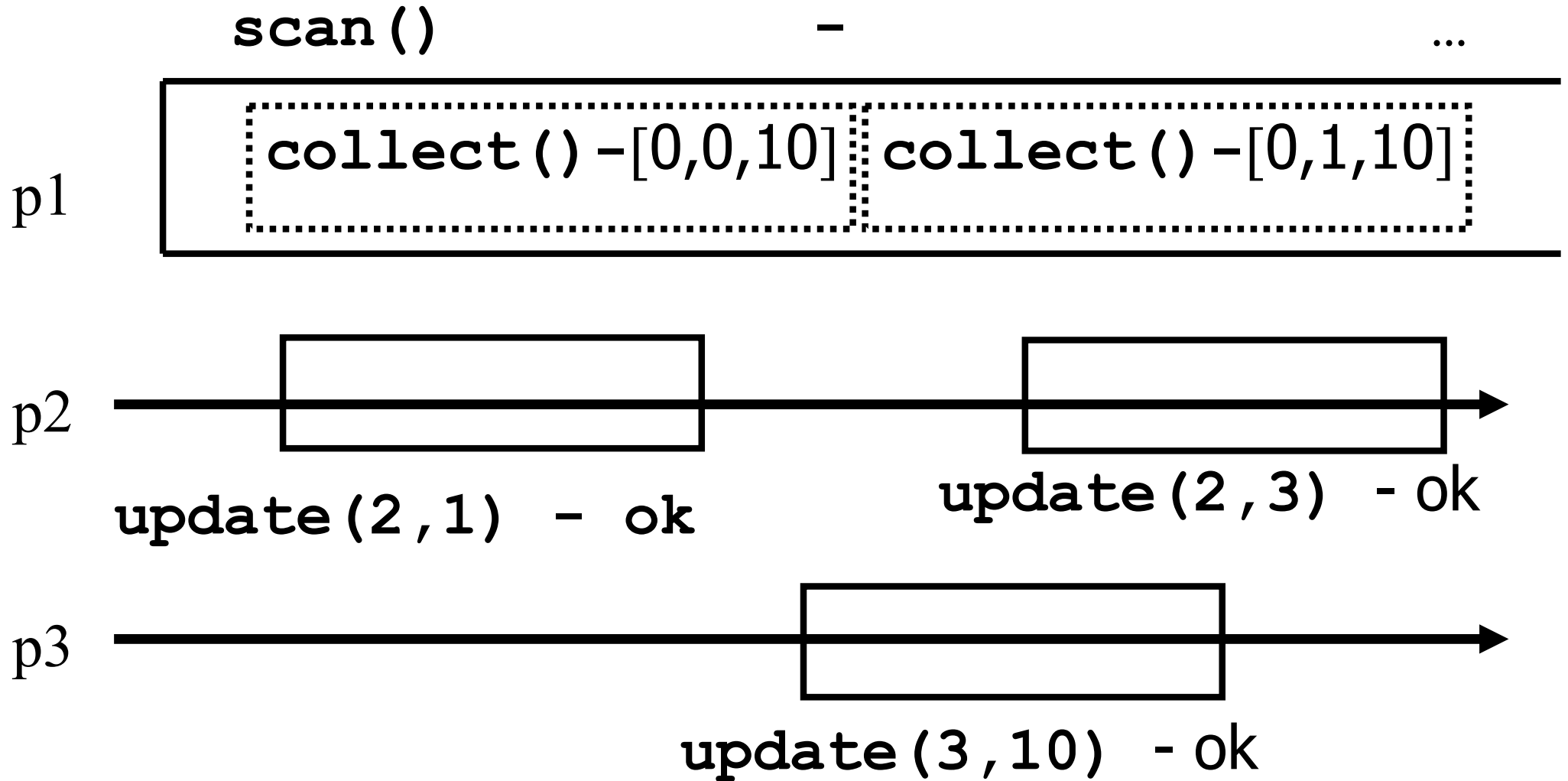
scan():

- temp1 := self.collect();
- while(true) do
 - temp2 := self.collect();
 - if (temp1 = temp2) then
 - return (temp1.val)
 - temp1 := temp2;

update(i,v):

- ts := ts + 1;
- Reg[i].write(v,ts);
- return(ok)

Wait-freedom?



Key idea for atomicity & wait-freedom

- The processes share an array of ***registers*** $\text{Reg}[1, \dots, N]$ that contains each:
 - a value,
 - a timestamp, and
 - a copy of the entire array of values

Key idea for atomicity & wait-freedom (cont'd)

- To ***scan***, a process keeps collecting and returns a collect if it did not change, or some collect returned by a concurrent ***scan***
 - Timestamps are used to check if the collect changes or if a scan has been taken in the meantime
- To ***update***, a process ***scans*** and writes the value, the new timestamp and the result of the scan

Snapshot implementation

Every process keeps a local timestamp ts

update(i, v):

- ts := ts + 1;***
- Reg[i].write($v, ts, self.scan()$);***
- return(ok)***

Snapshot implementation

scan():

- `t1 := self.collect(); t2 := t1`
- `while(true) do`
 - `t3 := self.collect();`
 - `if (t3 = t2) then return (t3);`
 - `for j = 1 to N do`
 - `if(t3[j,2] ≥ t1[j,2]+2) then`
 - `return (t3[j,3])`
 - `t2 := t3`

**Return the
first value in
each cell in t3**

Possible execution?

scan ()

-

[0,0,3]

p1



p2



p3



update (3, 1) -ok

update (3, 2) -ok

update (3, 3) -ok