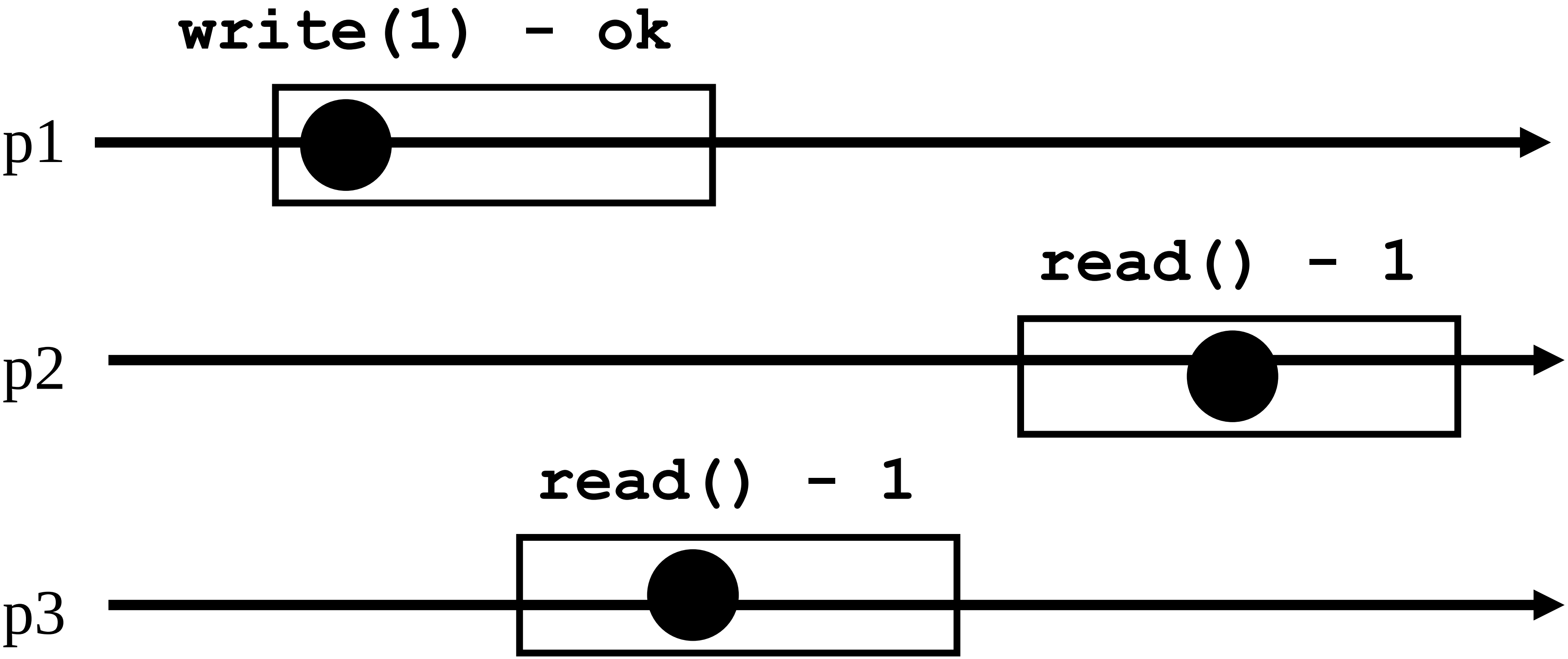
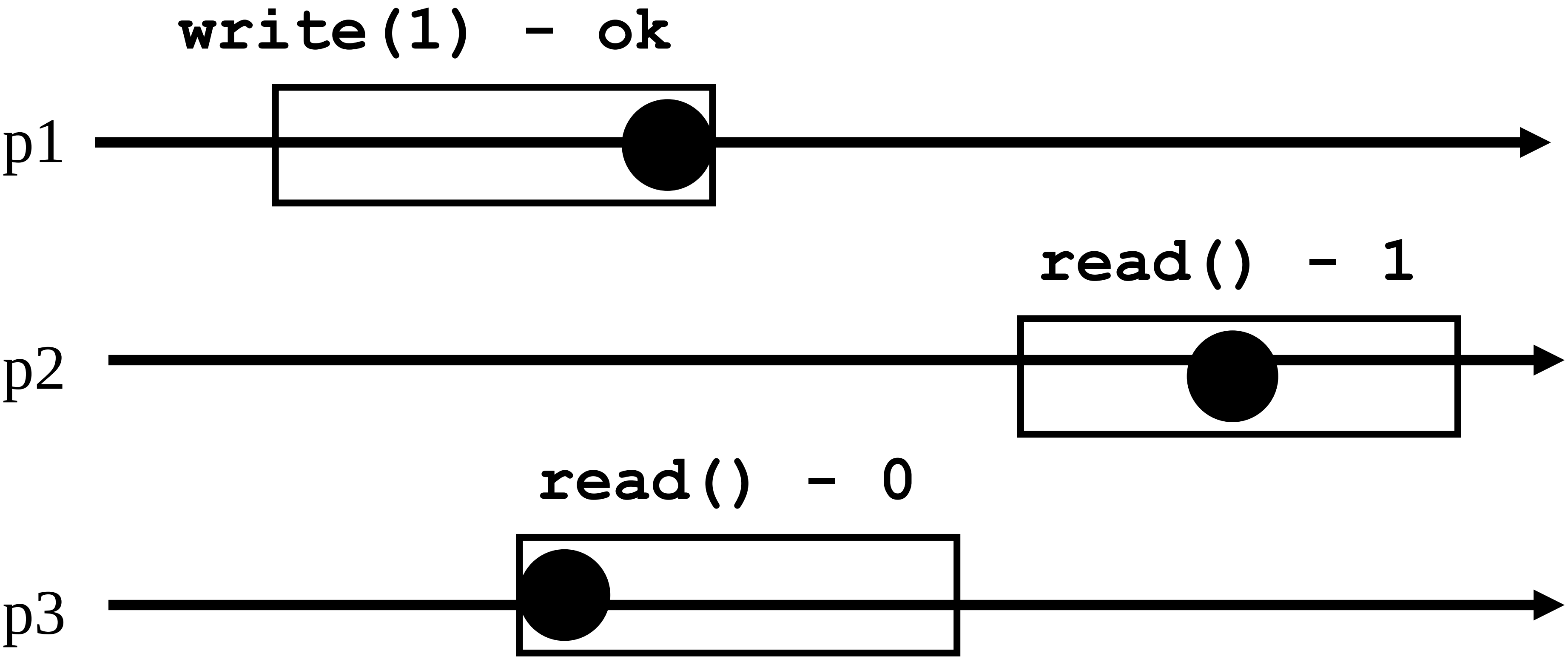
The Power of Registers

Prof R. Guerraoui
Distributed Computing 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)

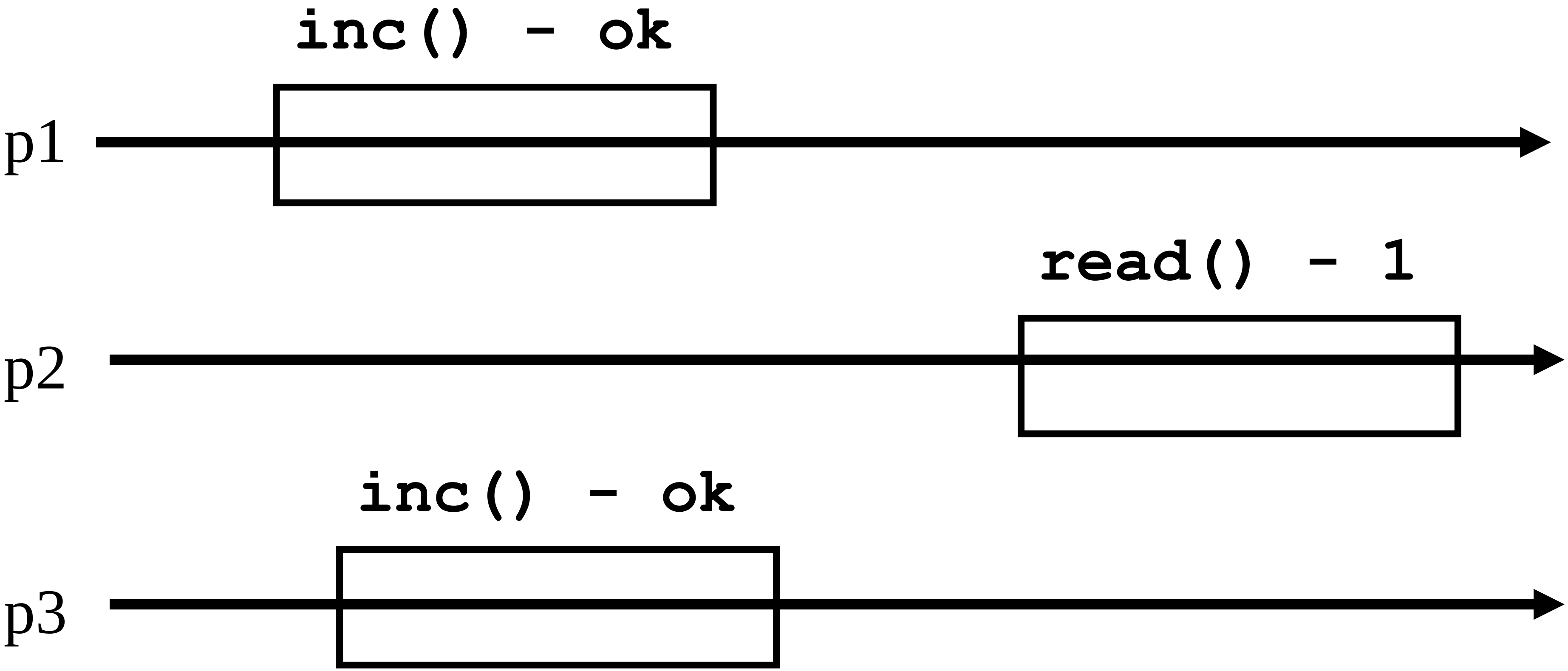
Counter (sequential spec)

- 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

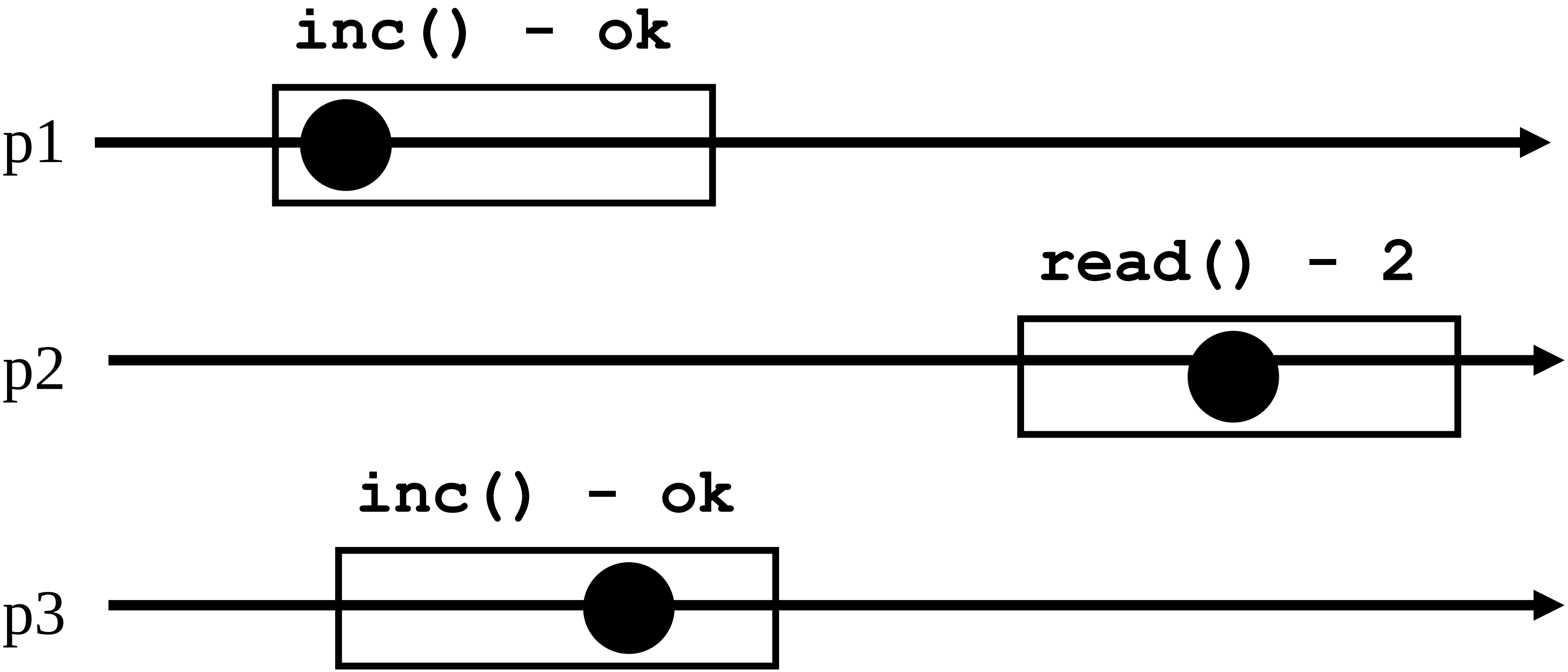
- The processes share an array of registers Reg[1,..,n]

- ***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)

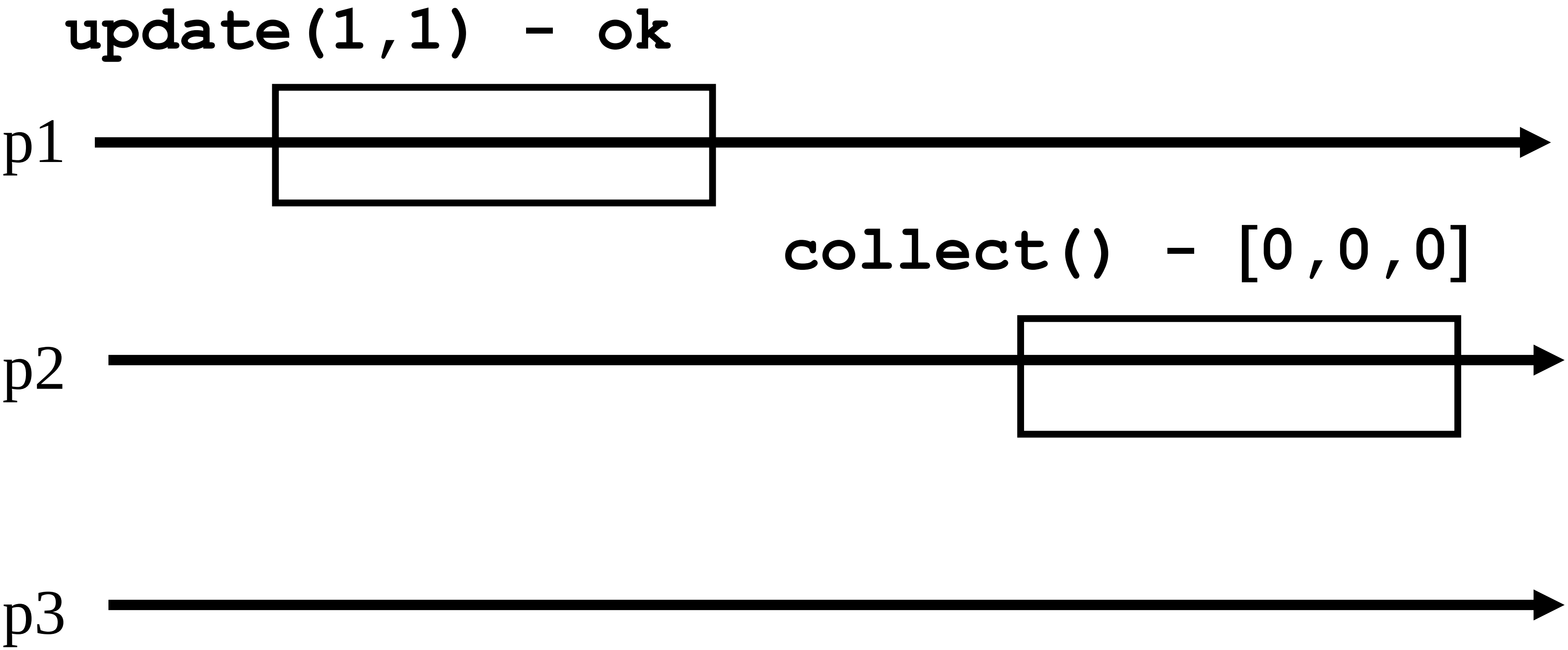
- A ***snapshot*** has operations ***update()*** and ***scan()*** and maintains an array *x* of size *n*
- ***scan():***
  - return(x)
- ***update(i,v):***
  - x[i] := v;
  - return(ok)

Very naive implementation

- Each process maintains an array of integer variables x init to [0,..,0]

- ***scan():***
  - return(x)
- ***update(i,v):***
  - x[i] := v;
  - return(ok)

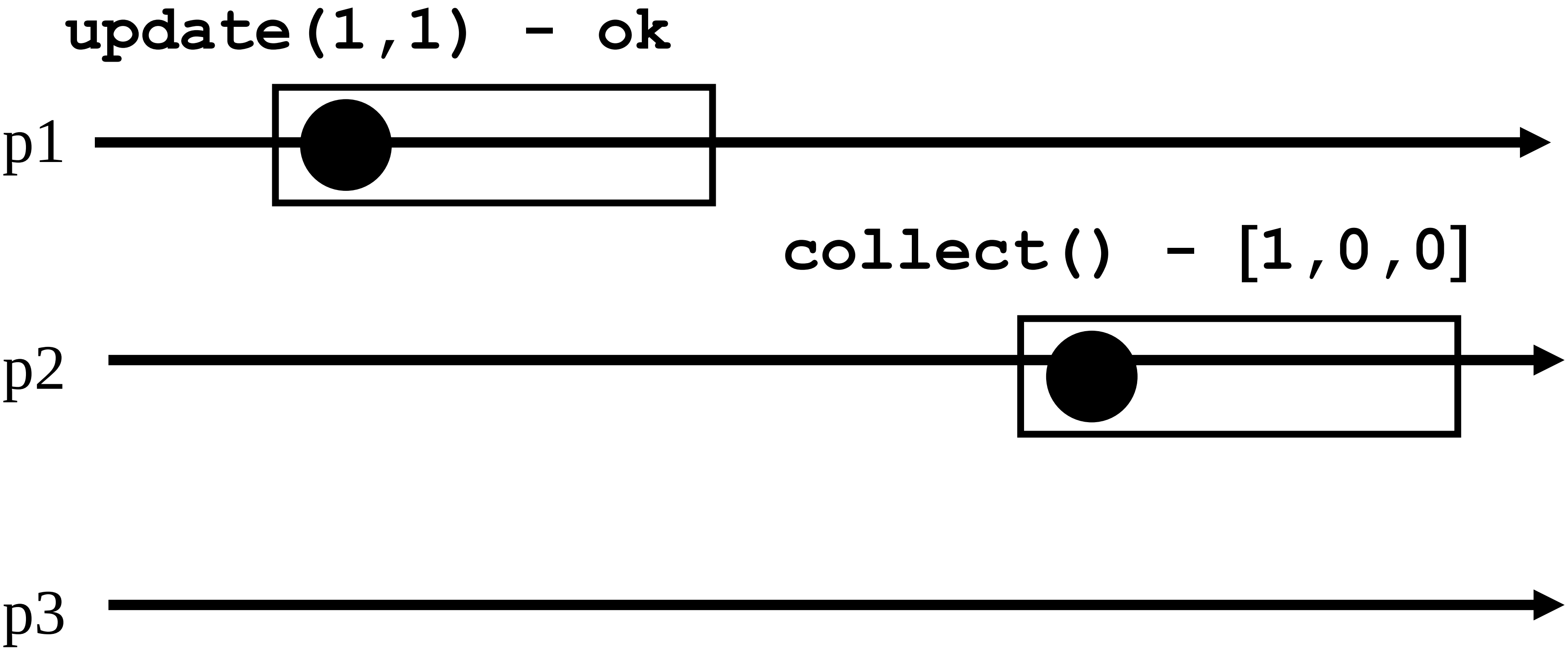
Atomic execution?



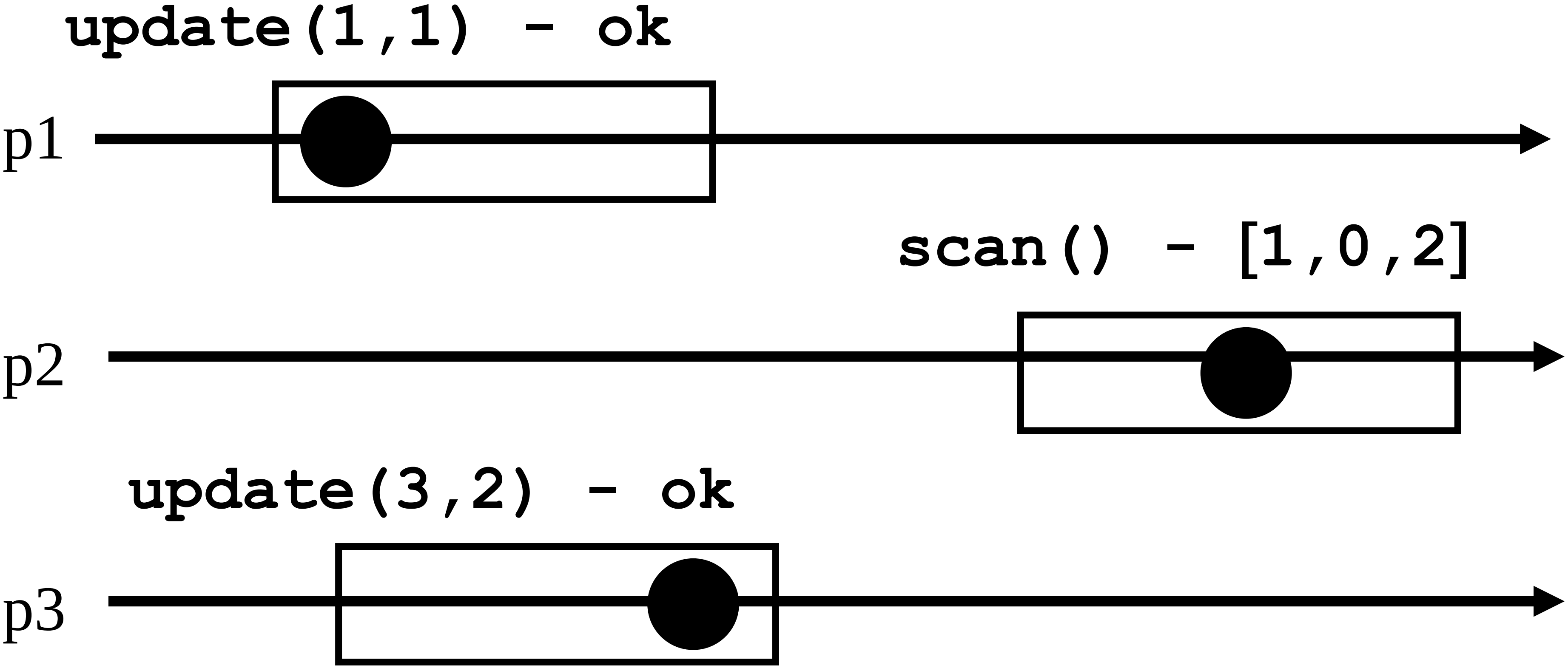
Less naive implementation

- 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)

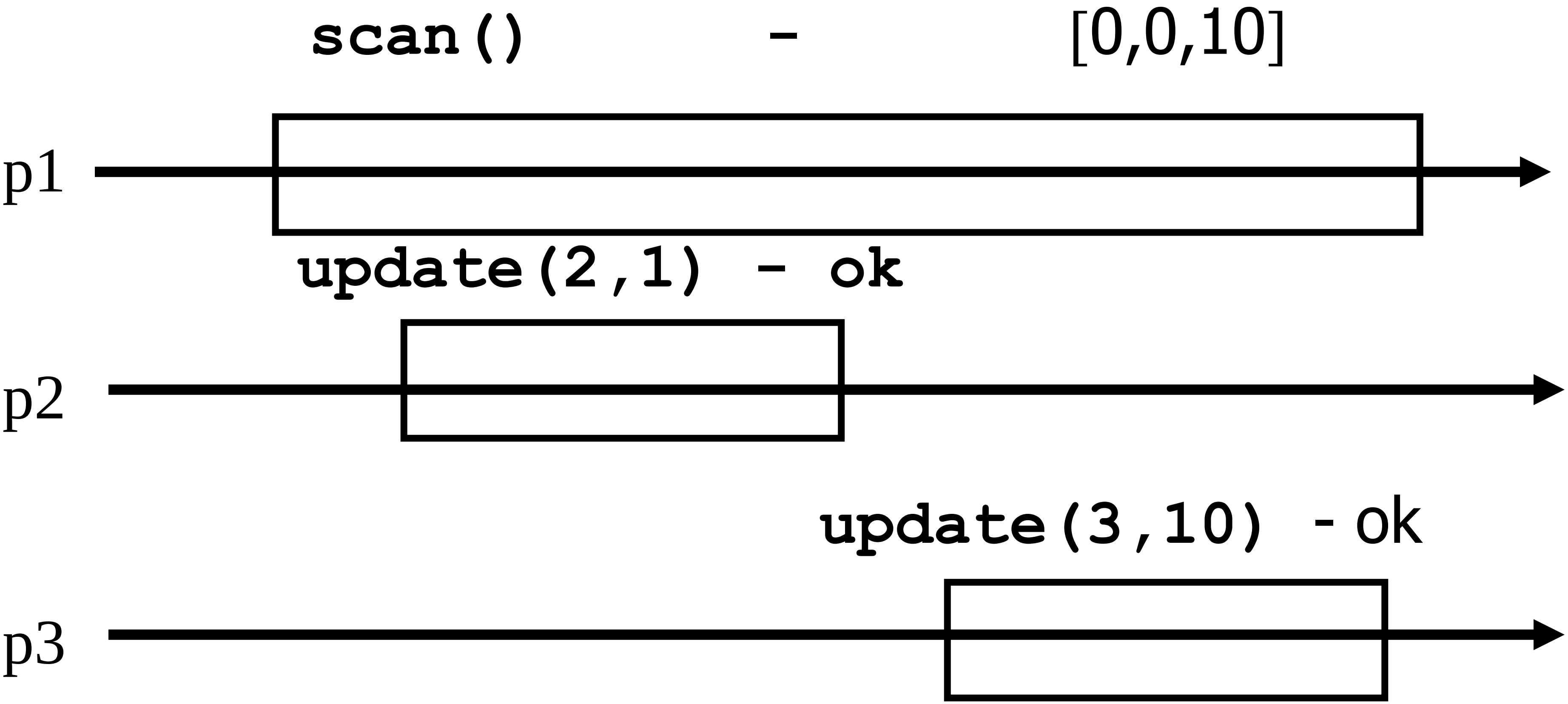
Atomic execution?



Atomic execution?



Atomic execution?



Non-atomic vs atomic snapshot

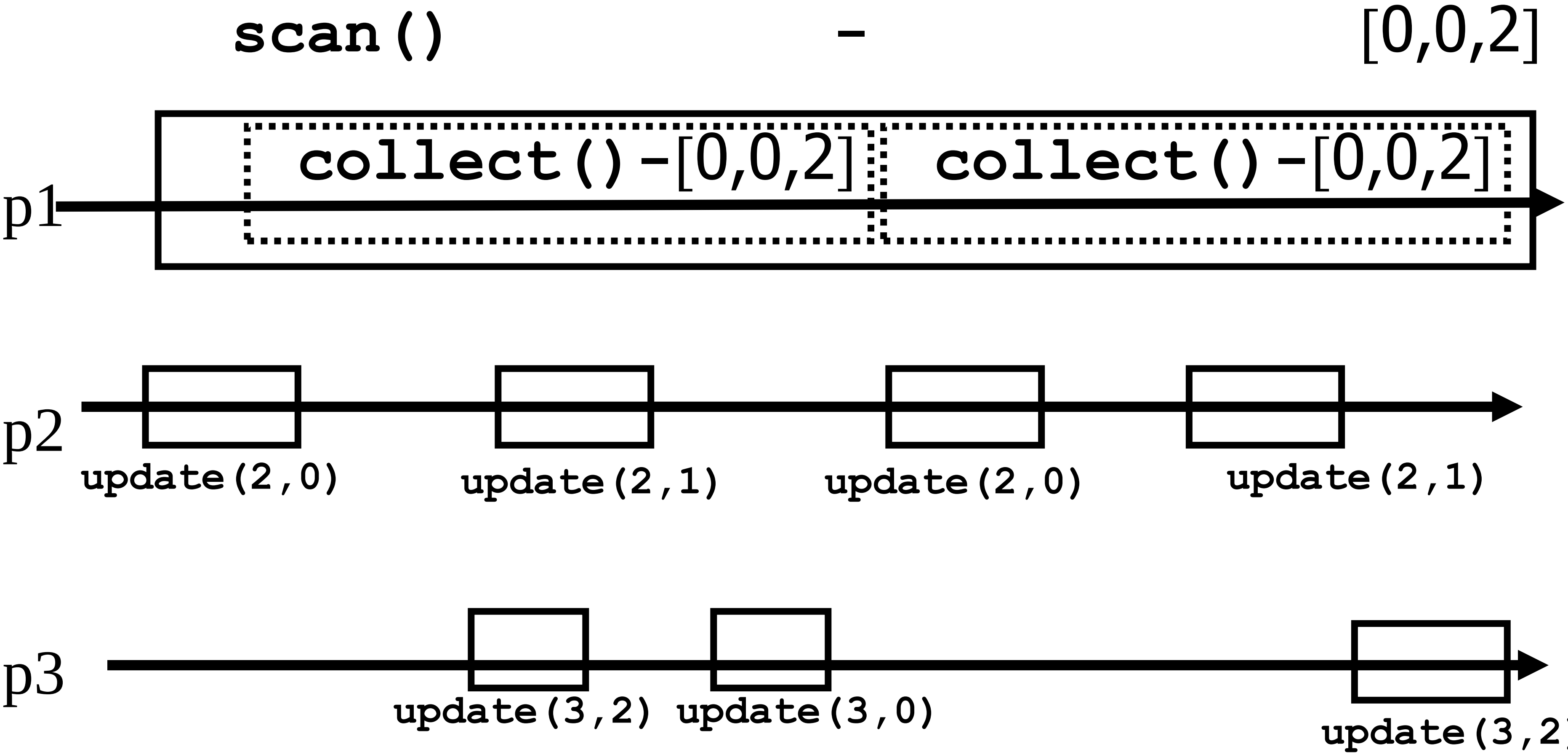
- What we implement here is some kind of ***regular*** snapshot:
  - A ***scan*** returns, for every index of the snapshot, the last written value or the value of any concurrent update
  - We call it ***collect***

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



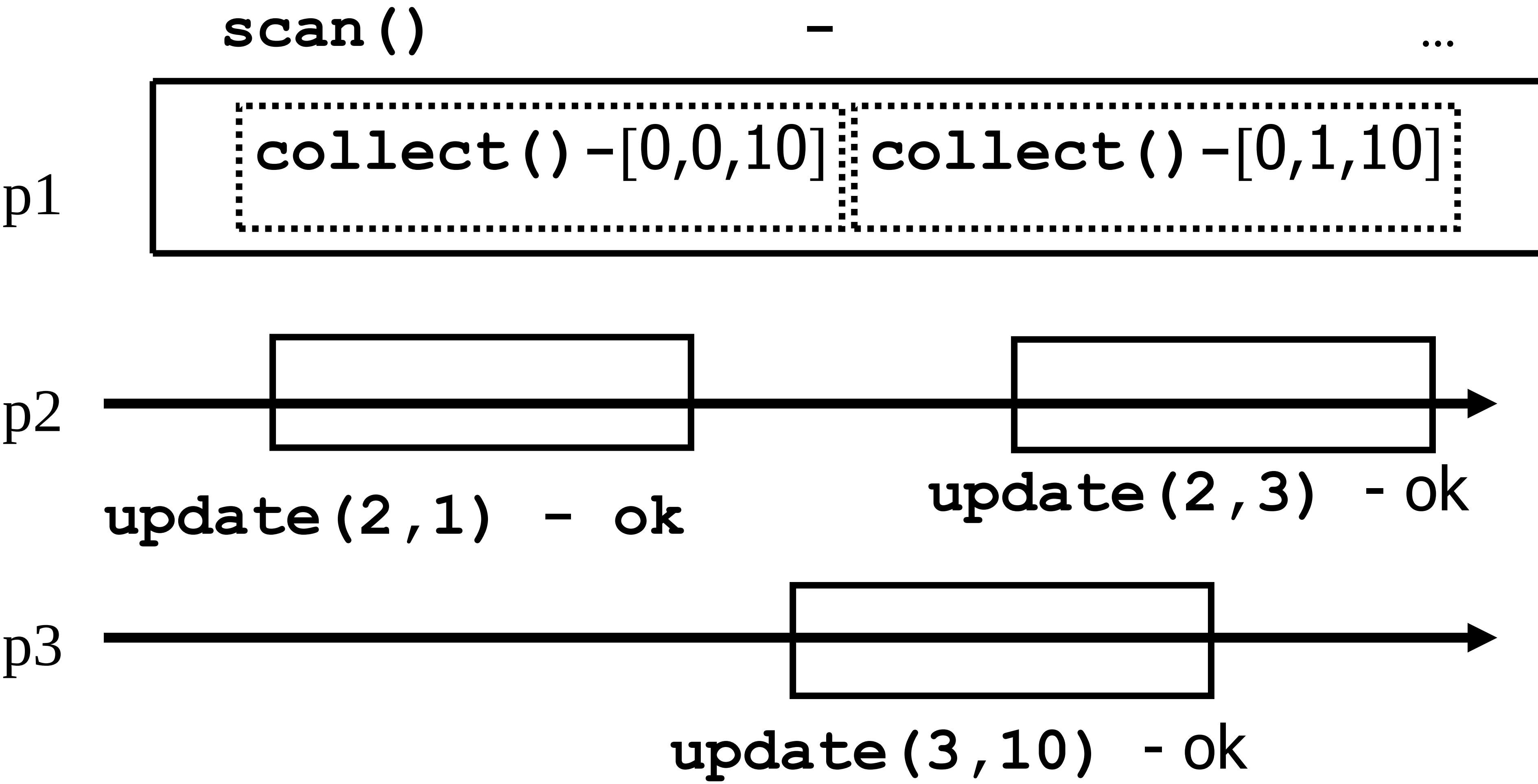
Enforcing atomicity

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