Computing with anonymous processes

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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)

Counter (atomic implementation)

- The processes share an array of SWMR registers Reg[1,..,n] **;** the writer of register Reg[i] is pi

- **inc():**
  - temp := Reg[i].read() + 1;
  - Reg[i].write(temp);
  - return(ok)

Counter (atomic implementation)

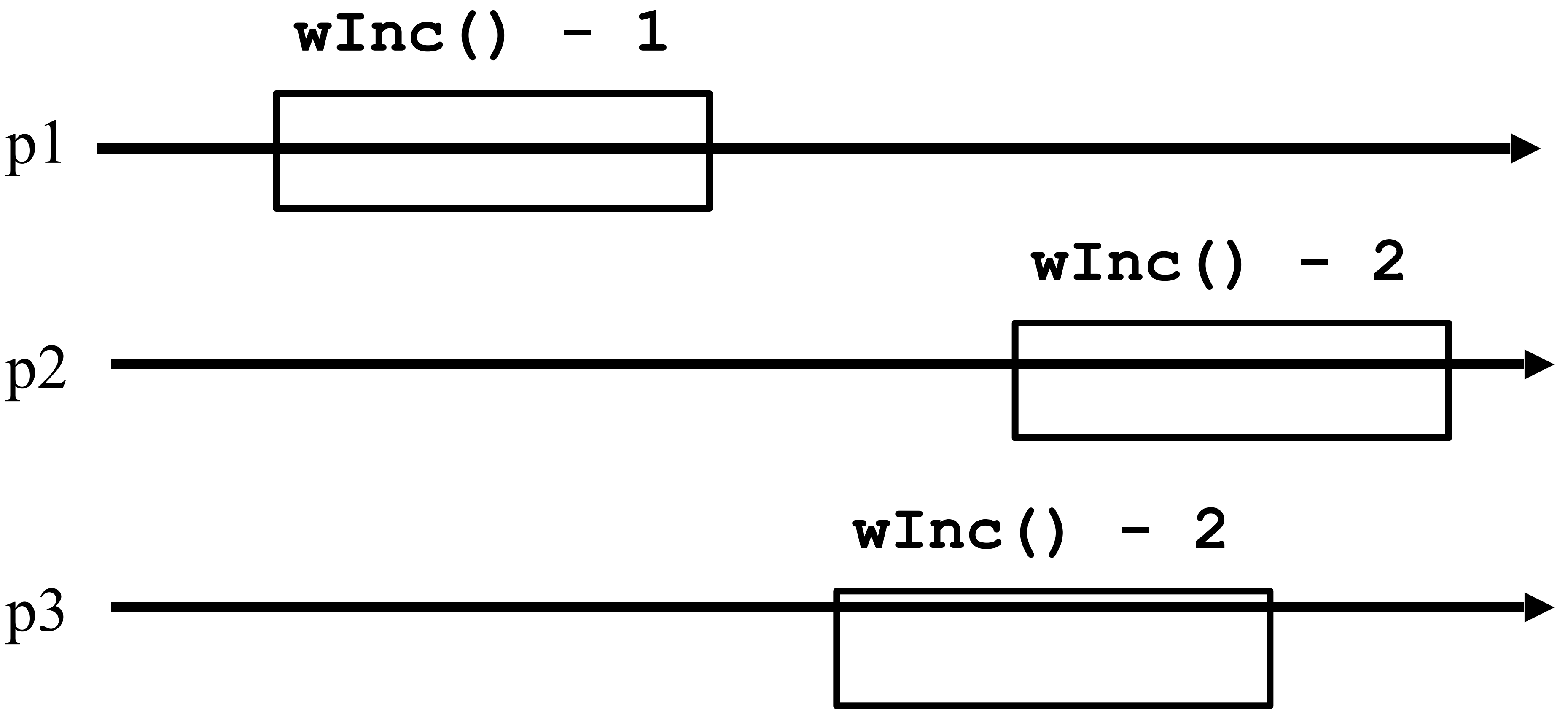
- **read():**
  - sum := 0;
  - for j = 1 to n do
    - sum := sum + Reg[j].read();
  - return(sum)

Weak Counter

- A **weak counter** has one operation **wInc()**
- **wInc():**
  - x := x + 1;
  - return(x)

- Correctness: (a) if op1 precedes another op2, then op2 returns a value that is larger than op1; (b) the value returned does not exceed the number of invocations
- NB. Resembles a regular Fetch&Inc object

Weak Counter Execution

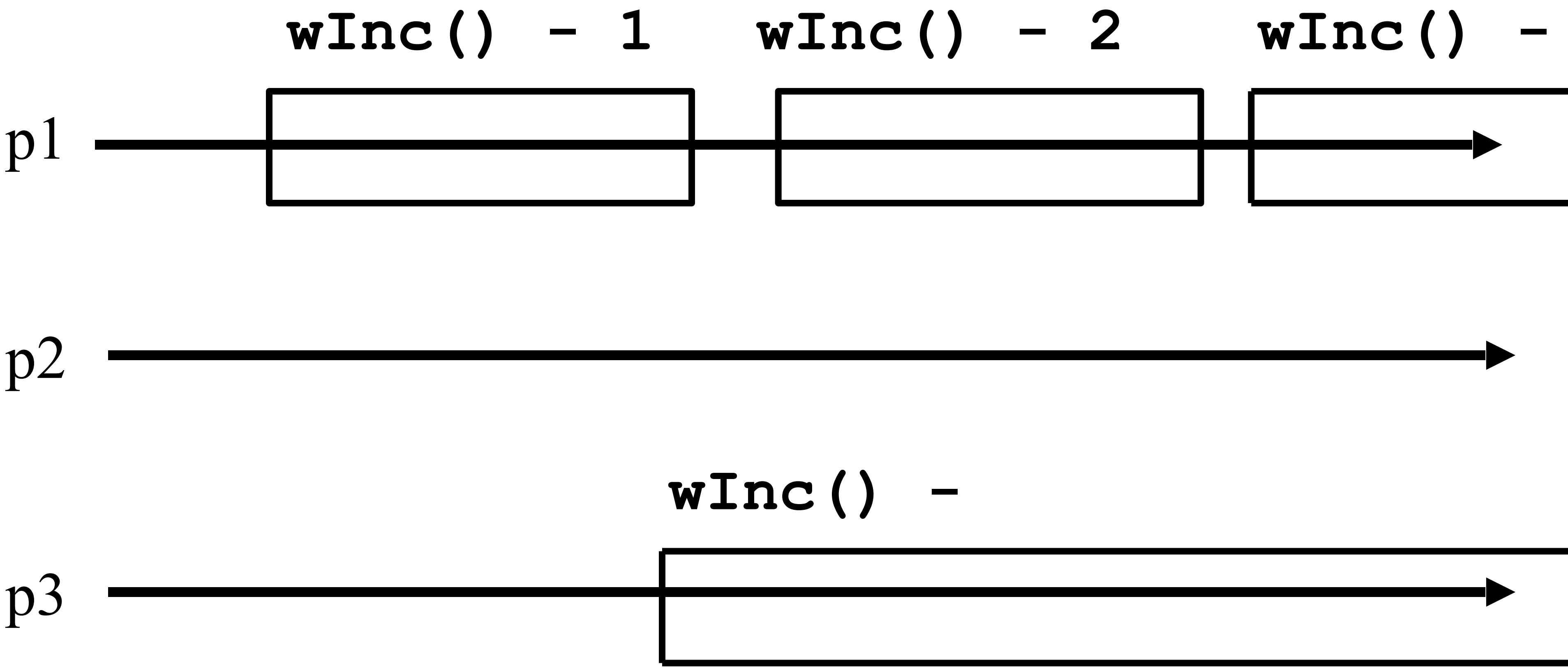


Weak Counter (lock-free implementation)

- The processes share an (infinite) array of MWMR registers Reg[1,..,n,..,], init to 0

- **wInc():**
  - i := 0;
  - while (Reg[i].read() ≠ 0) do
    - i := i + 1;
  - Reg[i].write(1);
  - return(i);

Weak Counter Execution



Weak Counter (wait-free implementation)

- The processes also use a MWMR register L
- **wInc():**
  - i : = 0;
  - while (Reg[i].read() ≠ 0) do
  - if L has been updated n times then
    - return the largest value seen in L
  - i := i + 1;
  - L.write(i);
  - Reg[i].write(1);
  - return(i);

Weak Counter (wait-free implementation)

- **wInc():**
  - t := l := L.read(); i := k:= 0;
  - while (Reg[i].read() ≠ 0) do
  - i : = i + 1;
  - if L.read() ≠ l then
    - l := L.read(); t := max(t,l); k :=k+1;
    - if k = n then return(t);

  L.write(i);
  - Reg[i].write(1);
  - return(i);

Snapshot (sequential spec)

- A **snapshot** has operations **update()** and **scan()** and maintains an array x of size n

- **scan():**
  - return(x)
- NB. No component is devoted to a process

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

Key idea for atomicity & wait-freedom

- The processes share a **Weak Counter**: Wcounter, init to 0;
- 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 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 := Wcounter.wInc();
  - Reg[i].write(v,ts,self.scan());
  - return(ok)

Snapshot implementation

- **scan():**
  - ts := Wcounter.wInc();
  - while(true) do
    - If some Reg[j] contains a collect with a higher timestamp than ts, then return that collect
    - If n+1 sets of reads return identical results then return that one

Consensus (obstruction-free)

- We consider binary consensus
- The processes share two infinite arrays of registers: $Reg_0[i]$ and $Reg_1[i]$
- Every process holds an integer i init to 1
- Idea: to impose a value v, a process needs to be fast enough to fill in registers $Reg_v[i]$

Consensus (obstruction-free)

- **propose(v):**
  - while(true) do
    - if $Reg_{1-v}[i] = 0$ then
    - $Reg_v[i] := 1;$
    - if $i > 1$ and $Reg_{1-v}[i-1] = 0$ then
      return(v);
    - else v:= 1-v;
    - i := i+1;

    end

Consensus (solo process)

`q(1)`

`Reg0(1)=0`
`Reg1(1):=1`
`Reg0(2)=0`
`Reg1(2):=1`
`Reg0(1)=0`

Consensus (lock-step)

`q(1)`	`p(0)`
`Reg0(1)=0`	`Reg1(1)=0`
`Reg1(1):=1`	`Reg0(1):=1`
`Reg0(2)=0`	`Reg1(2)=0`
`Reg1(2):=1`	`Reg0(2):=1`
`Reg0(1)=1`	`Reg0(1)=1`

Consensus (binary)

- **propose(v):**
  - while(true) do
    - If $Reg_{1-v}[i] = 0$ then
    - $Reg_v[i] := 1$;
    - if $i > 1$ and $Reg_{1-v}[i-1] = 0$ then return(v);
    - else if $Reg_v[i] = 0$ then $v := 1-v$;
    - if $v = 1$ then wait(2i)
    - $i := i+1$;

    end