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)

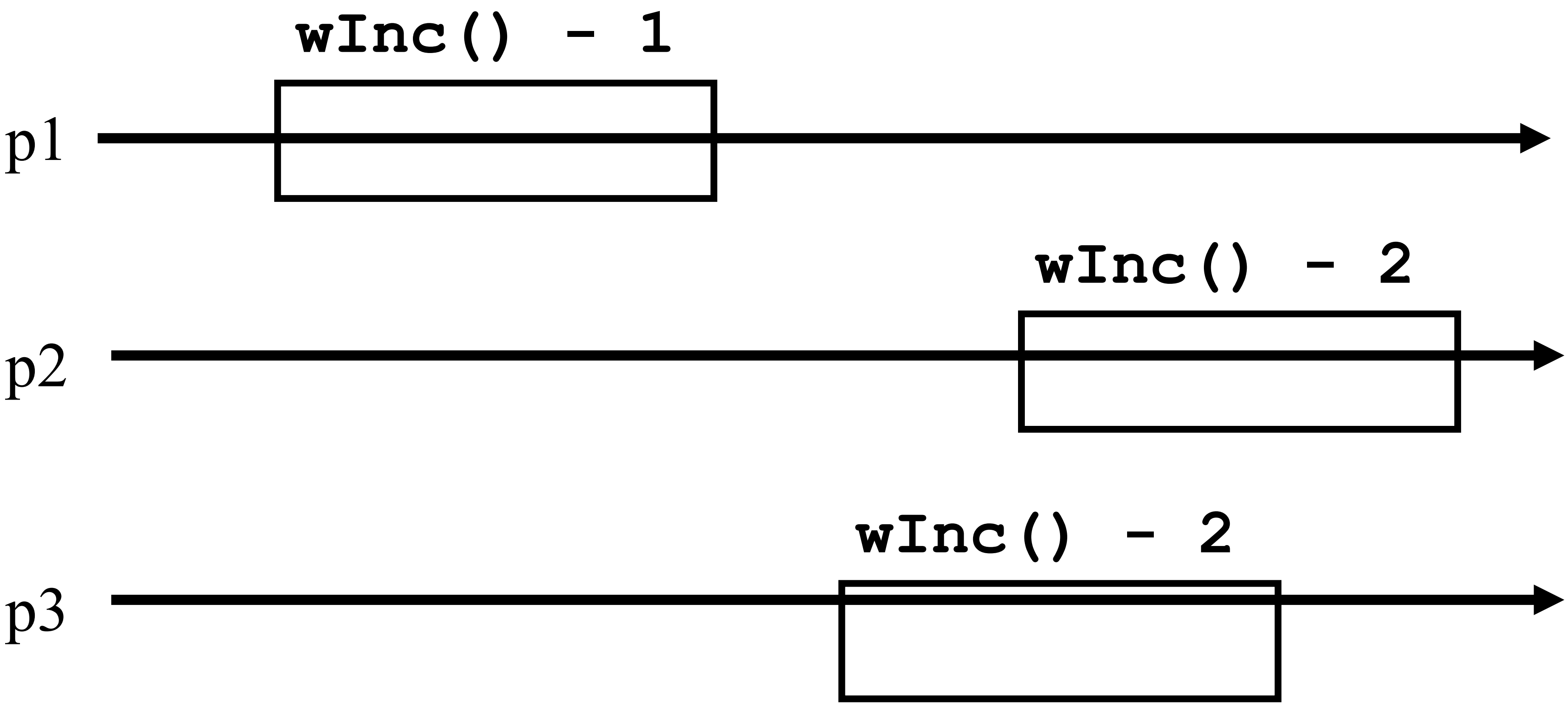
Counter (atomic implementation)

- ***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: if an operation precedes another, then the second returns a value that is larger than the first one

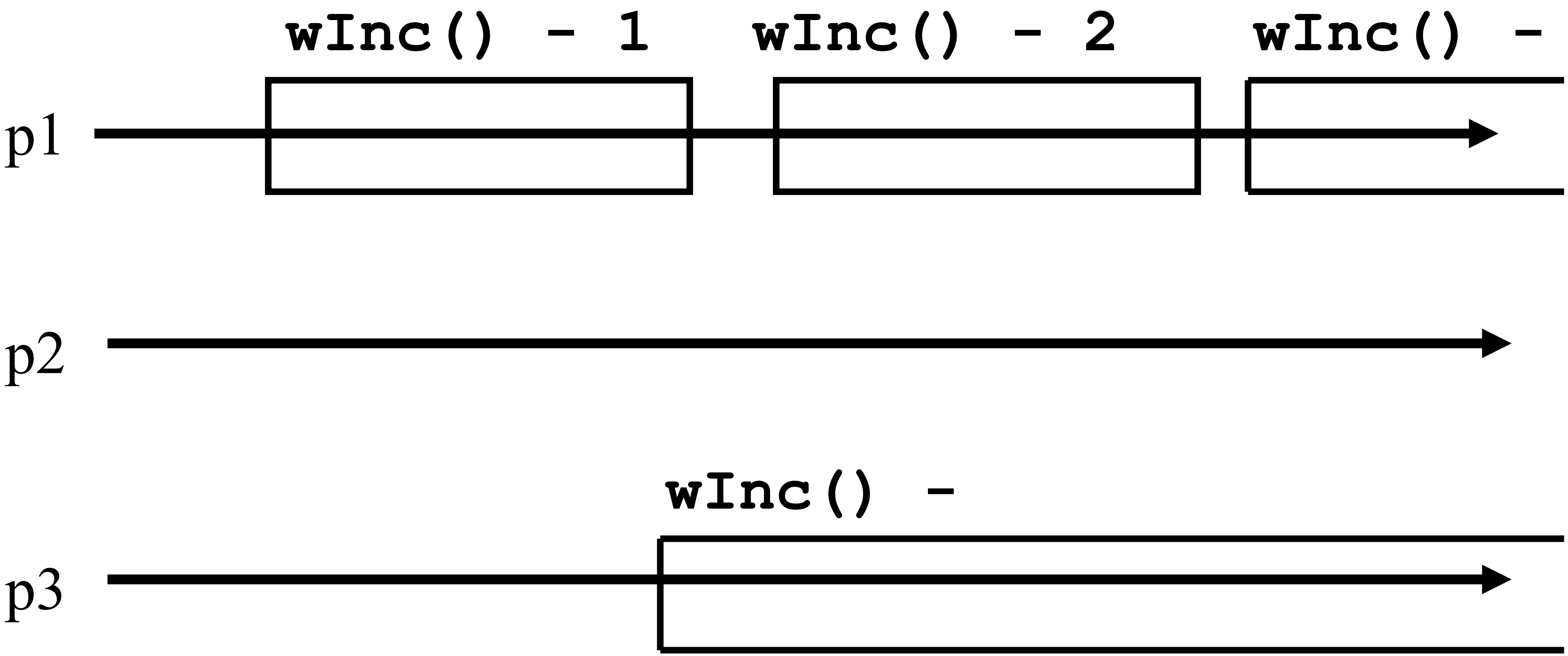
Weak counter execution



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

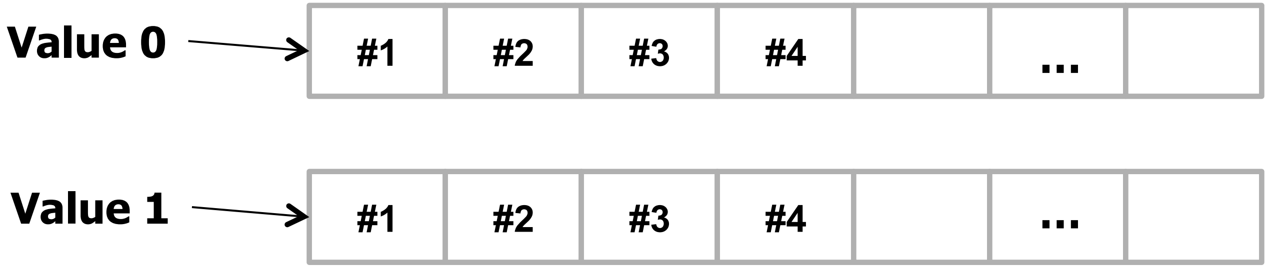
- ***update(i,v):***
  - ts := Wcounter.wInc();
  - Reg[i].write(v,ts,self.scan());
  - return(ok)

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 index integer i, init to 1
- Idea: to impose a value v, a process needs to be fast enough to fill in registers in $Reg_v[i]$

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

My team may be winning

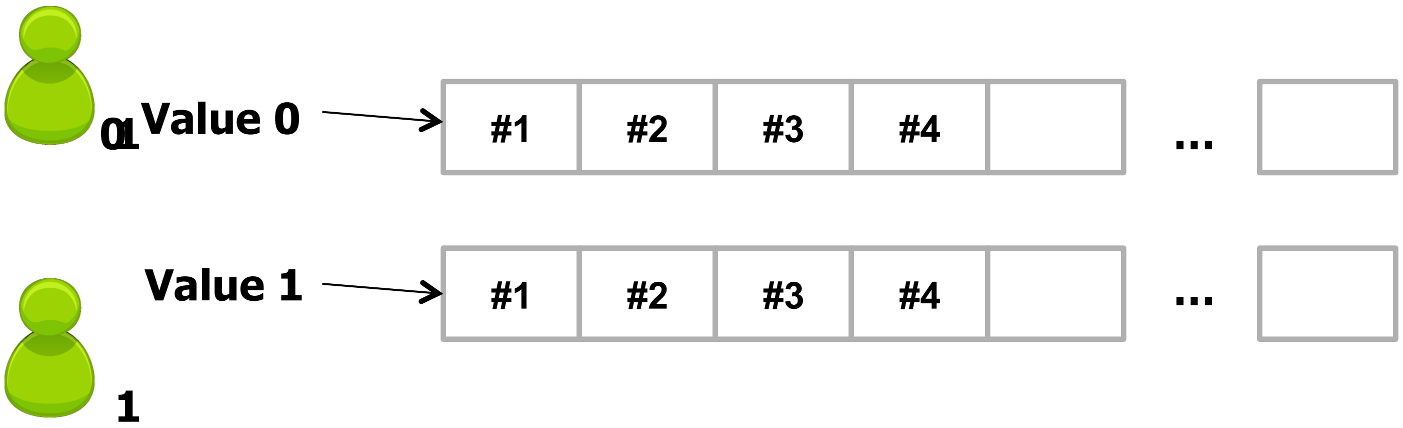
Score 1 for my team

If we're leading by 2, we won!

If we're losing, I switch teams!

A simple execution

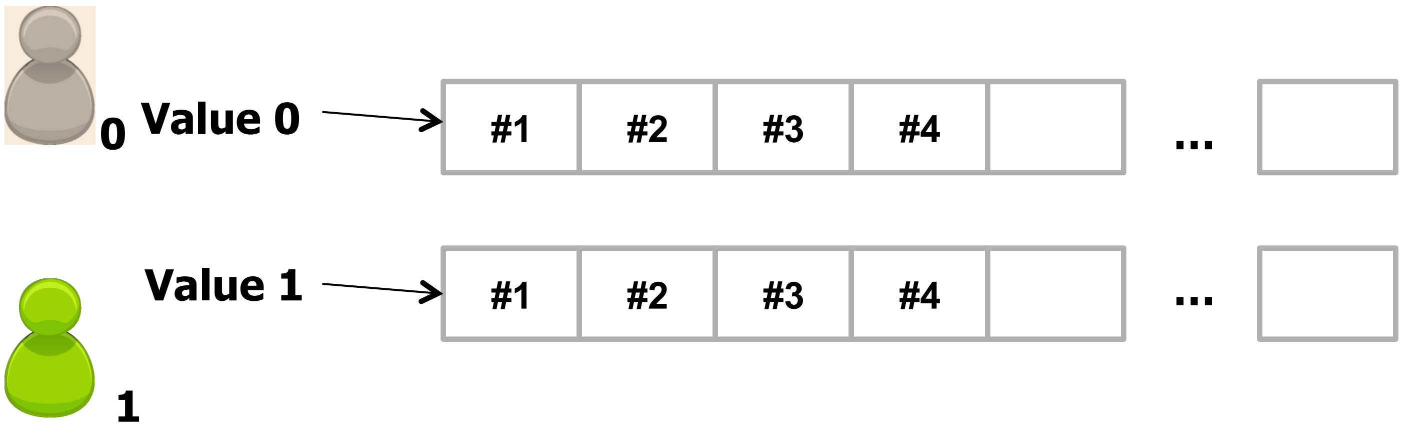
- Team 0 vs Team 1
- Solo execution:



- Process p_1 (green) comes in alone, and marks the first two slots of Reg1
- Processes that come later either have value 1 and decide 1, or switch to value 1 and decide 1

Lock-step execution

- Team 0 vs Team 1
- Lock-step:



- If the two processes proceed in perfect lock-step, then the algorithm will go on forever
- Obstruction-free, but **not** wait-free

Algorithm tip

When designing a concurrent algorithm, it helps to first check correctness in *solo* and *lock-step* executions

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

Can we make it wait-free?

- We need to assume *eventual synchrony*
- Definition:
  In every execution, there exists a time *GST (global stabilization time)* after which the processes' internal clocks are perfectly synchronized

Consensus (binary)

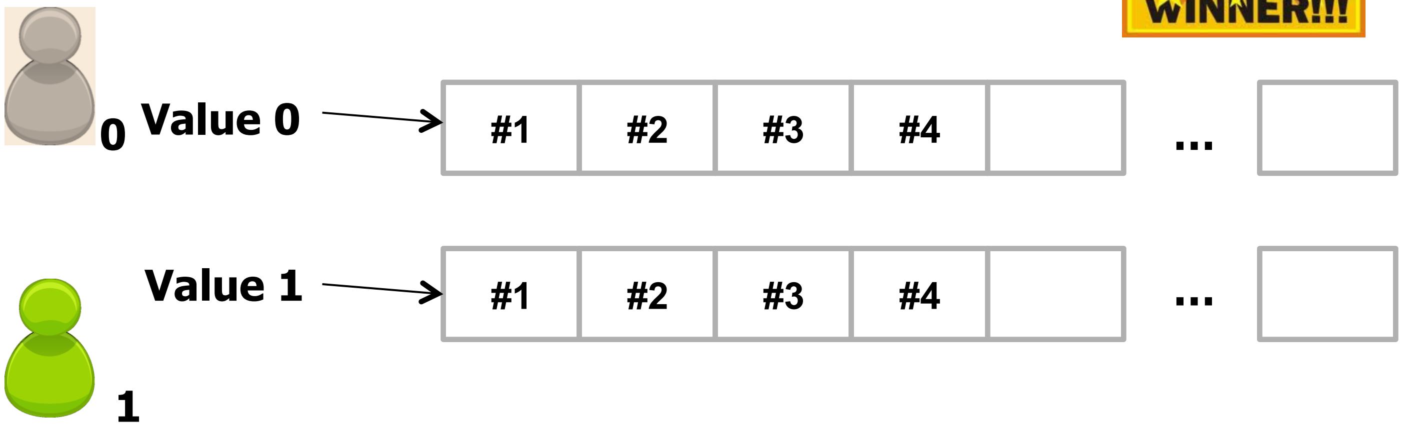
- ***propose(v):***
  - while(true) do
    - If $Reg_{1-v}[i] = 0$ then
    - $Reg_v[i] := 1$;
    - if $i > 1$ and $Reg_{1-v}[i-1] = 0$ then return(v);
    - else if $Reg_v[i] = 0$ then $v := 1-v$;
    - if $v = 1$ then wait(2i)
    - $i := i+1$;

  end

One of the teams becomes *slower*!

Wait-free (intuition)

- Team 0 vs Team 1
- Lock-step:



- The processes in team 1 have to wait for 2i steps after each loop
- Hence, *eventually*, they become so slow that team 0 wins

References

- Writeup containing all algorithms and more:

http://ic2.epfl.ch/publications/documents/IC_TECH_REPORT_200496.pdf