Caltech, CMS. CS/IDS 142: Lecture 6.2
Distributed Dining Philosophers
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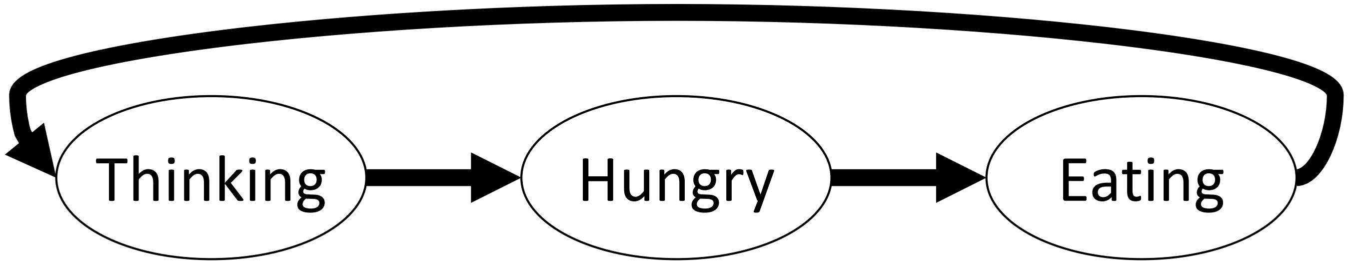
Take away concepts from the course:

- State transition systems.
- Always (invariant, safety). Nothing bad ever happens.
- Progress. Variant function. Lyapunov function. Metric. The system never gets further away from its goal and eventually gets closer.
- Global view of the designer mapped to local view of the agent.
- Data structures, e.g. graphs

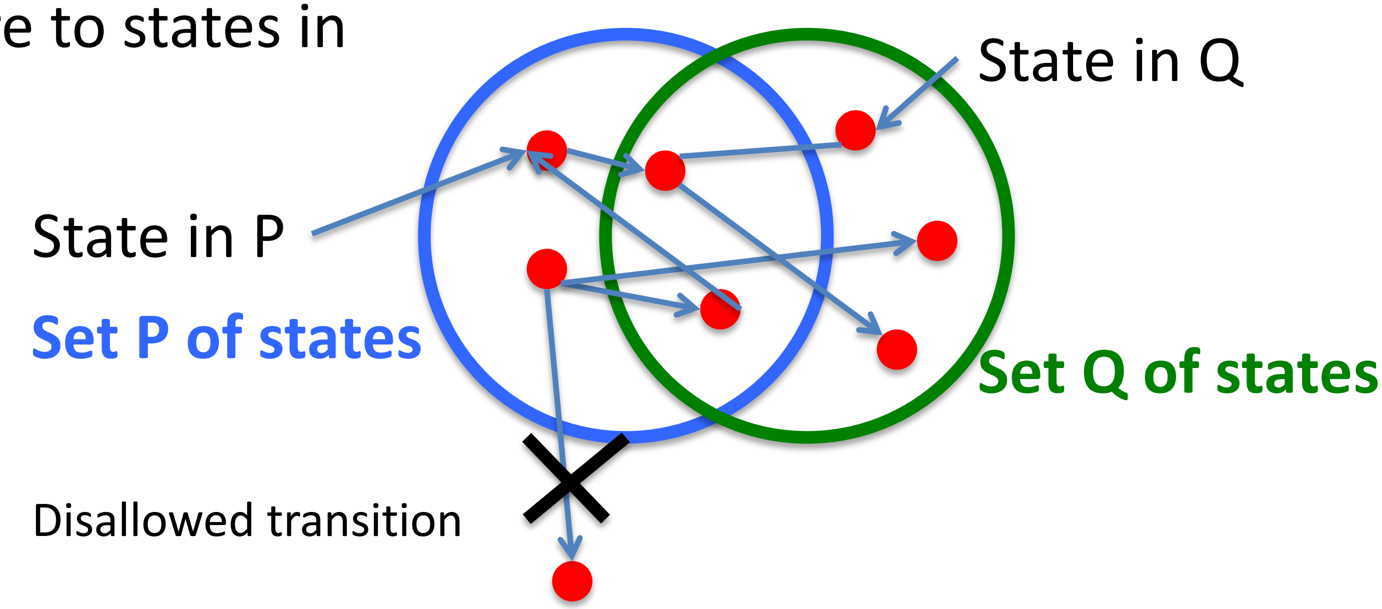
Unless Property



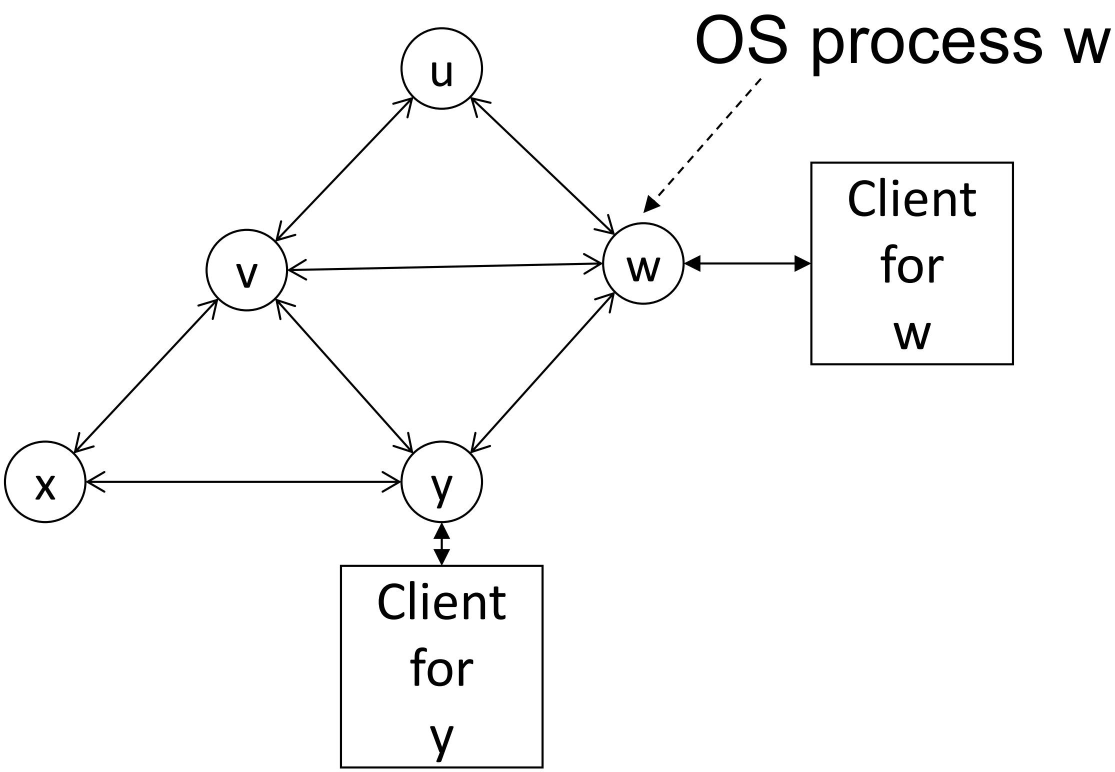
P unless Q:

All transitions from states in which P holds are to states in which Q holds

- **thinking unless hungry**
- **hungry unless eating**
- **eating unless thinking**



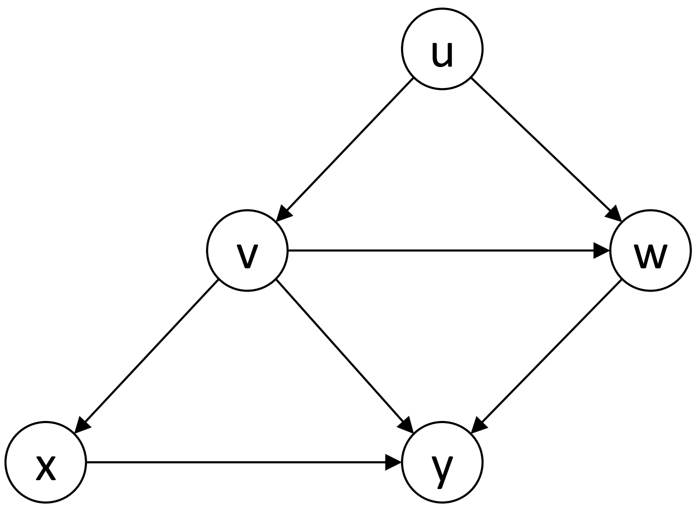
Given: Undirected graph. Each node consists of an OS process and a client process

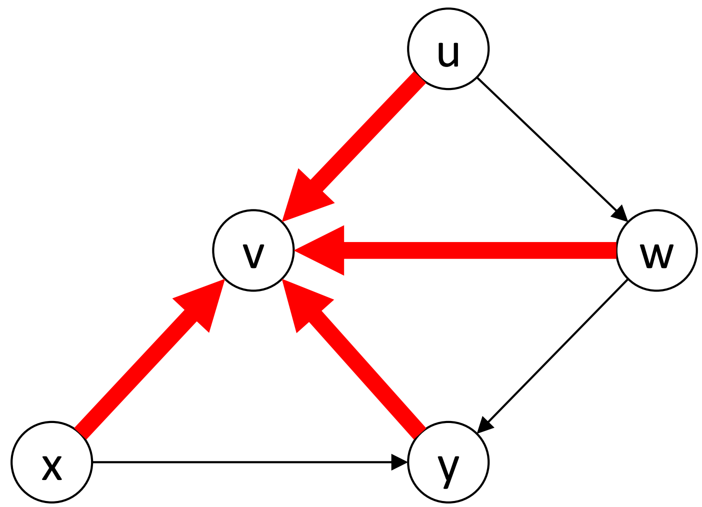


Specification:
Always: Neighboring clients are not in critical sections.
Eventually: Every client waiting to enter its critical section does so.
Given: Clients remain in critical sections for finite time.
Channels between neighbors.

Always: Priority graph is acyclic.
So: how should priorities change when a process eats?

v holds all its forks and eats

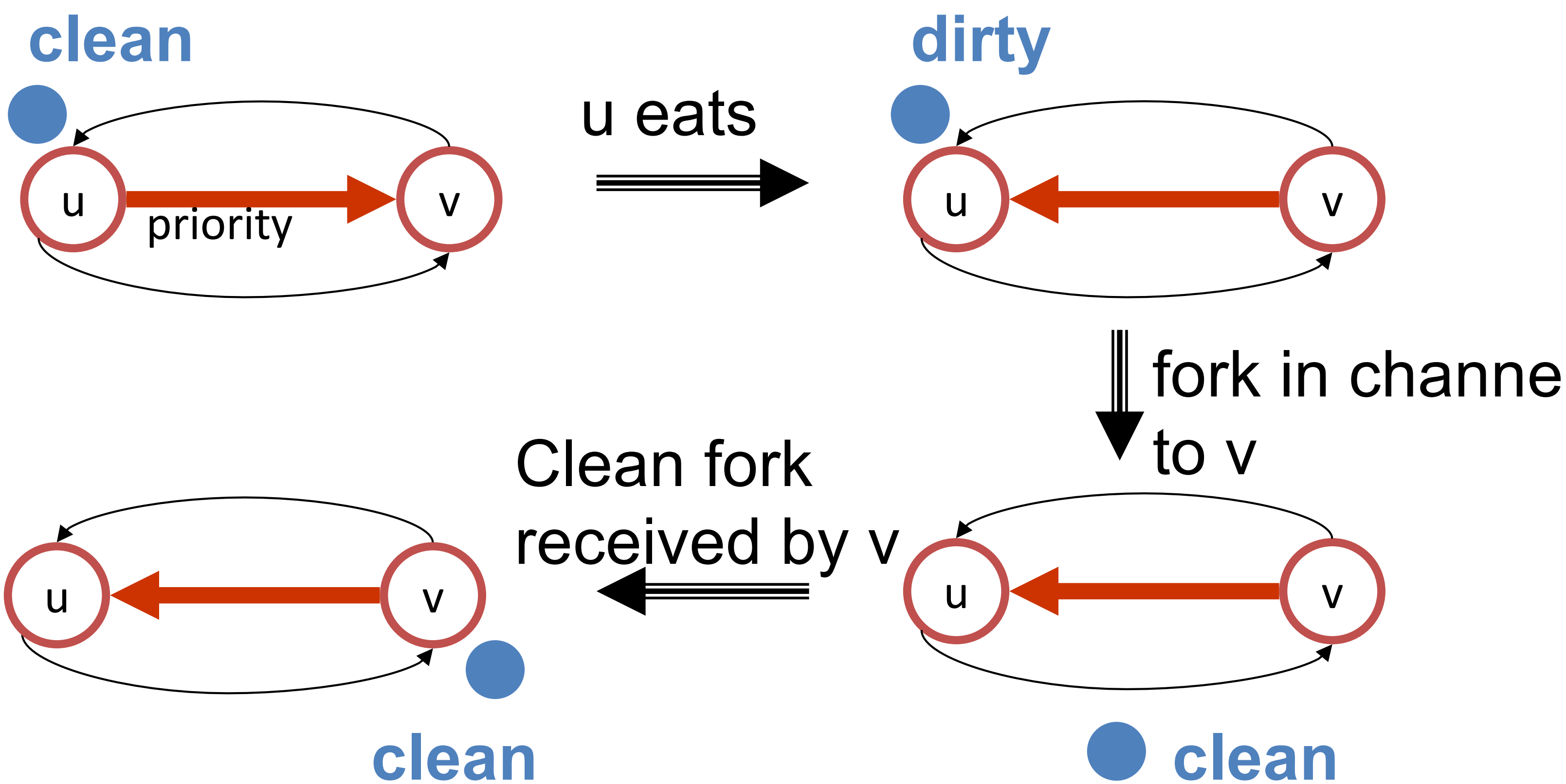




What should happen to edge directions when v eats?

- Make all edges directed towards v?

An agent holding a dirty fork has lower priority.
An agent holding a clean fork has higher priority
Fork in channel from u to v implies v has priority



Priority changes only when a clean fork becomes dirty

Always properties:

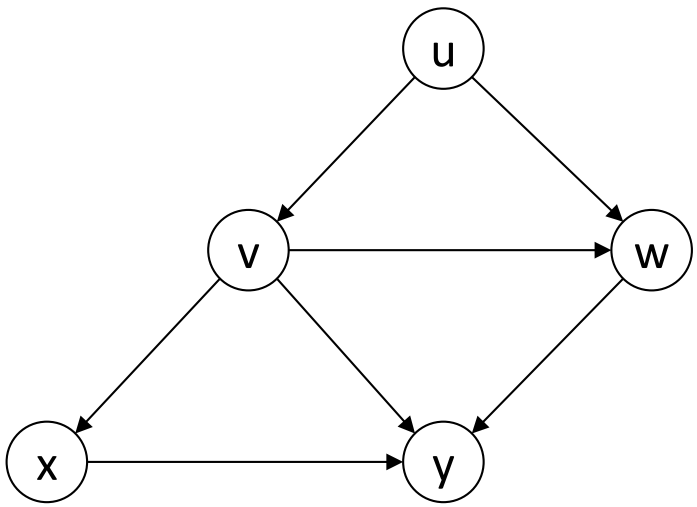
- Thinking philosopher does not hold clean forks. (It may hold dirty forks.)
- Eating philosopher holds all forks incident on it, and all these forks are dirty.
- A clean fork is either held by a hungry philosopher or is in a channel to a hungry philosopher.

Proposal for an algorithm

- Eating philosopher that gets a request for a fork sends the fork after it finishes eating. (If it does not get a request for a fork it holds on to it.)
- Thinking or hungry philosopher that gets a request for a fork sends the fork if it is dirty, and holds on to the fork if it is clean.

Is the algorithm correct? Safety: obvious. Progress? Not clear

What can go wrong? Can a philosopher y remain hungry for ever because it never gets a fork from a neighbor?



Suppose y becomes hungry. Can you think of a scenario where y never gets its forks?

Could a cabal of philosophers eat repeatedly and cause others to starve for ever?

The only way to prove progress:

Find a function *f* from states to a well-founded set such that:

Safety: No state transition takes the system further from its goal. **For all k: Stable(f < k)**

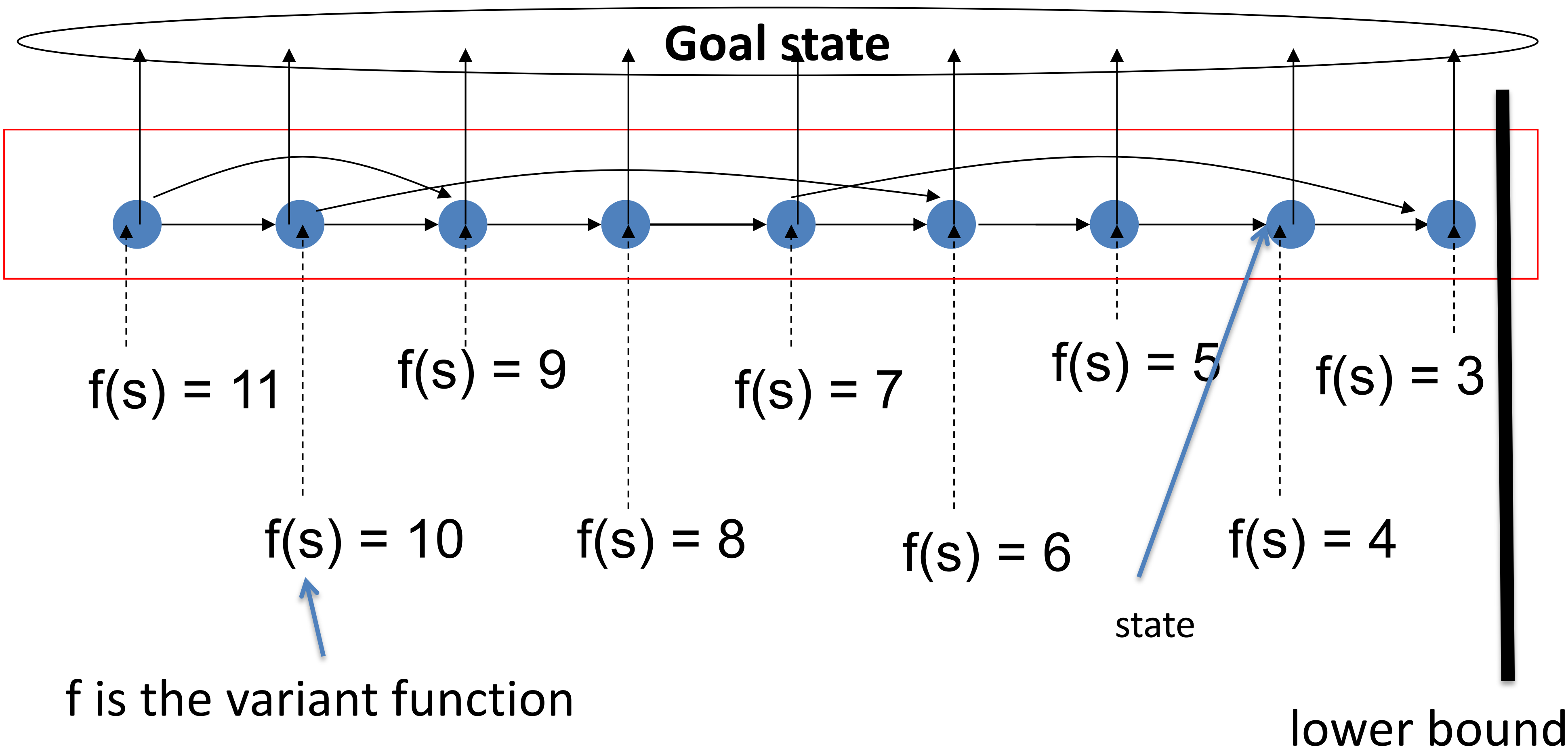
Progress: Eventually, a state transition occurs which takes the system closer to its goal:

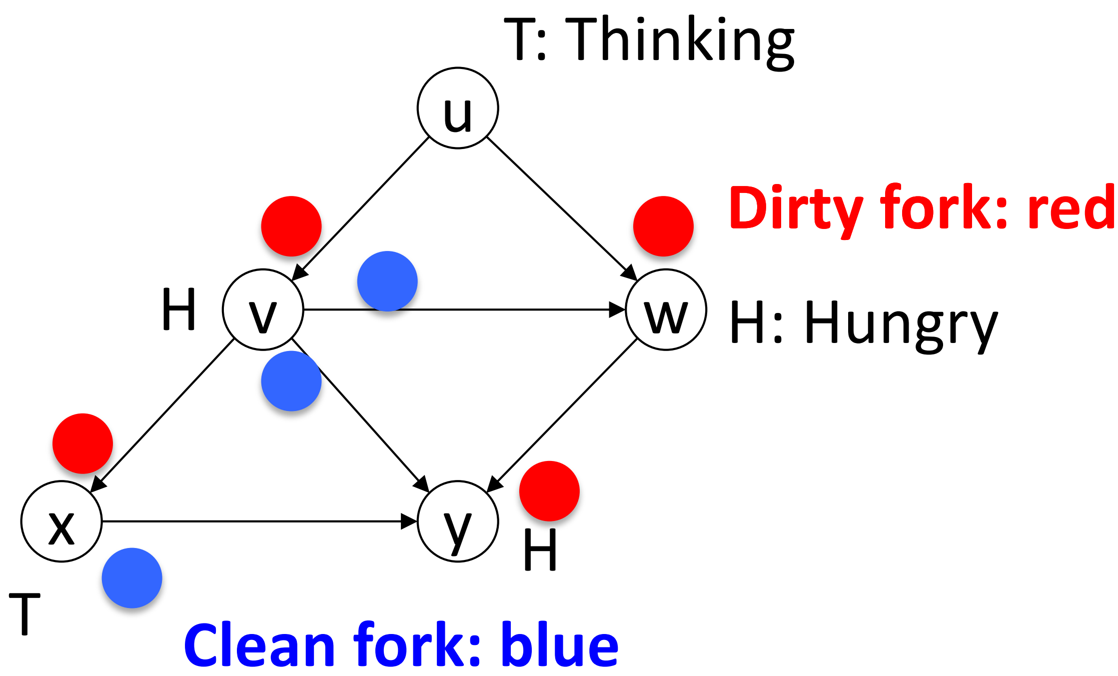
For all k: (not goal and f = k) leads-to (goal or f < k)

f is bounded below. Induction on well-founded sets tells us that f cannot decrease infinitely.

(Cannot carry out induction on some continuous functions. We prove convergence using limit arguments. See Lyapunov functions, CDS.)

Safety: Every transition reaches goal or decreases f
Progress: There exists a fair transition which either reaches goal or decreases f





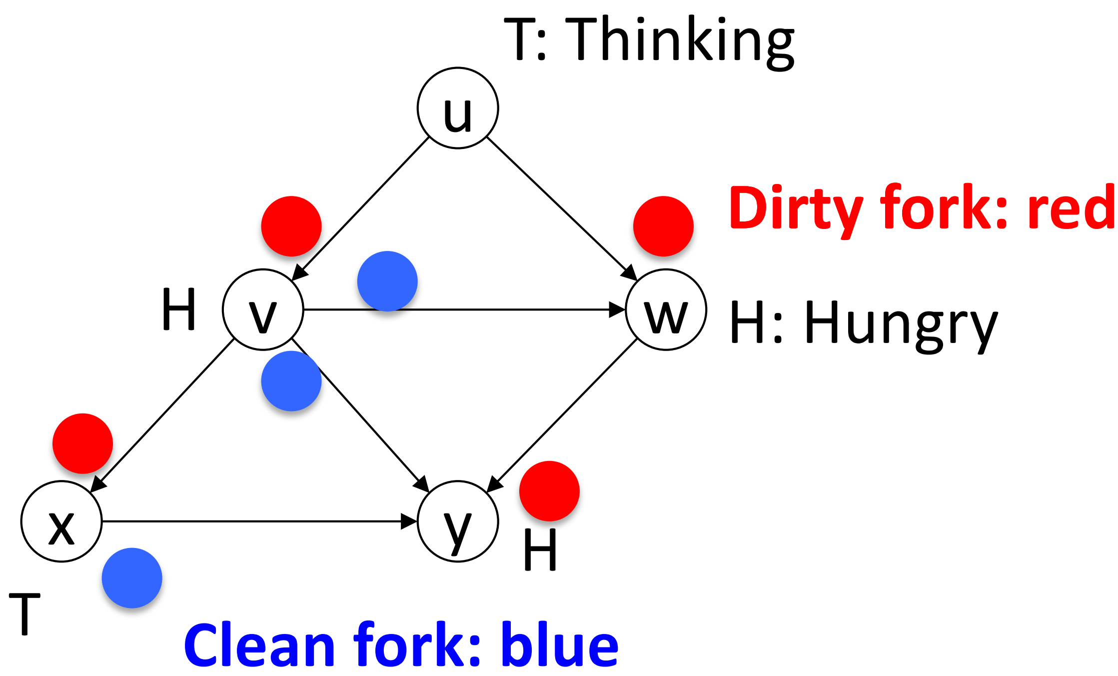
f(s):
Lexicographic ordering (number of higher priority thinking processes,
number of higher priority hungry processes)

Safety: No transition takes the system further from its goal.

Proof?

Consider transitions:

- thinking to hungry: decreases or no change to f
- hungry to eating: decreases or no change to f
- eating to thinking: no change to f



f(s):
Lexicographic ordering (number of higher priority thinking processes,
number of higher priority hungry processes)

Progress: Prove that there exists a fair transition which results in the goal or decreases f.

Proof outline: Highest priority hungry process transits to eating or a higher priority thinking neighbor transits to hungry.

Writing code for a message-passing process

When a process of type p gets a message of type m then:

1. p changes its local variables (i.e. its state)
2. Sends messages m’, m’’,.. to its neighbors.

Steps in coding:

- Identify message types
  - Between Client and OS: request, resource tokens
  - Between OS neighbors: forks, request
- Identify local variables:
  - OS: List of forks, requests that the process holds.
  - Client: list of tokens it holds.
- Write actions.