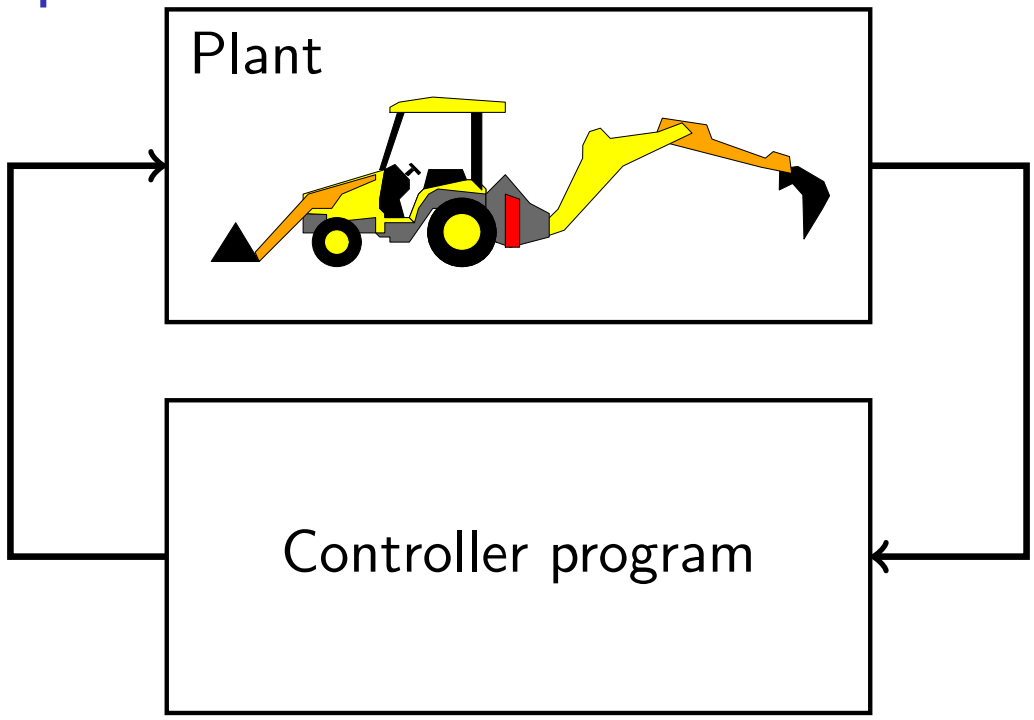
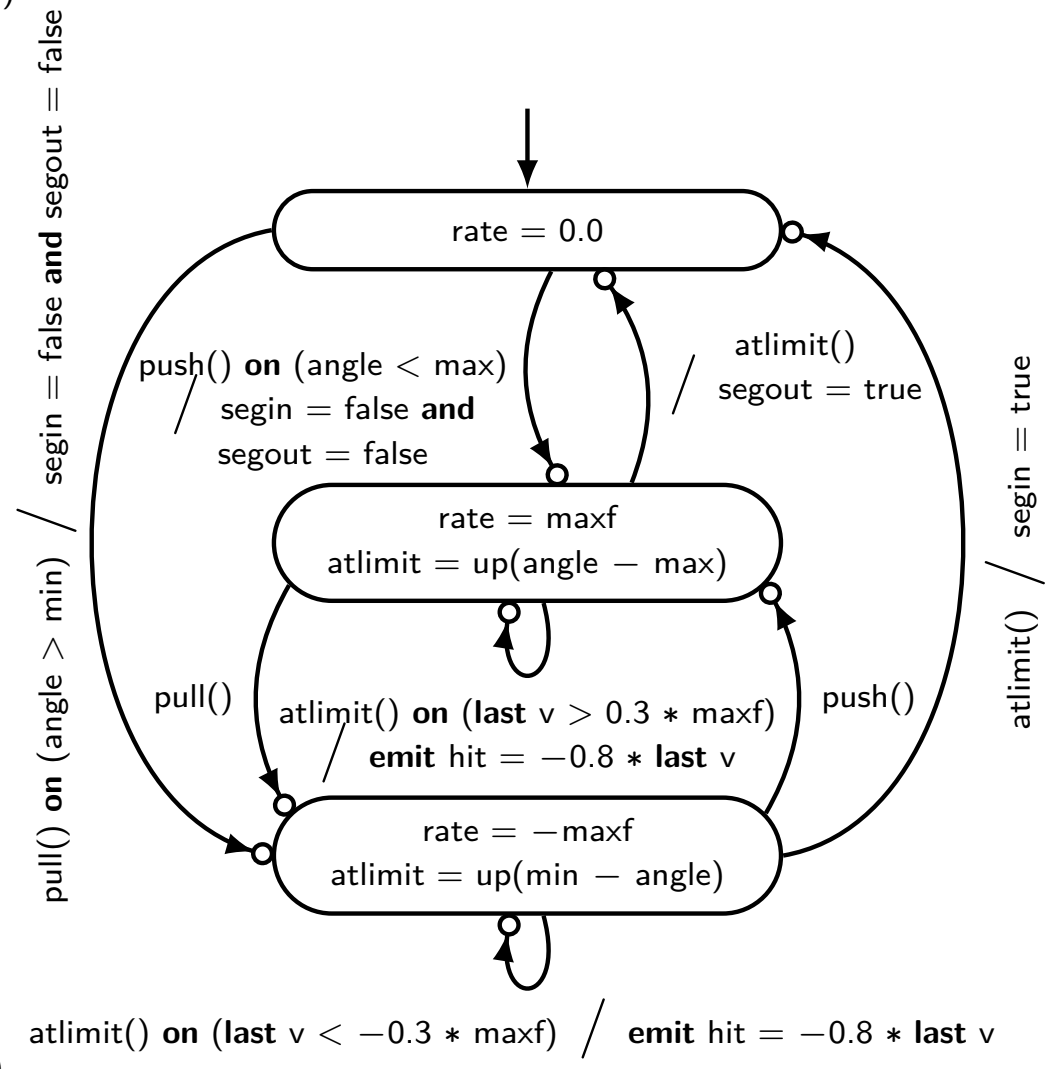
Backhoe example



- Intended for teaching reactive programming.
- The *controller* is a regular synchronous program.
- The *plant* dynamics are modeled using hybrid automata and first-order ODEs.
- The two interact via boolean flows and signals.
  Signals can be compared with 'edge triggering' (⌜/⌞) or 'function-call triggers' in Simulink.

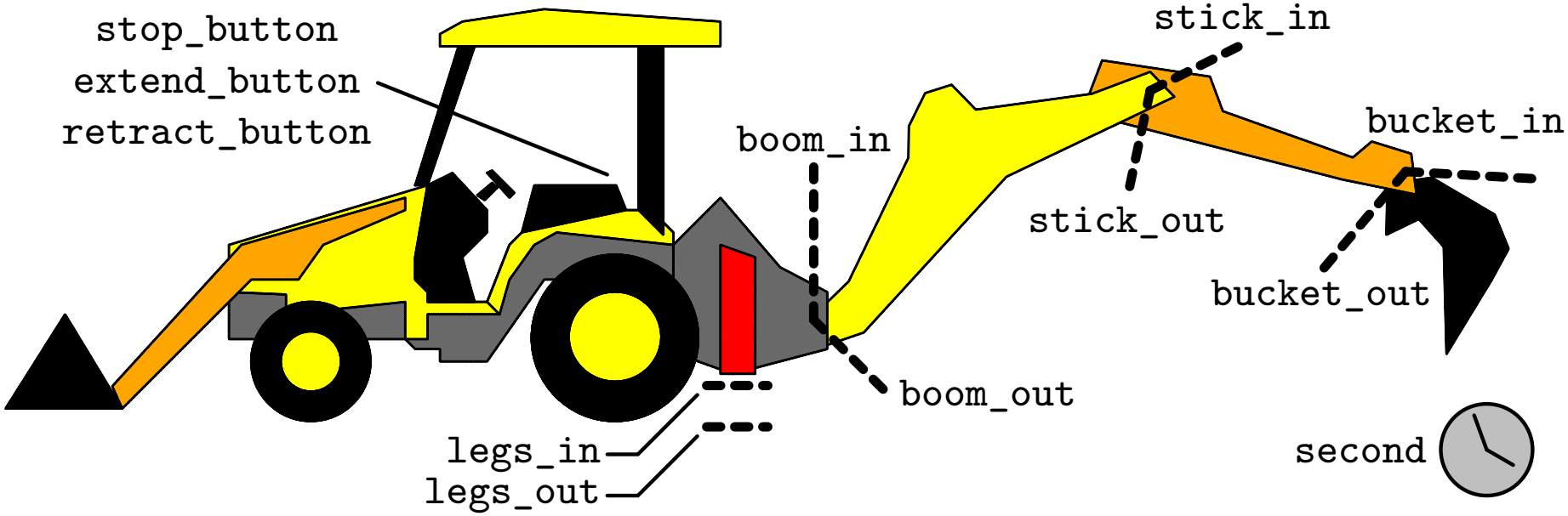
Modeling a segment

```
let hybrid segment ((min, max, i), maxf, (push, pull, go))
 = ((segin, segout), angle) where

 rec der angle = v init i
 and error = v_r −. v
 and der v = (0.7 /. maxf) ∗. error +. 0.3 ∗. z init 0.0
           reset hit(v0) → v0
 and der z = error init 0.0 reset hit(_) → 0.0
 and v_r = if go then rate else 0.0

 and init segin = angle <= min
 and init segout = angle >= max

 and automaton
   | Stuck → do rate = 0.0
     until push() on (angle < max) then
       do segin = false and segout = false in Pushing
     else  pull() on (angle > min) then
       do segin = false and segout = false in Pulling

   | Pushing → local atlimit in
     do rate = maxf and atlimit = up(angle −. max)
     until atlimit on (last v > 0.3 ∗. maxf) then do
             emit hit = −0.8 ∗. last v in Pushing
     else (atlimit) then do segout = true in Stuck
     else pull() then Pulling

   | Pulling → local atlimit in
     do rate = −. maxf and atlimit = up(min −. angle)
     until atlimit on (last v < −0.3 ∗. maxf) then do
             emit hit = −0.8 ∗. last v in Pulling
     else  (atlimit) then do segin = true in Stuck
     else  push() then Pushing
```



Backhoe: sensors and actuators

Sensors (plant outputs / controller inputs)



Actuators (plant inputs / controller outputs)

alarm_lamp	legs_extend	boom_pull	stick_pull	bucket_pull
done_lamp	legs_retract	boom_push	stick_push	bucket_push
cancel_lamp	legs_stop	boom_drive	stick_drive	bucket_drive

(pull = in; push = out)