CS 839: Systems Verification

# Lecture 18: Lock invariants

## Learning outcomes

1. Understand how concurrent separation logic extends sequential separation logic
2. Recall the rules for using lock invariants

## Concurrent separation logic

1. Semantics is different, so need new soundness theorem
2. Need a rule for $\mathrm{spawn}$
3. What else do we need to verify real programs?

**Definition** (*CSL soundness*): For some pure $\Phi(v)$ (a Prop), if $\{P\}\ e\ \{\lambda v\, \Phi(v)\}$ and $([e], h) \rightsquigarrow_{tp} ([e'] +\!\!+ T, h')$, then if $e'$ is an expression then $([e'] +\!\!+ T, h')$ is not stuck, or $e' = v'$ for some value $v'$ and $\Phi(v')$ holds. Furthermore, no thread in $T$ is stuck in $h'$.

## Exercise: soundness for spawned threads

Suppose we said (T, h) is stuck only if *no* threads could take a step.

What does soundness say now?

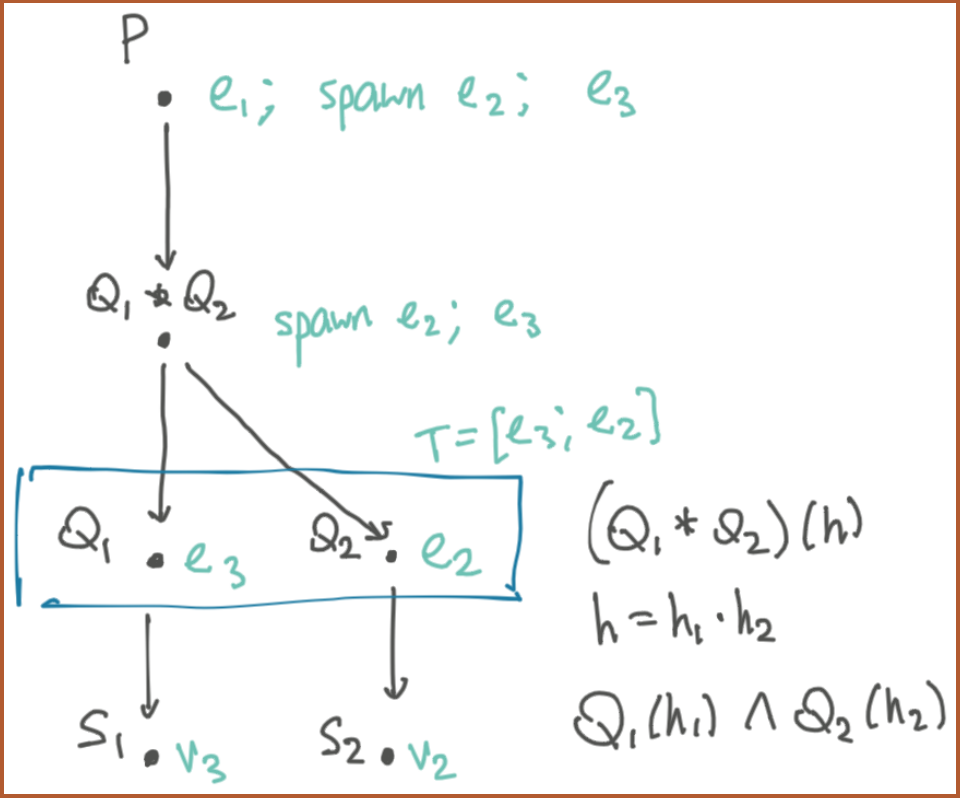
What program and specification would be true now that wasn't before?

## Reasoning about spawn

$$\frac{\{P\}\ e'\ \{Q\}}{\{\mathrm{wp}(e, True) * P\}\ \mathrm{spawn}\, e;\ e'\ \{Q\}}$$

This rule is actually just framing P around the call to spawn, but it's easier to follow how this would work.

Note that the wp(e, _) here can only be used once - it's not a Hoare triple.




Intuition behind CSL: resources are split and transferred to other threads. Similar to how we sent resources to function calls, except this time both the spawned thread and the following code are running; with a function we waited for it to finish before proceeding.

# Code demo

# Locks (`sync.Mutex`)

```
// a zero sync.Mutex is an unlocked mutex
func (m *sync.Mutex) Lock()
func (m *sync.Mutex) Unlock()
```

## Lock invariants

$$\{R\}\ m := \text{NewMutex}\ ()\ \{\text{isLock}(m, R)\}$$

$$\{\text{isLock}(\ell_m, R)\}\ \text{Lock}\ \ell_m\ \{R\}$$
$$\{\text{isLock}(\ell_m, R) * R\}\ \text{Unlock}\ \ell_\text{m}\ \{True\}$$

## Exercise: mutex invariant

Suppose we could get $isLock(\ell, R_1) * isLock(\ell, R_2)$ (note the same mutex). What would go wrong?

More code demo