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Writing Robust and Maintainable Concurrent Program

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What lessons can we learn from food seller about concurrency?

Making of kue lapis sagu

Making of kue lapis sagu

```
def build_layer(tray):
    start_mixer()
    pour_colour_mixture(colorama.Back.MAGENTA, tray)
    pour_colour_mixture(colorama.Back.GREEN, tray)
    pour_colour_mixture(colorama.Back.WHITE, tray)
```

Making of kue lapis sagu

```
def build_layer(tray):
    start_mixer()
    pour_colour_mixture(colorama.Back.MAGENTA, tray)
    pour_colour_mixture(colorama.Back.GREEN, tray)
    pour_colour_mixture(colorama.Back.WHITE, tray)

def start_mixer():
    perform_operation(1.0)

def pour_colour_mixture(color, tray):
    perform_operation(0.005)
    tray.append(color + '                    ')
```

Making of kue lapis sagu

```
def main():
    tray = []
    for _ in range(4):
        build_layer(tray)
```

Multithreading

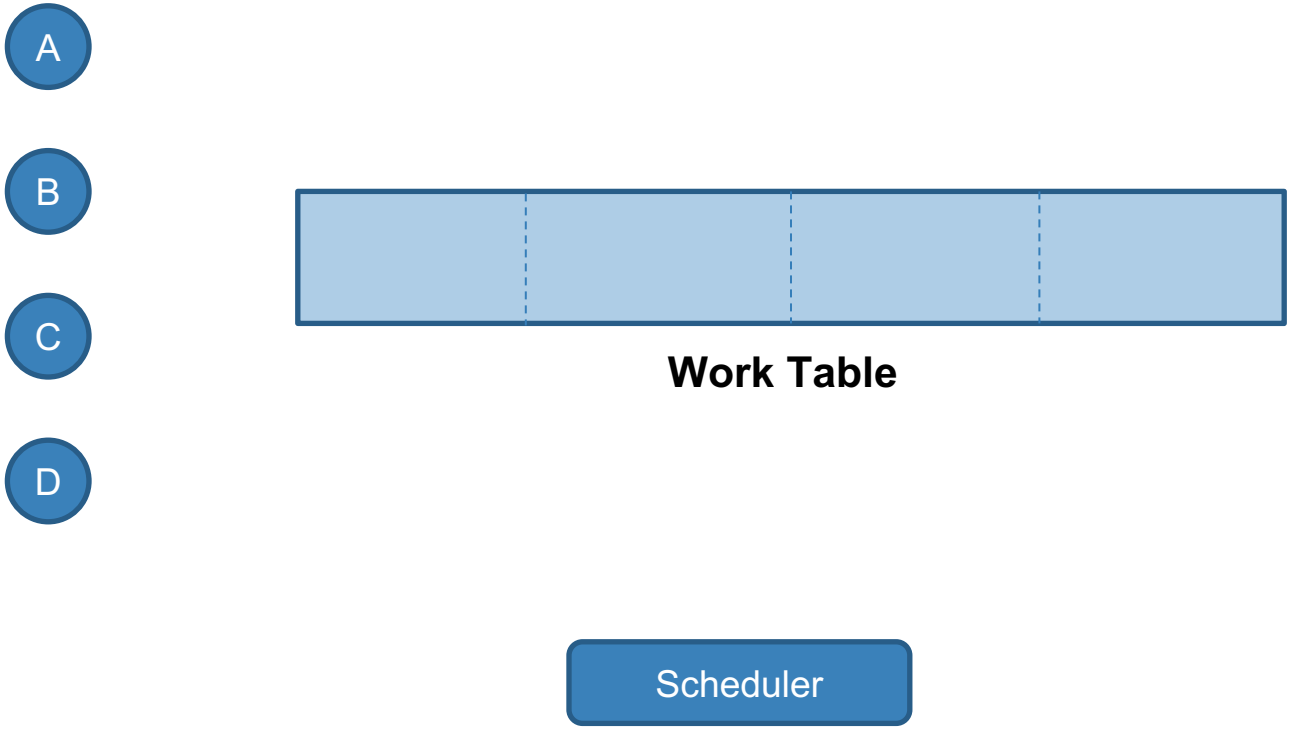
```
from threading import Thread

def main_thread():
    tray = []
    for _ in range(4):
        t = Thread(target=build_layer, args=(tray,))
        t.start()
```

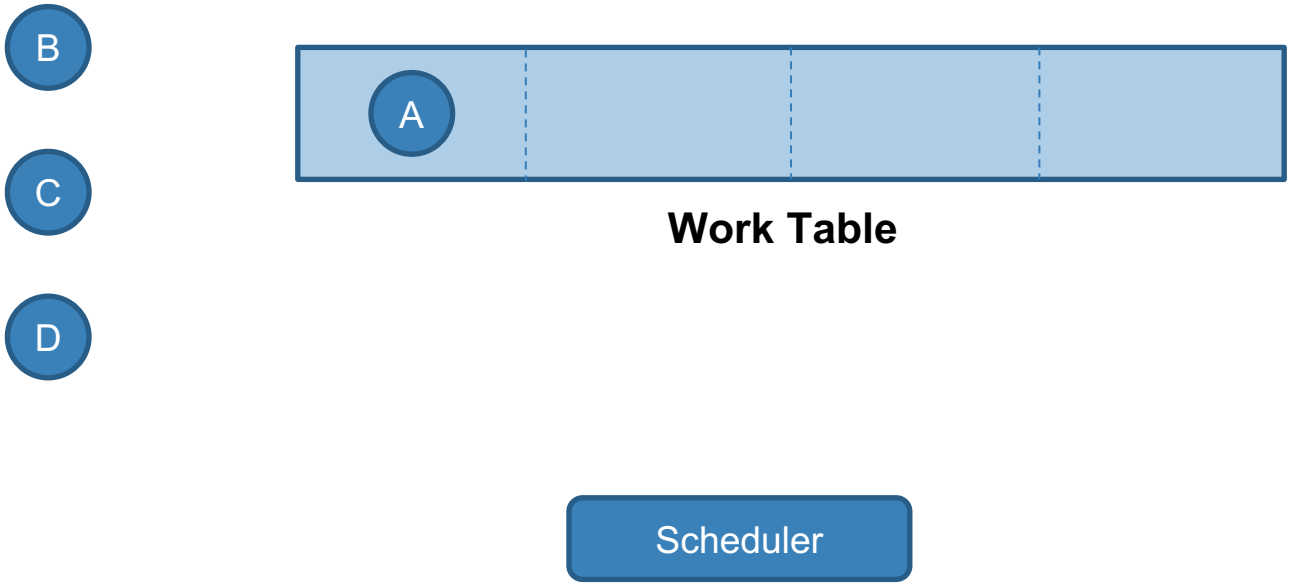
Multithreading

- Python interpreter is not thread safe
- GIL (Global Interpreter Lock) ensures that only 1 thread can run at a time

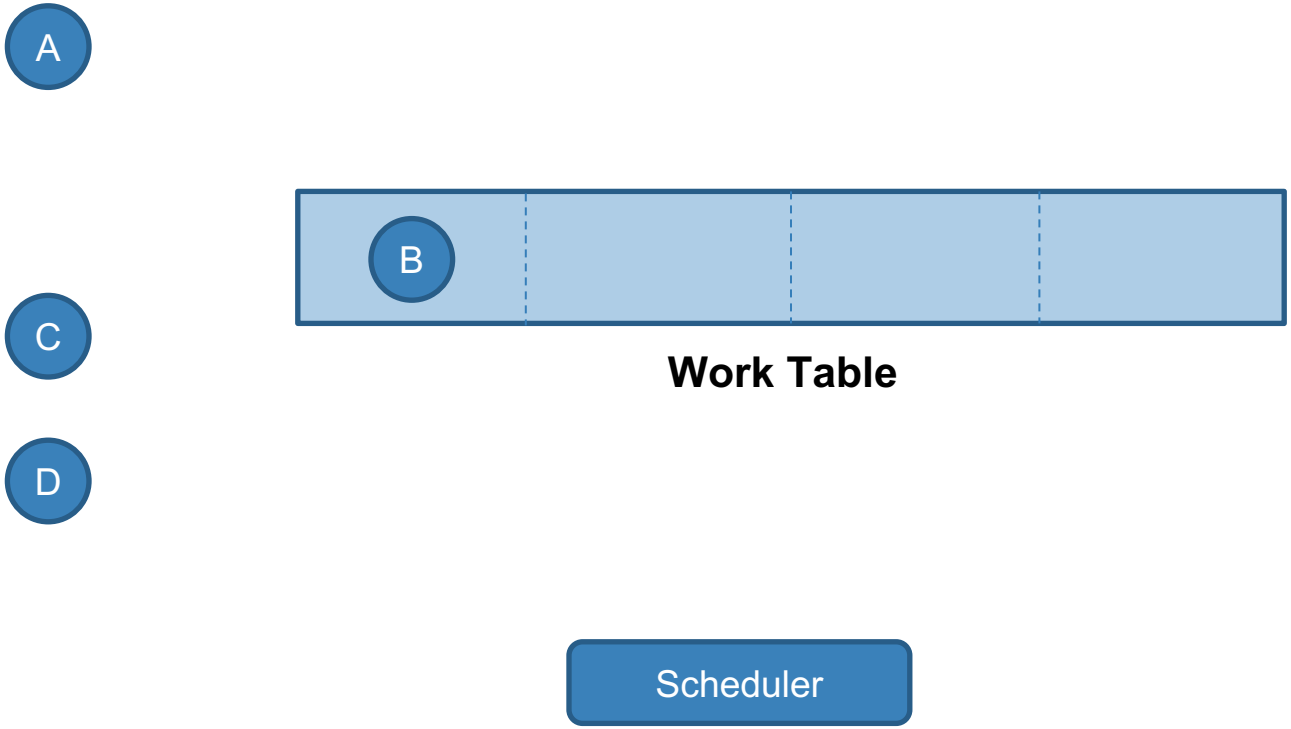
Multithreading



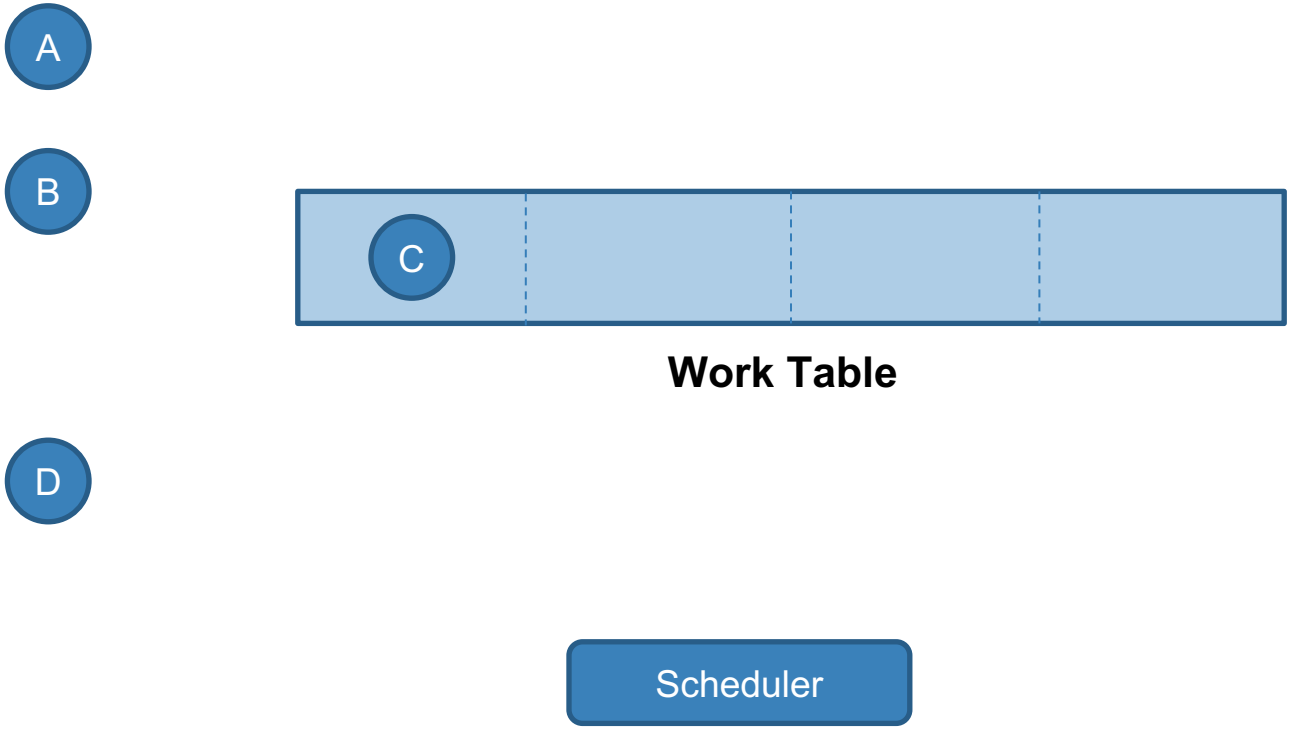
Multithreading



Multithreading



Multithreading



What is the purpose of threading then?

Multithreading

I/O Operation vs Compute Operation

- Compute operation occurs in processor
- I/O operation occurs outside the processor

Examples

- Disk operation
- Network operation
- Http call or web api
- Sleep

Multithreading

```
def start_mixer():
    perform_io_operation(1.0)
```

Tip 1: Use multithreading for I/O operation

Watch out for synchronization problem due to preemption

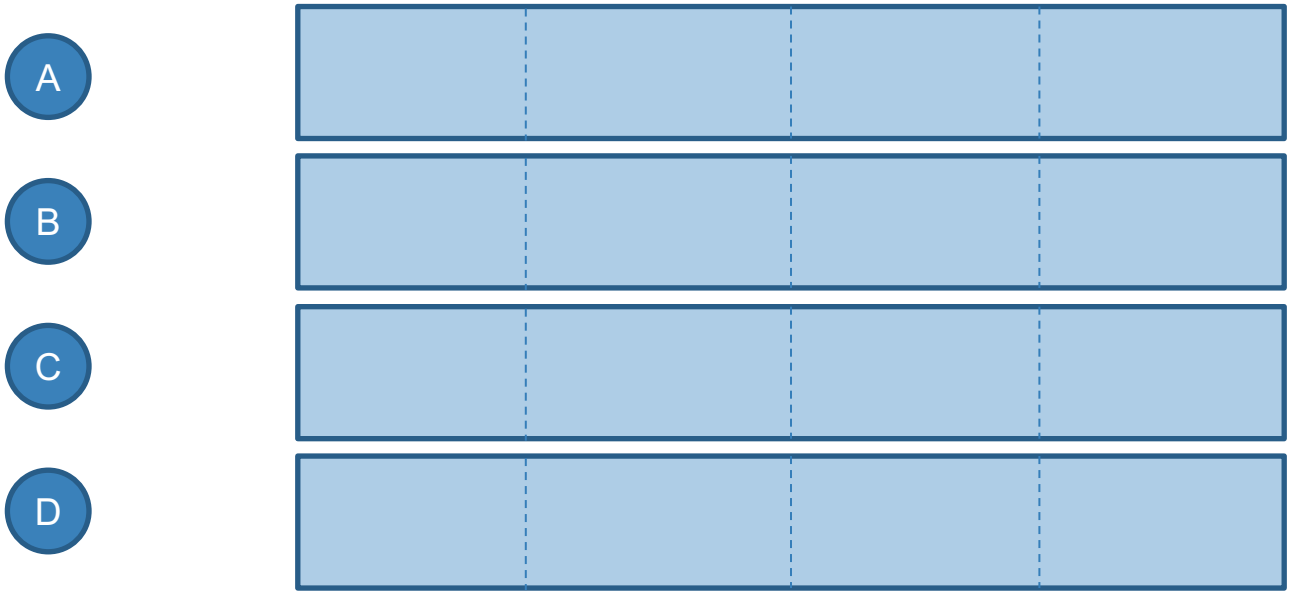
What if I want to achieve parallelism?

Multiprocessing

```
from multiprocessing import Process, Queue

def main():
    tray = []
    result = Queue()
    for _ in range(4):
        p = Process(target=build_layer, args=(tray, result))
        p.start()
```

Multiprocessing



Tip 2: Use multiprocessing to achieve parallelism in compute operation

Watch out for the need for serialization

The synchronization problem

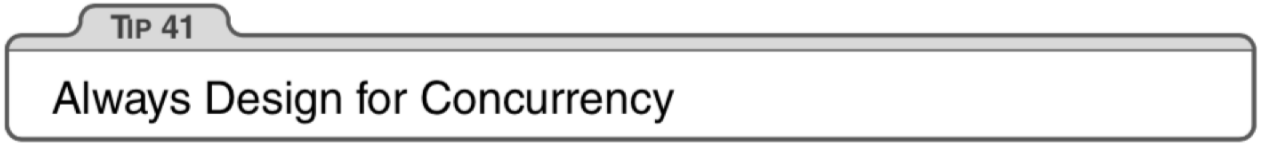
Solution 1: Use lock?

```
lock = Lock()

def build_layer(tray):
    start_mixer()
    with lock:
        pour_colour_mixture(colorama.Back.MAGENTA, tray)
        pour_colour_mixture(colorama.Back.GREEN, tray)
        pour_colour_mixture(colorama.Back.WHITE, tray)
```

Solution 2: Always design for concurrency

The Pragmatic Programmer by Andrew Hunt and David Thomas



- **To Prevent:** Programming by coincidence

No shared state & No side effect

```
def main_thread():
    tray = []
    for _ in range(4):
        t = Thread(target=build_layer, args=(tray,))
        t.start()
```

No shared state

No shared state

```
def main_thread():
    result = []
    threads = []
    for _ in range(4):
        tray = []
        t = Thread(target=build_layer, args=(tray,))
        t.start()
        threads.append(t)
        result.append(tray)
    for t in threads:
        t.join()

    final_tray = reduce(lambda acc, tray: acc + tray, result, [])
```

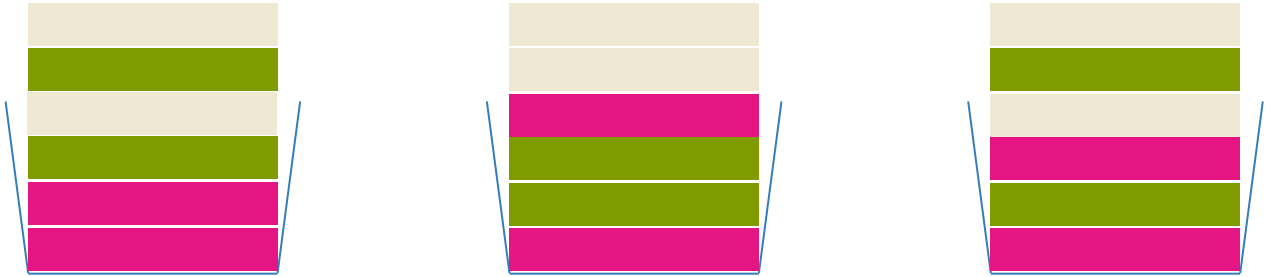
No shared state

```
from concurrent.futures import ThreadPoolExecutor

def main_pool():
    with ThreadPoolExecutor() as pool:
        result = pool.map(build_layer, range(4))
    final_tray = reduce(lambda acc, tray: acc + tray, result, [])
```

Idempotent state

The meaning of the state does not change, even when updates to the state do not happen in the same sequence.



Idempotent state

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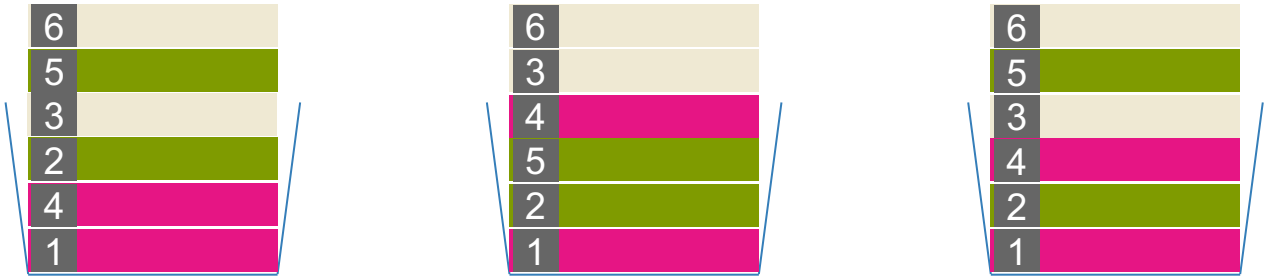


Idempotent state

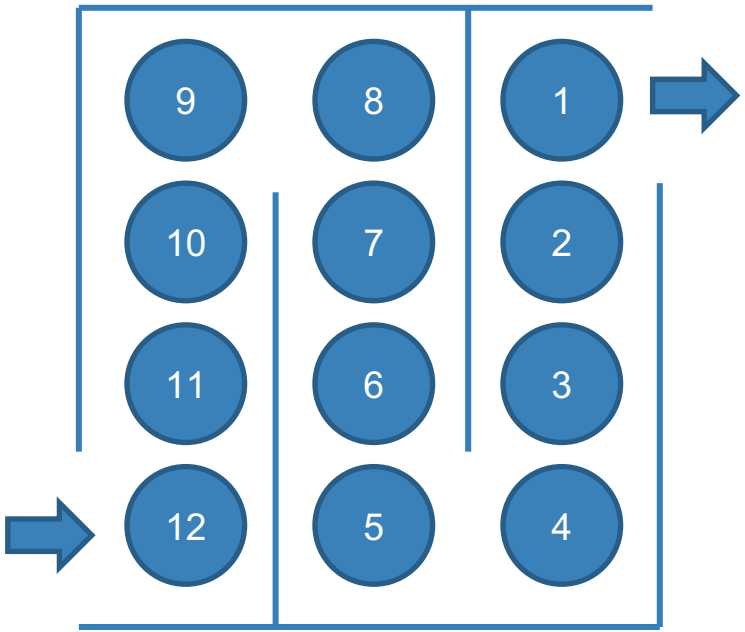
Further discussion: Final chapter of
“Seven Concurrency Models in Seven Weeks” by Paul Butcher

Design for concurrency

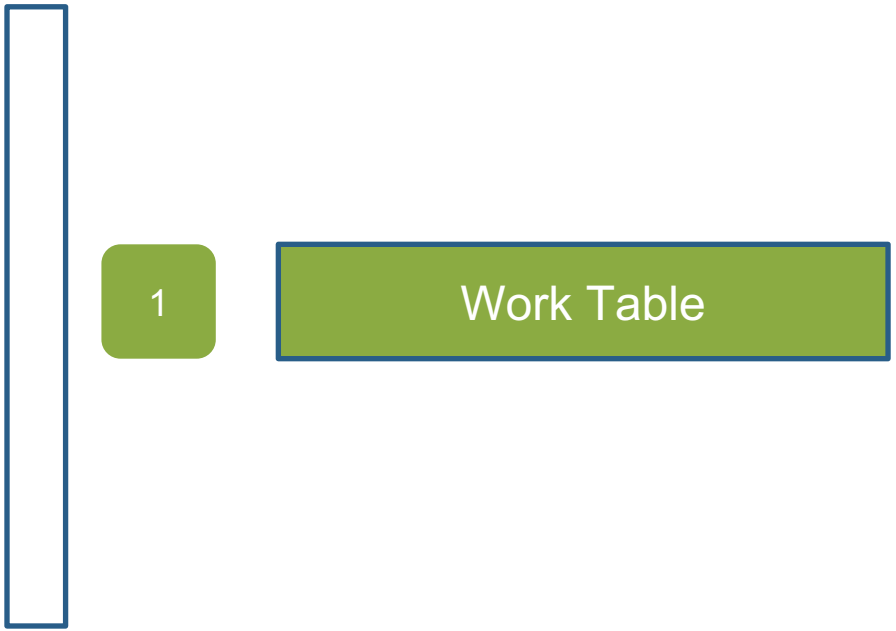
Tip 3: No shared state & no side effect
Tip 4: Use pool.map from concurrent.futures
Tip 5: Have an idempotent state

Once we have designed code for concurrency, we can apply different concurrent model easily.

Restaurant queue



12 Customers in the queue

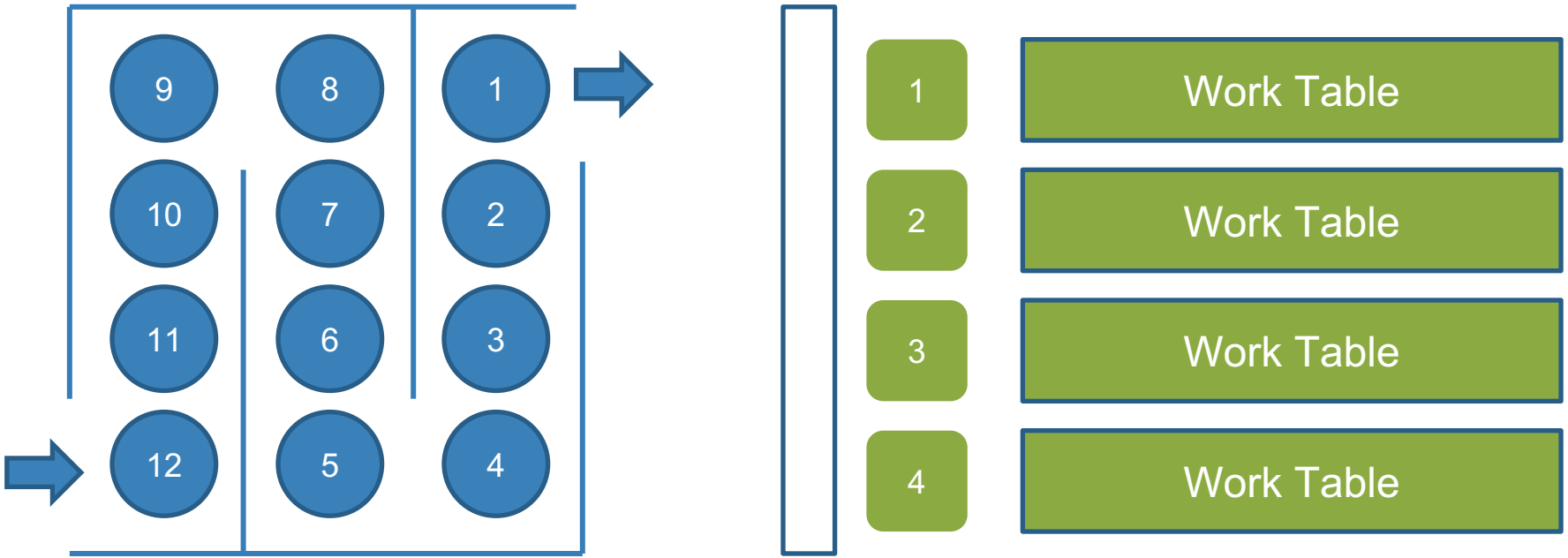


Restaurant queue

```
def prepare_order(_):
    take_order(_)
    prepare_sandwich()
    prepare_kue_lapis()
    prepare_ice_cream()
    prepare_milk_shake()
```

Try embarrassingly parallel

Embarrassingly Parallel



12 Customers in the queue

Embarrassingly Parallel

```
def main_multi_process(num_of_customer):
    with ProcessPoolExecutor(4) as pool:
        pool.map(prepare_order, range(num_of_customer))
```

Look for I/O operations,

and implement fan-out fan-in model

Fan-out fan-in

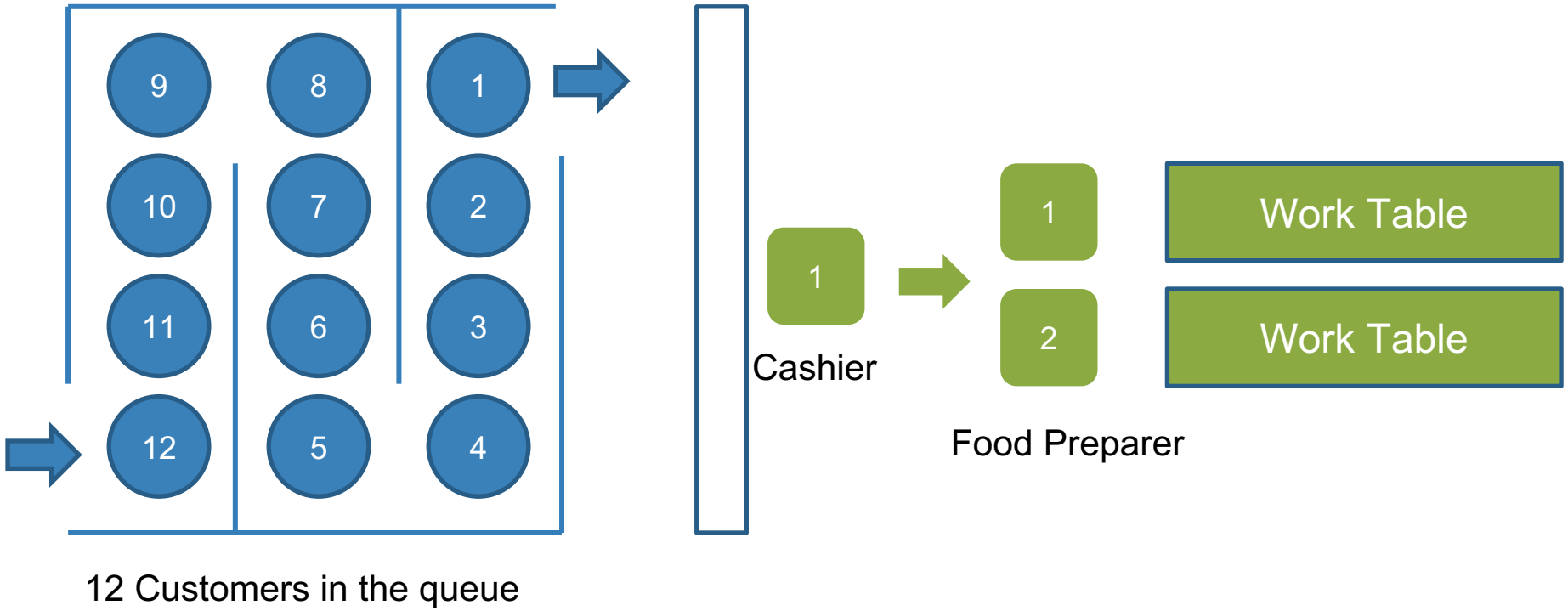
Pycon 2014 by Brett Slatkin on fan-out and fan-in: https://youtu.be/CWmq-jtkemY

Fan-out fan-in (using asyncio)

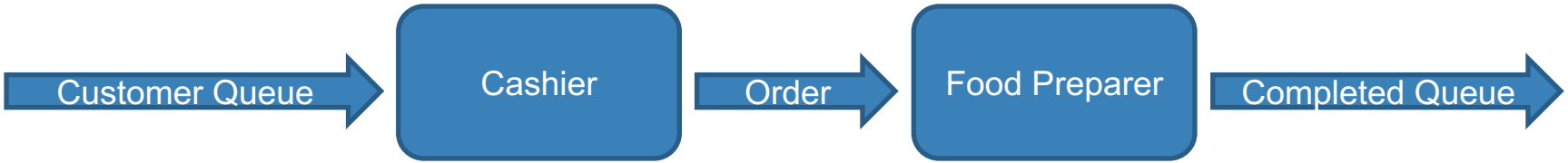
```
async def prepare_food():
    awaiting_kue_lapis = prepare_kue_lapis()
    awaiting_milk_shake = prepare_milk_shake()
    prepare_sandwich()
    prepare_ice_cream()
    await asyncio.wait([awaiting_kue_lapis, awaiting_milk_shake])
```

Try pipelining

Producer Consumer Queue



Producer Consumer Queue



Producer Consumer Queue

```
def main(num_of_user):
    customer_queue = multiprocessing.JoinableQueue()
    order_queue = multiprocessing.JoinableQueue()
    completed_queue = multiprocessing.Queue()

    cashier = Actor(customer_queue, order_queue, take_order)
    preparer1 = Actor(order_queue, completed_queue, prepare_order)
    preparer2 = Actor(order_queue, completed_queue, prepare_order)

    cashier.start()
    preparer1.start()
    preparer2.start()

    for user_no in range(num_of_user):
        customer_queue.put(user_no + 1)
```

Summary

- Always design for concurrency
- Understand the basic building block of concurrency in Python
- Make use of the appropriate concurrency model.

THANK YOU

For questions or suggestions:

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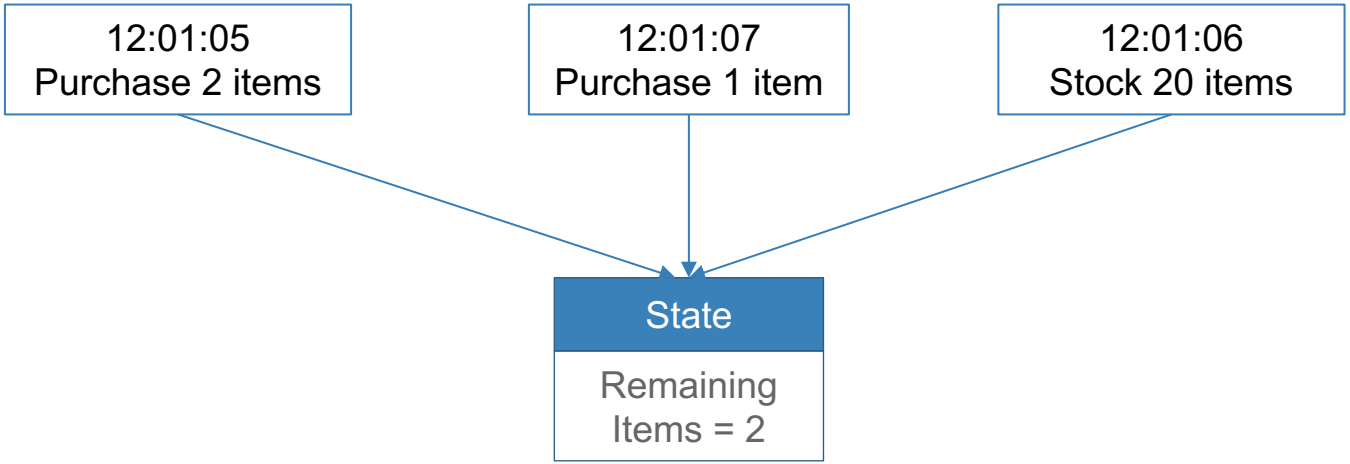
Idempotent state

Inventory management system



Idempotent state

Store transaction events which can be played back to calculate the total remaining item.

Idempotent State
12:01:05 Purchase 2 items
12:01:07 Purchase 1 item
12:01:06 Stock 20 items