Boosting Simulation Performance with Python

Eran Friedman

Fabric

COMMONSENSE ROBOTICS

Outline

- Importance of simulations
- Simulation architecture
- SimPy library
- Implementation and challenges
- Distributed simulation

1024

Simulation

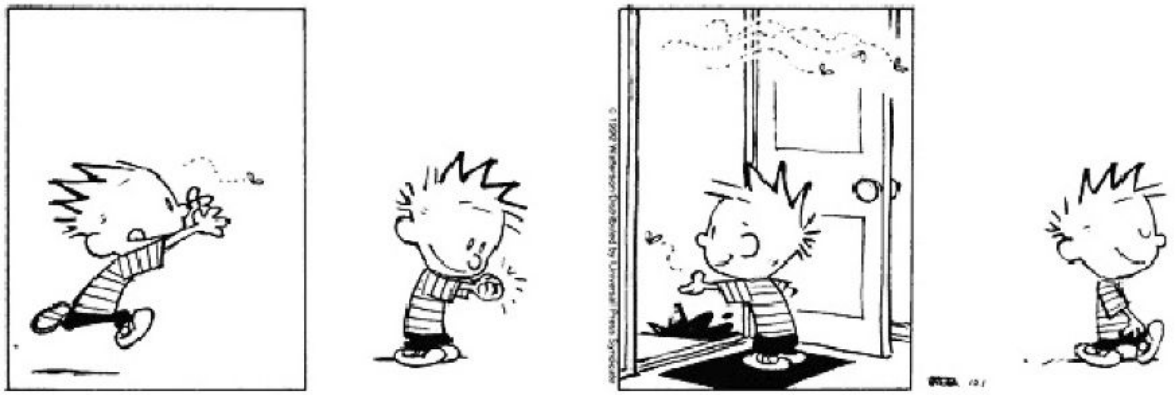
> *“An approximate imitation of the operation of a process or system …”*
>
> - Wikipedia

Importance of Simulations

Automated regression tests

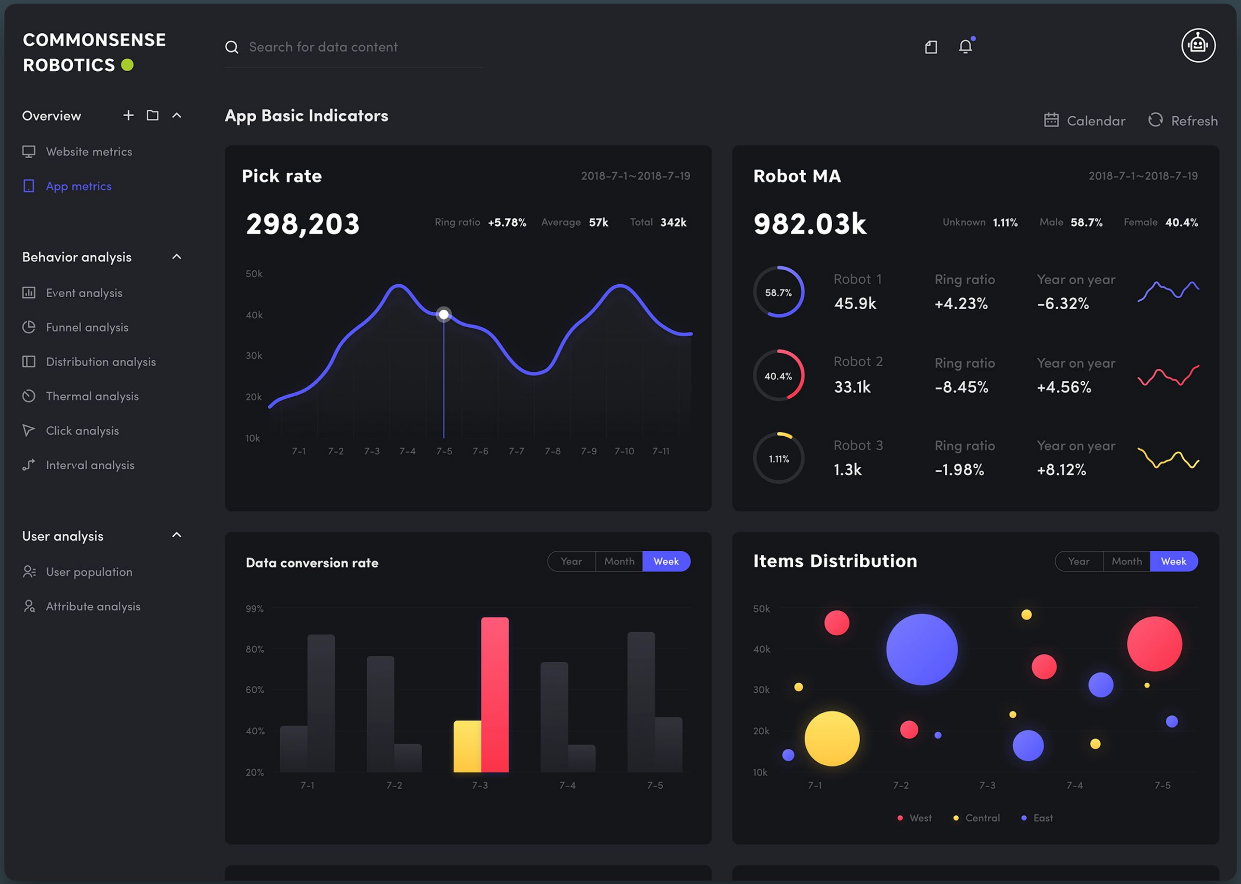
Regression:

“when you fix one bug, you introduce several newer bugs.”



Importance of Simulations

Analyze performance & compare algorithms



Importance of Simulations

Run in the cloud

Importance of Simulations

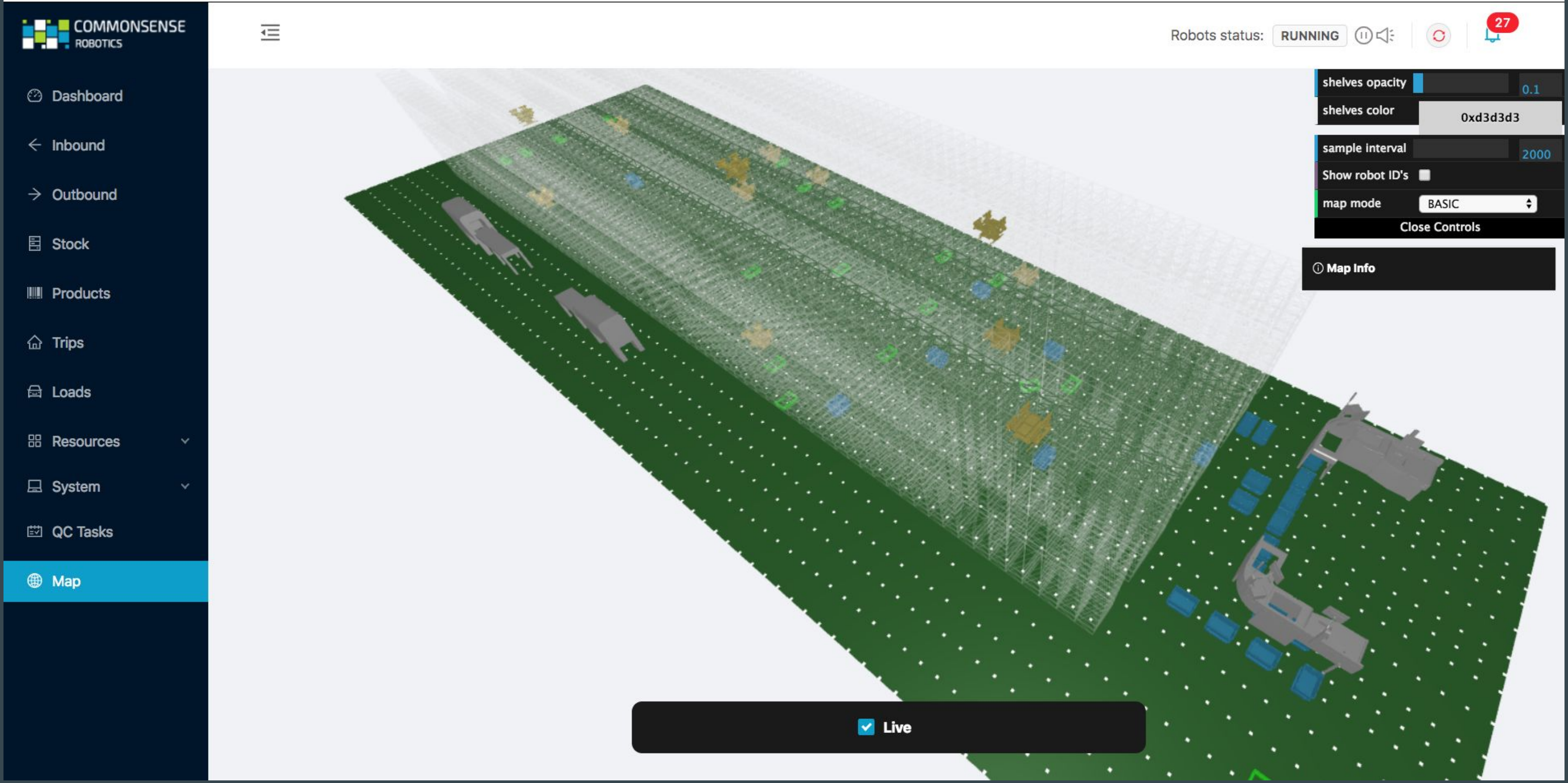
Verify warehouse layout

Importance of Simulations

Inject failures & improve robustness

Importance of Simulations

Simulate a large facility



Robots status: RUNNING

shelves opacity 0.1

shelves color 0xd3d3d3

sample interval 2000

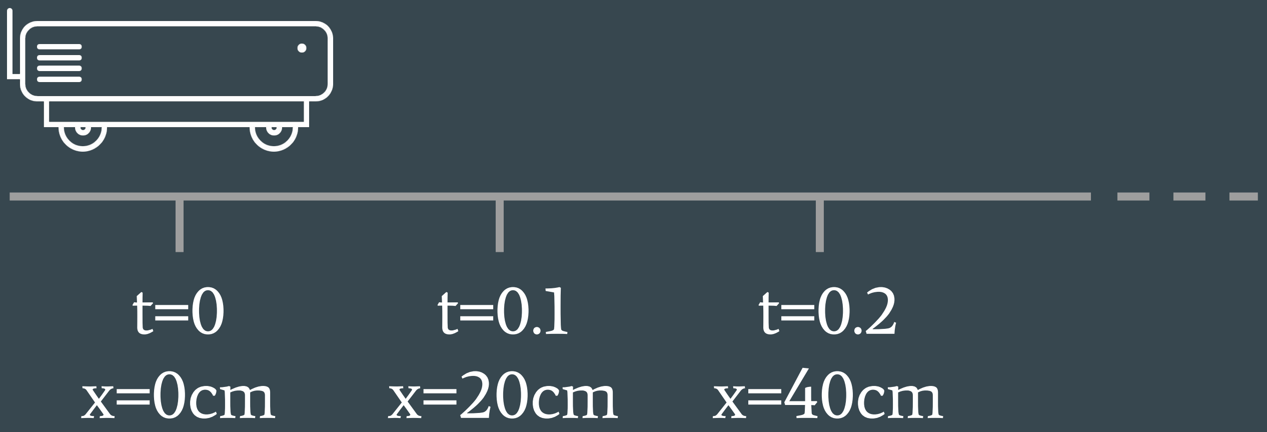
Show robot ID's □

map mode BASIC

☑ Live

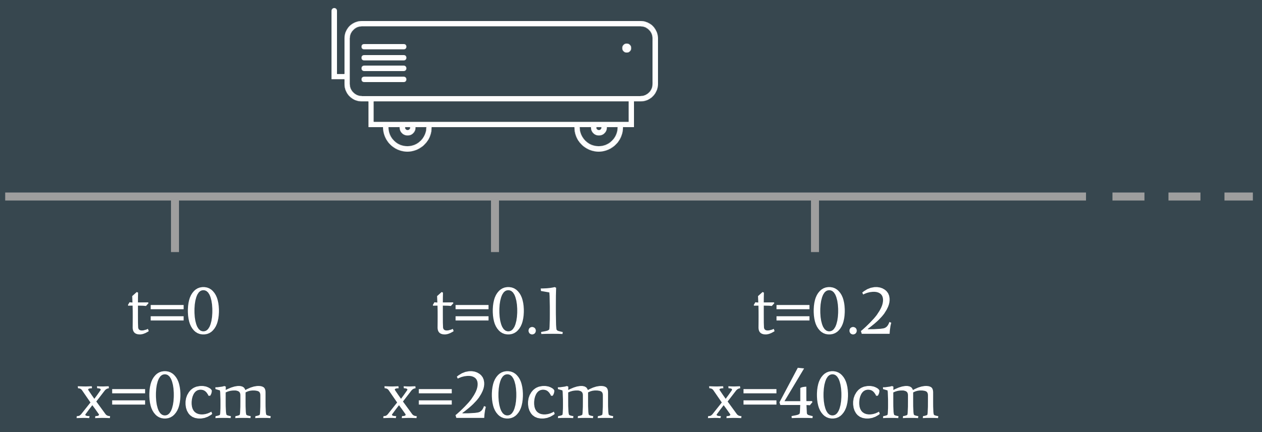
Discrete-Event Simulation (DES)

- Operations are modeled as sequence of events
- Simulation jumps to the next event
- Simulation maintains its own clock
- Example: 2 m/s, 10 time-ticks/second



Discrete-Event Simulation (DES)

- Operations are modeled as sequence of events
- Simulation jumps to the next event
- Simulation maintains its own clock
- Example: 2 m/s, 10 time-ticks/second



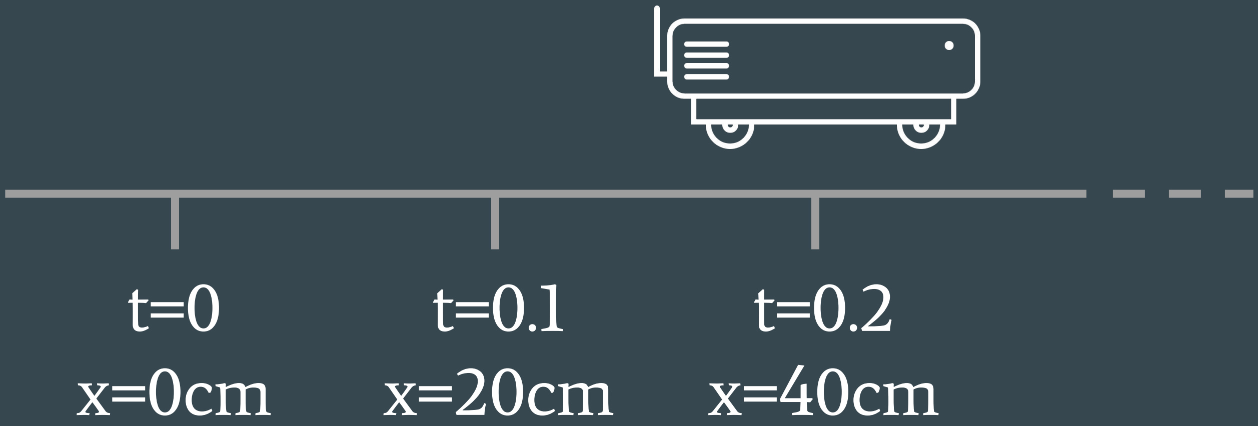
t=0
x=0cm

t=0.1
x=20cm

t=0.2
x=40cm

Discrete-Event Simulation (DES)

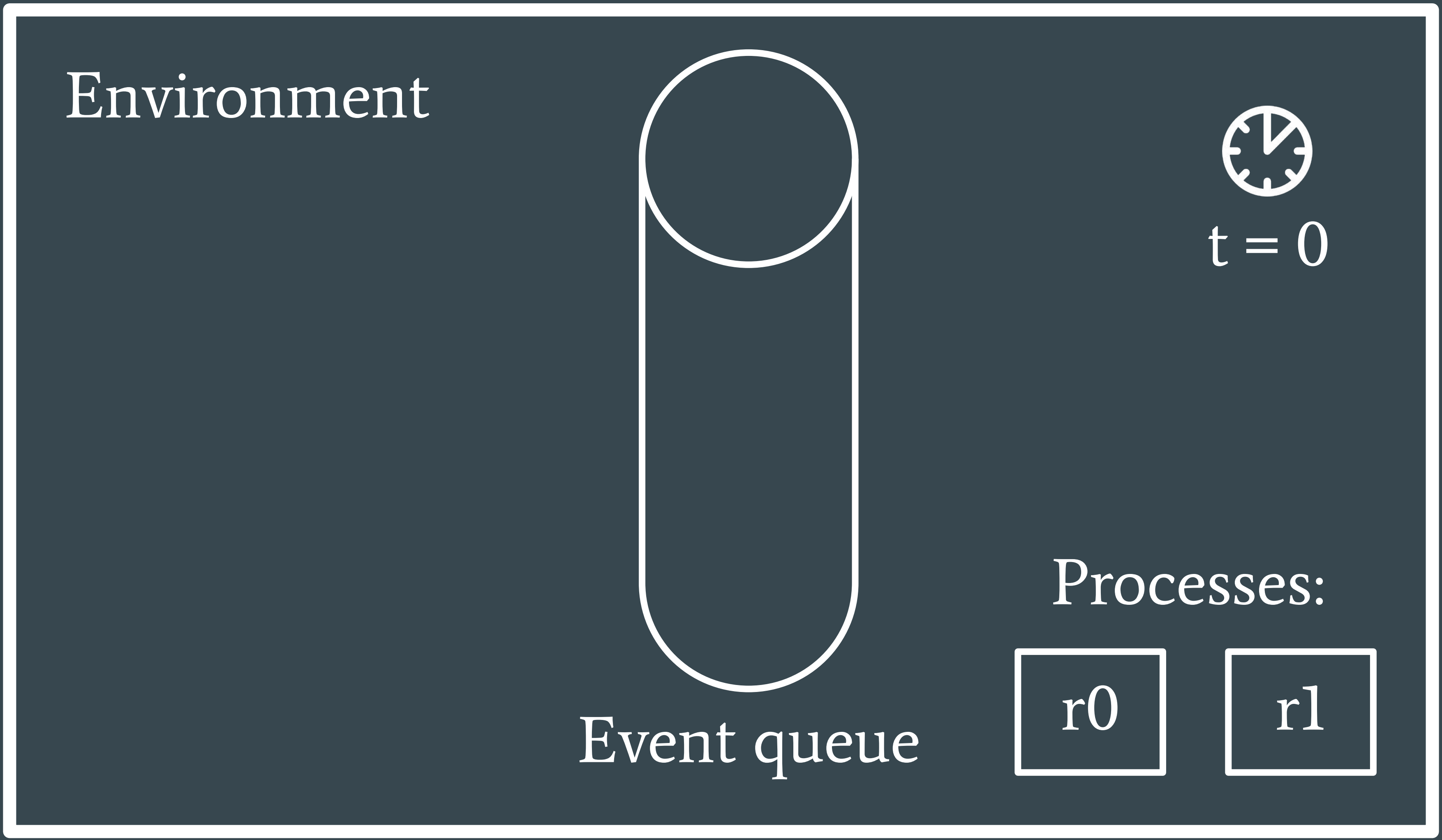
- Operations are modeled as sequence of events
- Simulation jumps to the next event
- Simulation maintains its own clock
- Example: 2 m/s, 10 time-ticks/second



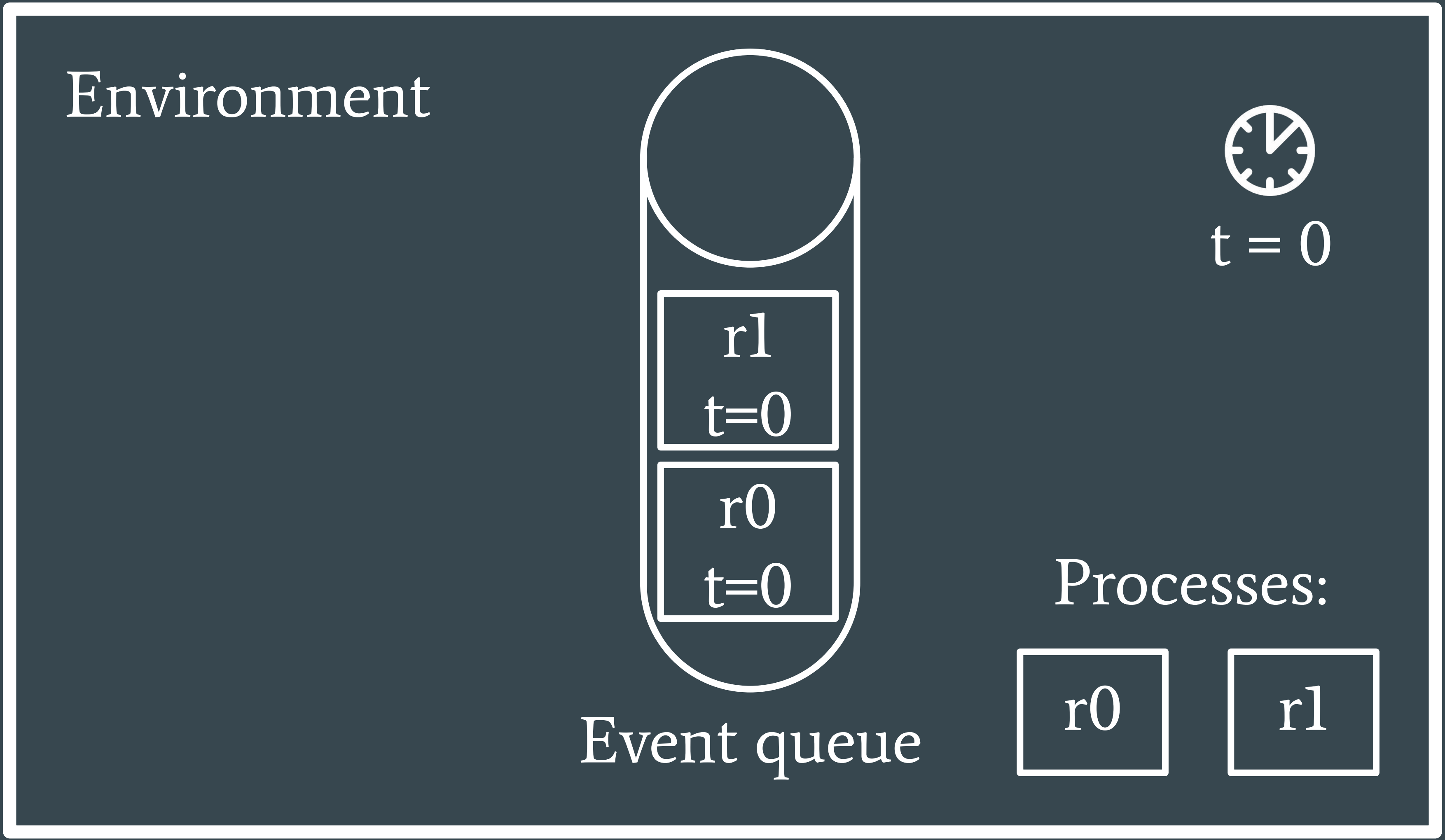
SimPy Library

- Discrete-event simulation (DES) framework
- Created in 2002
- MIT license
- Pure Python
- No dependencies
- Stable release - 3.0.11

SimPy Overview



SimPy Overview



Environment

r1
t=0

r0
t=0

Event queue

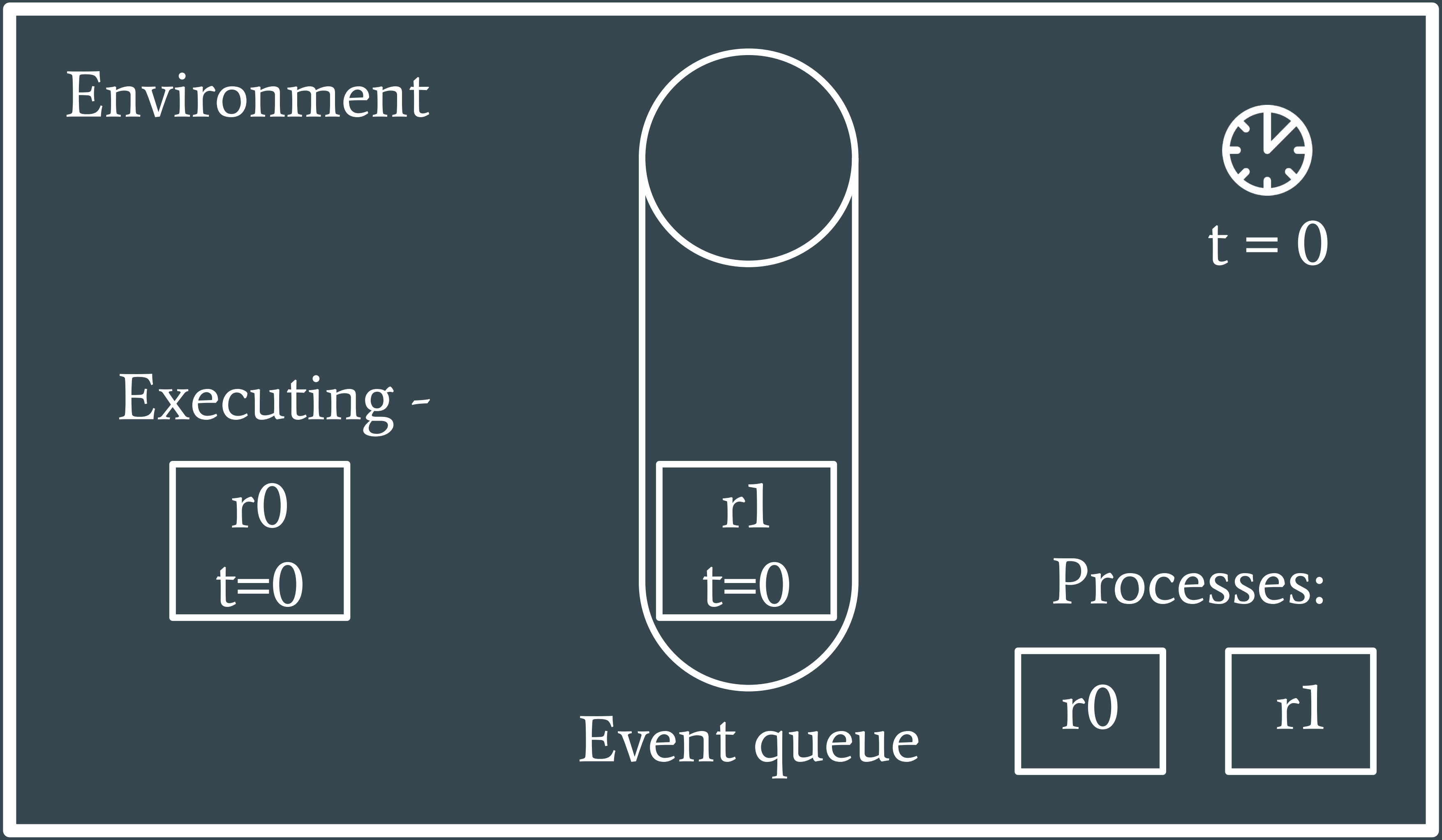
t = 0

Processes:

r0

r1

SimPy Overview



Environment

t = 0

Executing -

r0
t=0

r1
t=0

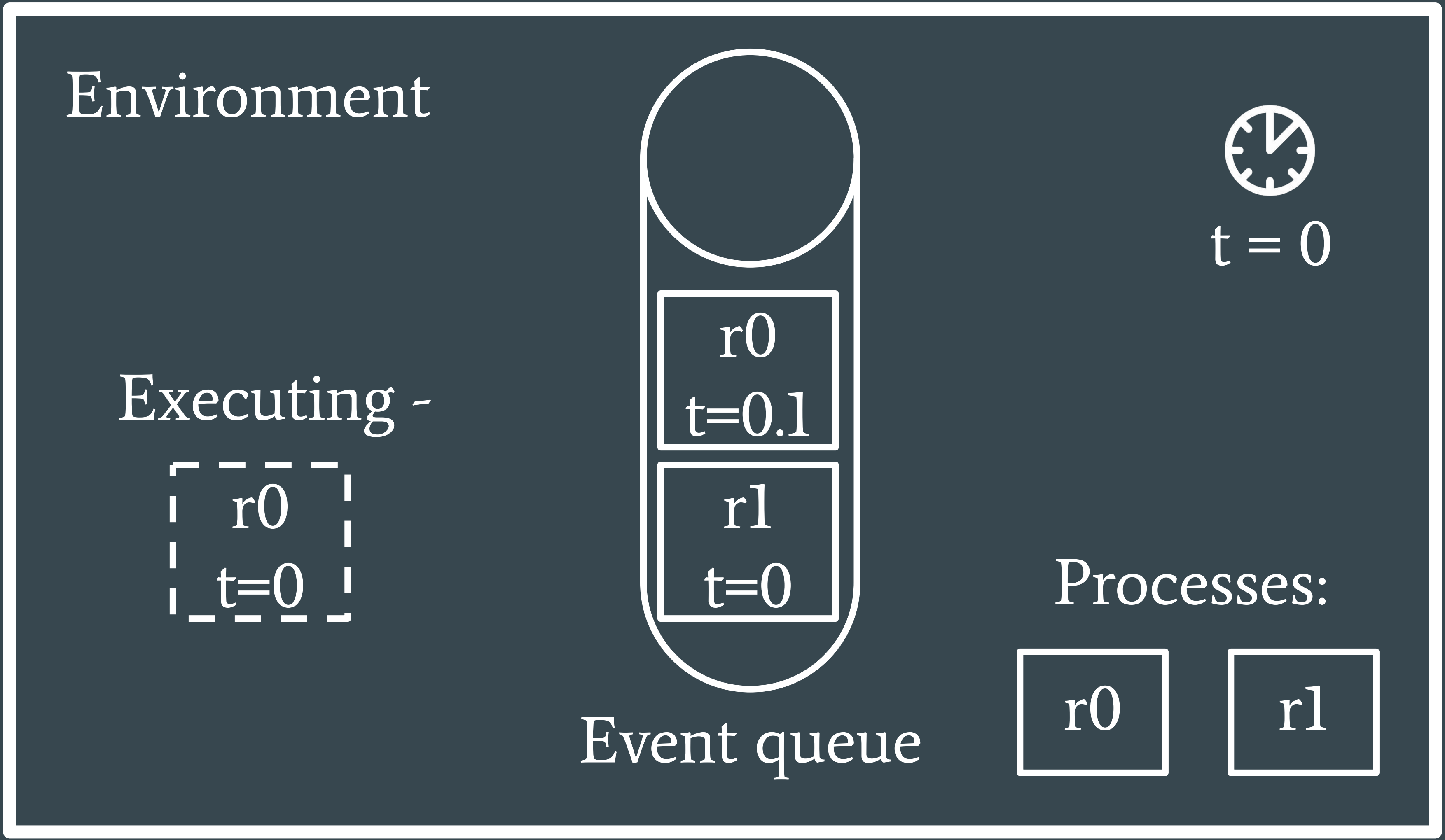
Event queue

Processes:

r0

r1

SimPy Overview



Environment

Executing -

r0
t=0

r0
t=0.1

r1
t=0

Event queue

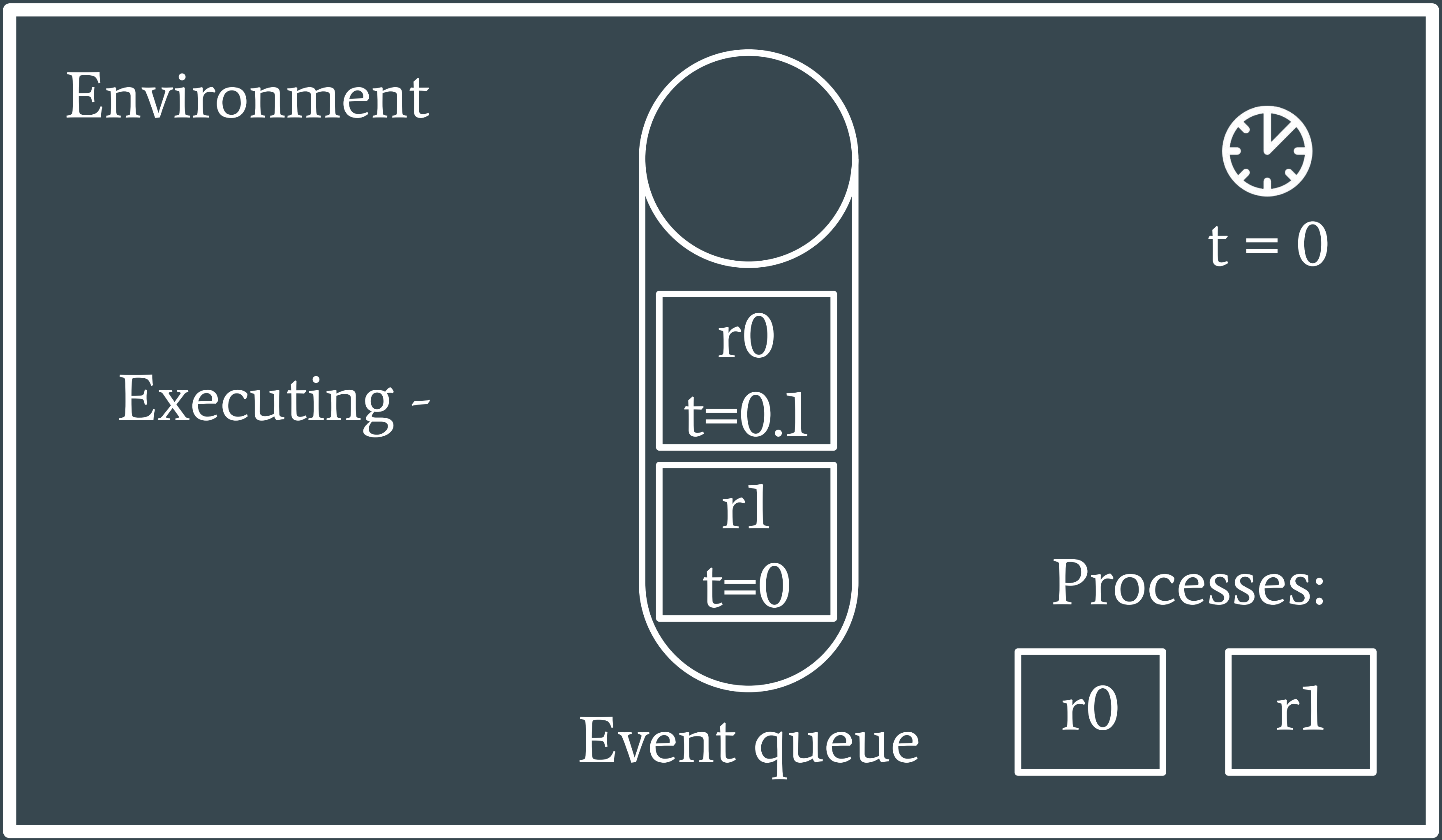
t = 0

Processes:

r0

r1

SimPy Overview



Environment

Executing -

r0
t=0.1

r1
t=0

Event queue

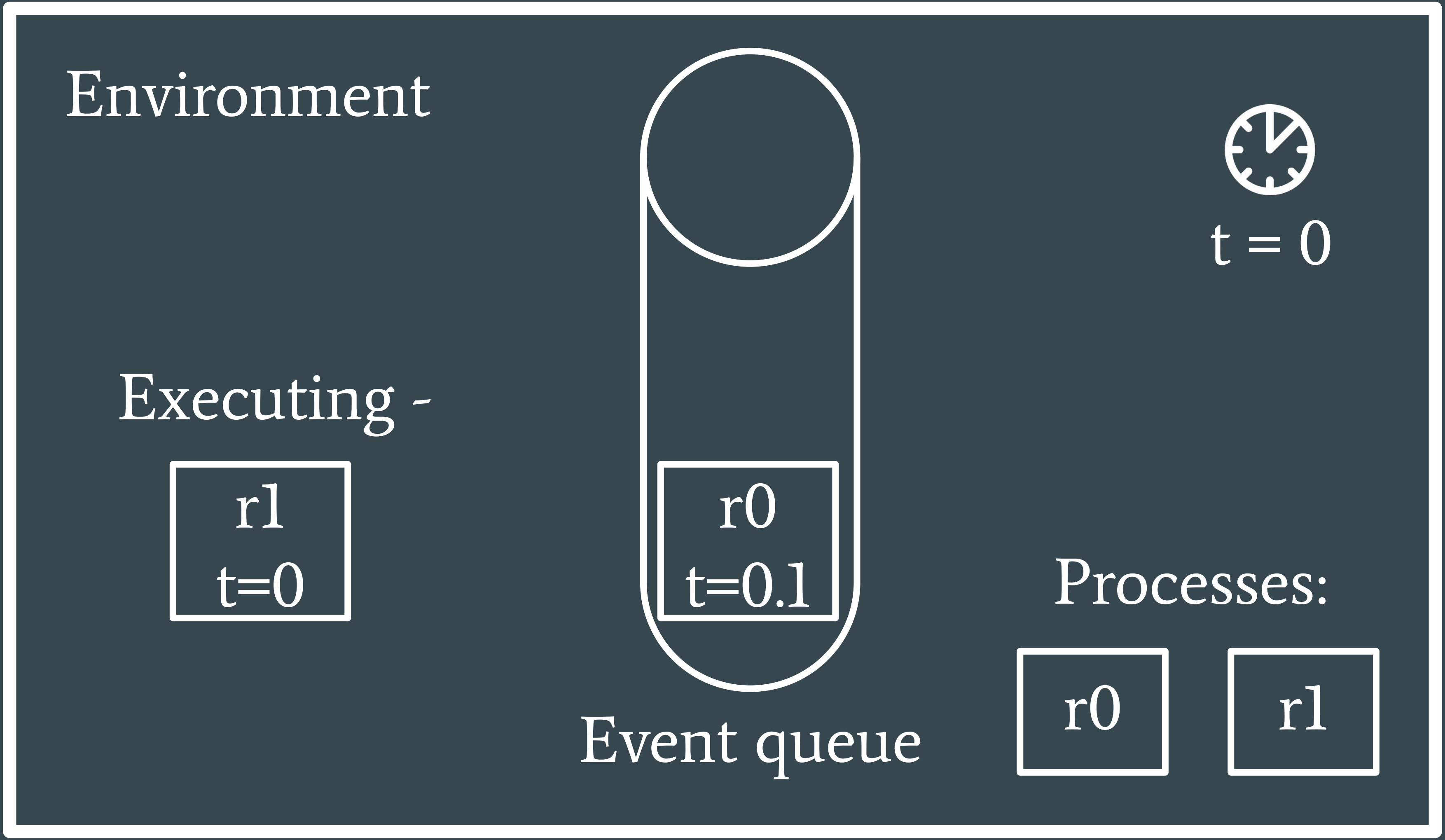
t = 0

Processes:

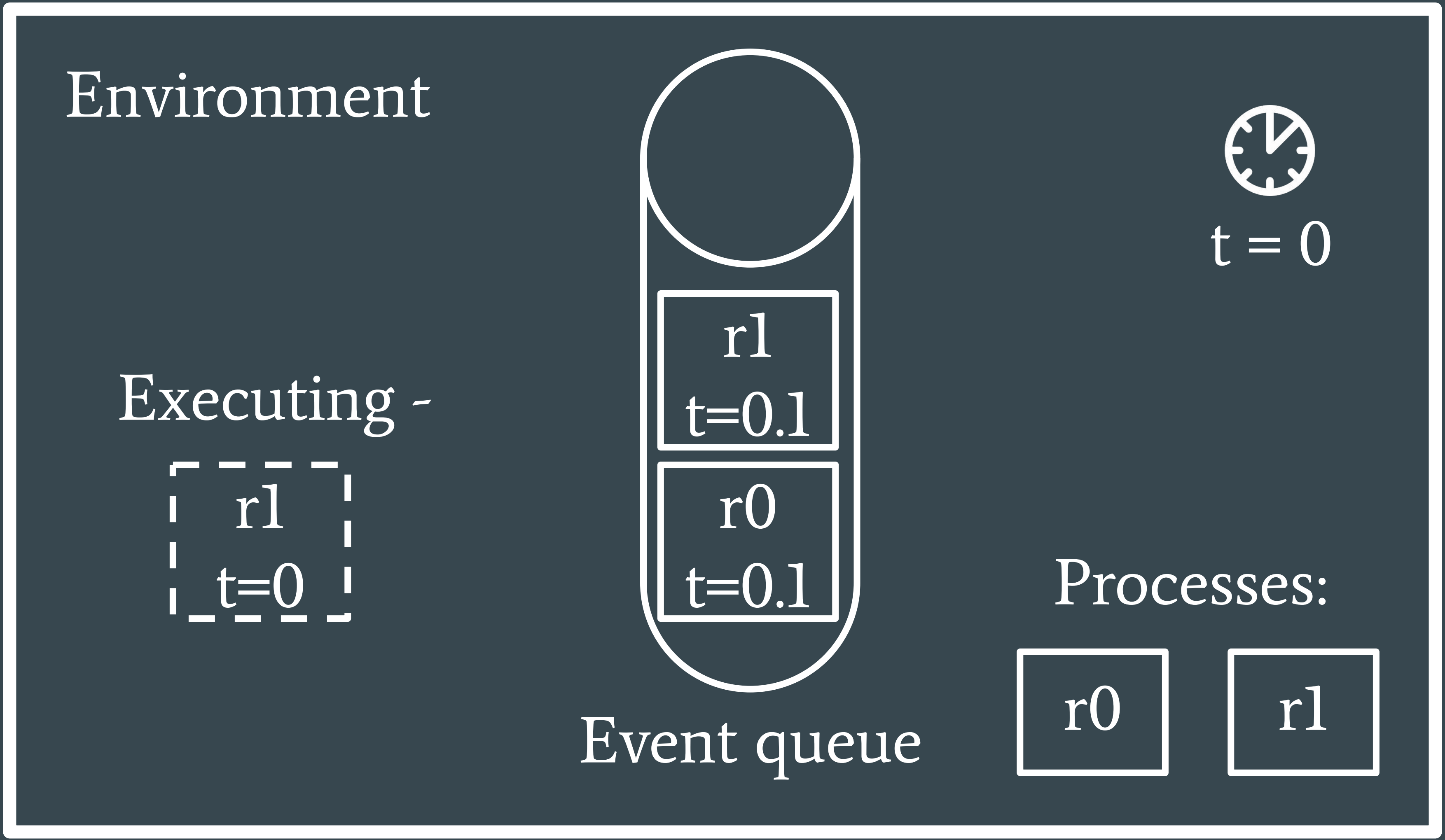
r0

r1

SimPy Overview



SimPy Overview



Environment

Executing -

r1
t=0

r1
t=0.1

r0
t=0.1

Event queue

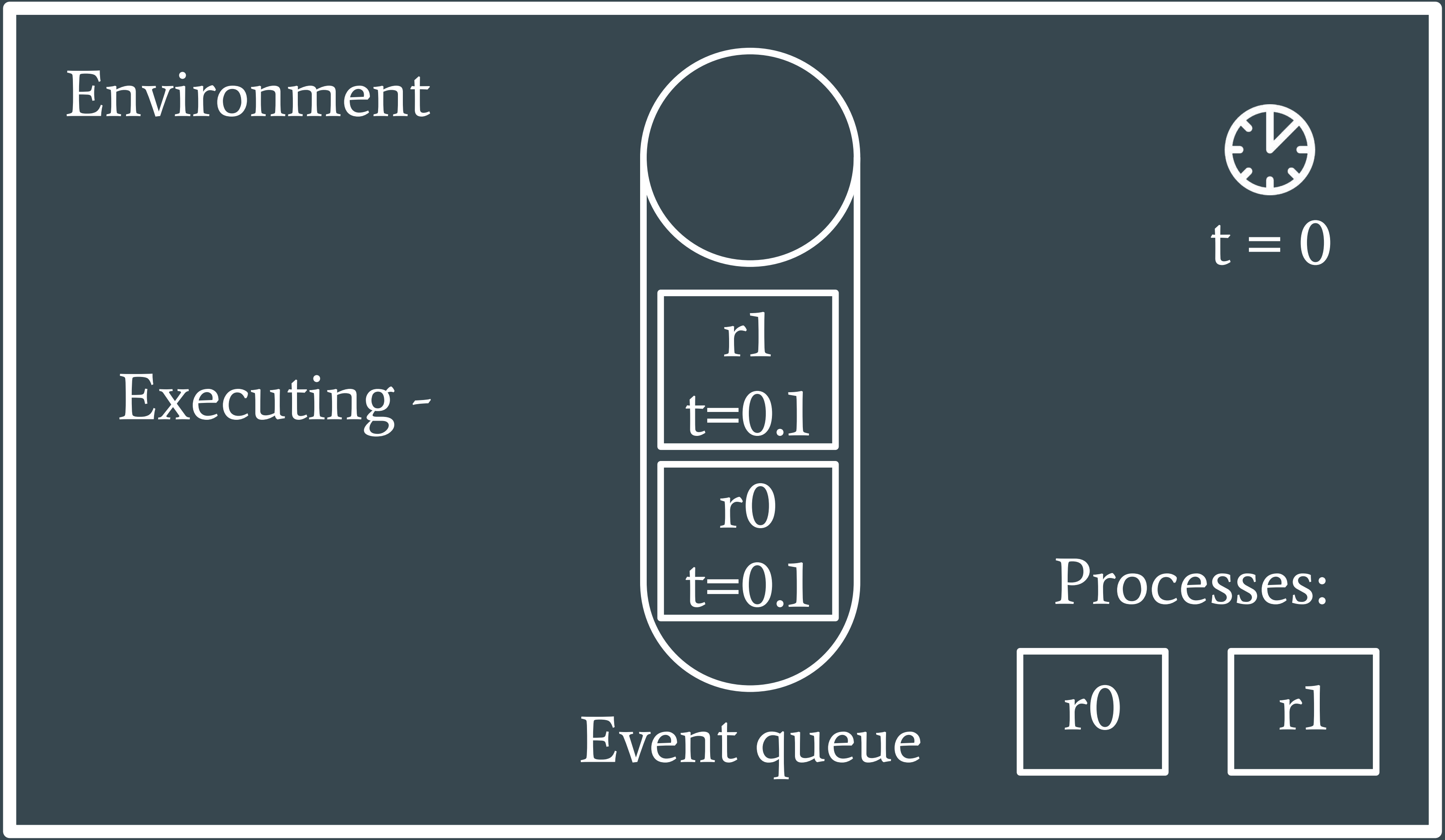
t = 0

Processes:

r0

r1

SimPy Overview



Environment

Executing -

r1
t=0.1

r0
t=0.1

Event queue

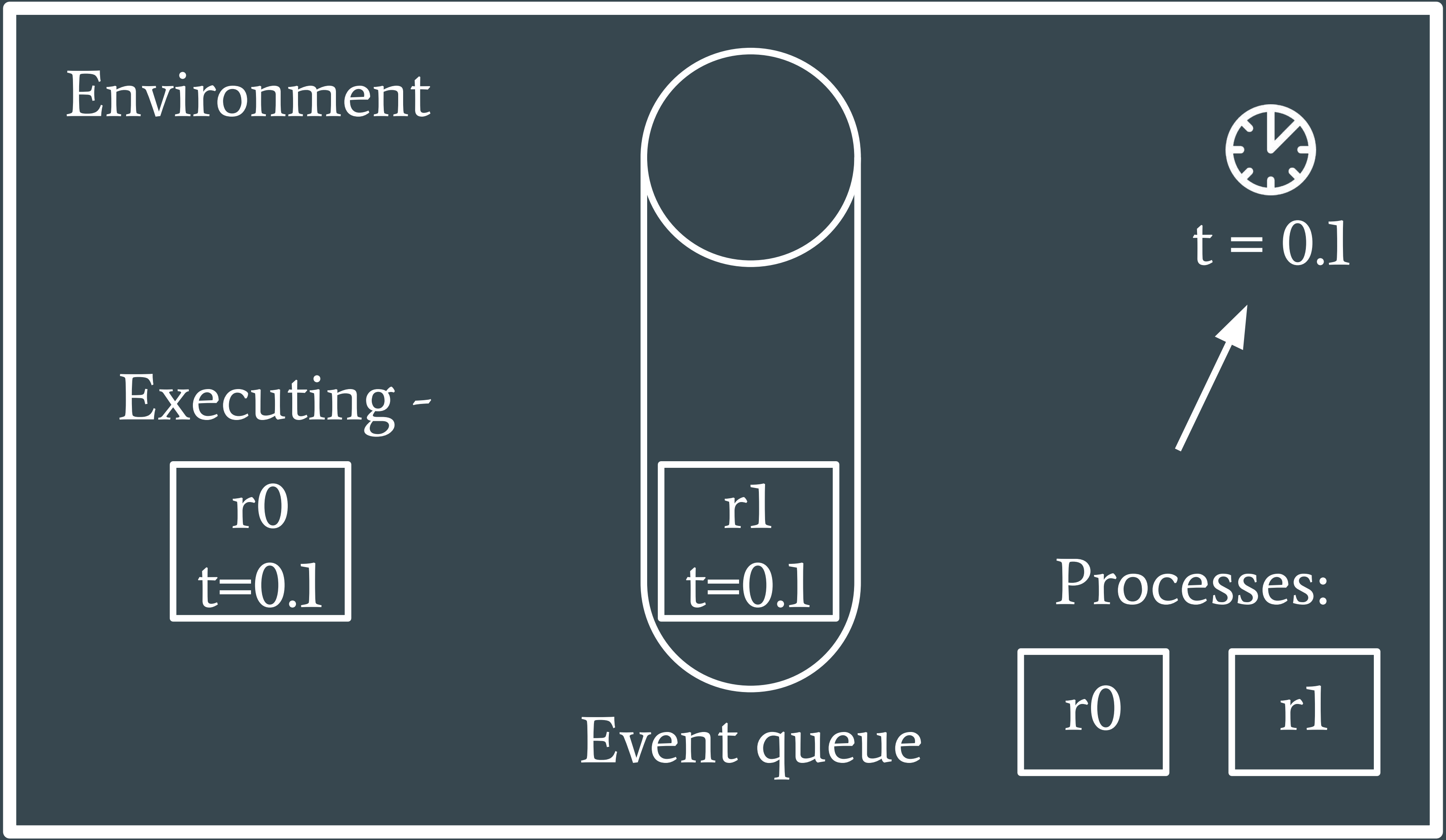
t = 0

Processes:

r0

r1

SimPy Overview



Environment

Executing -

r0
t=0.1

r1
t=0.1

Event queue

t = 0.1

Processes:

r0

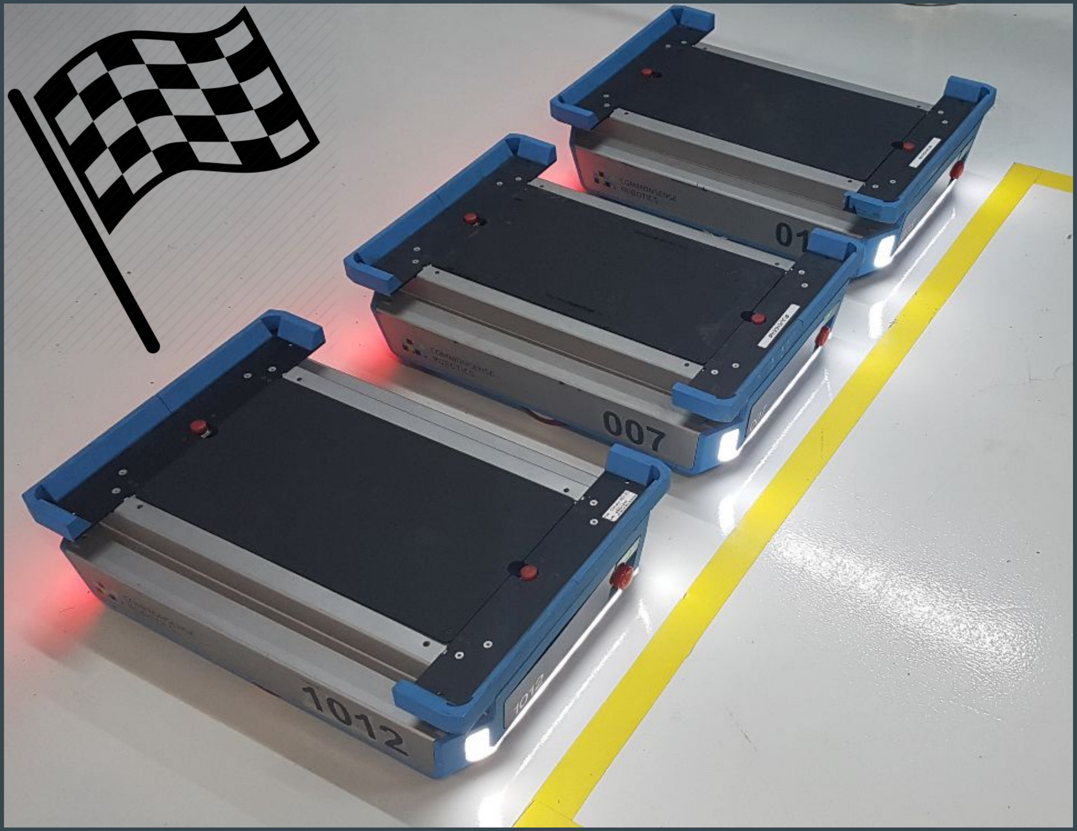
r1

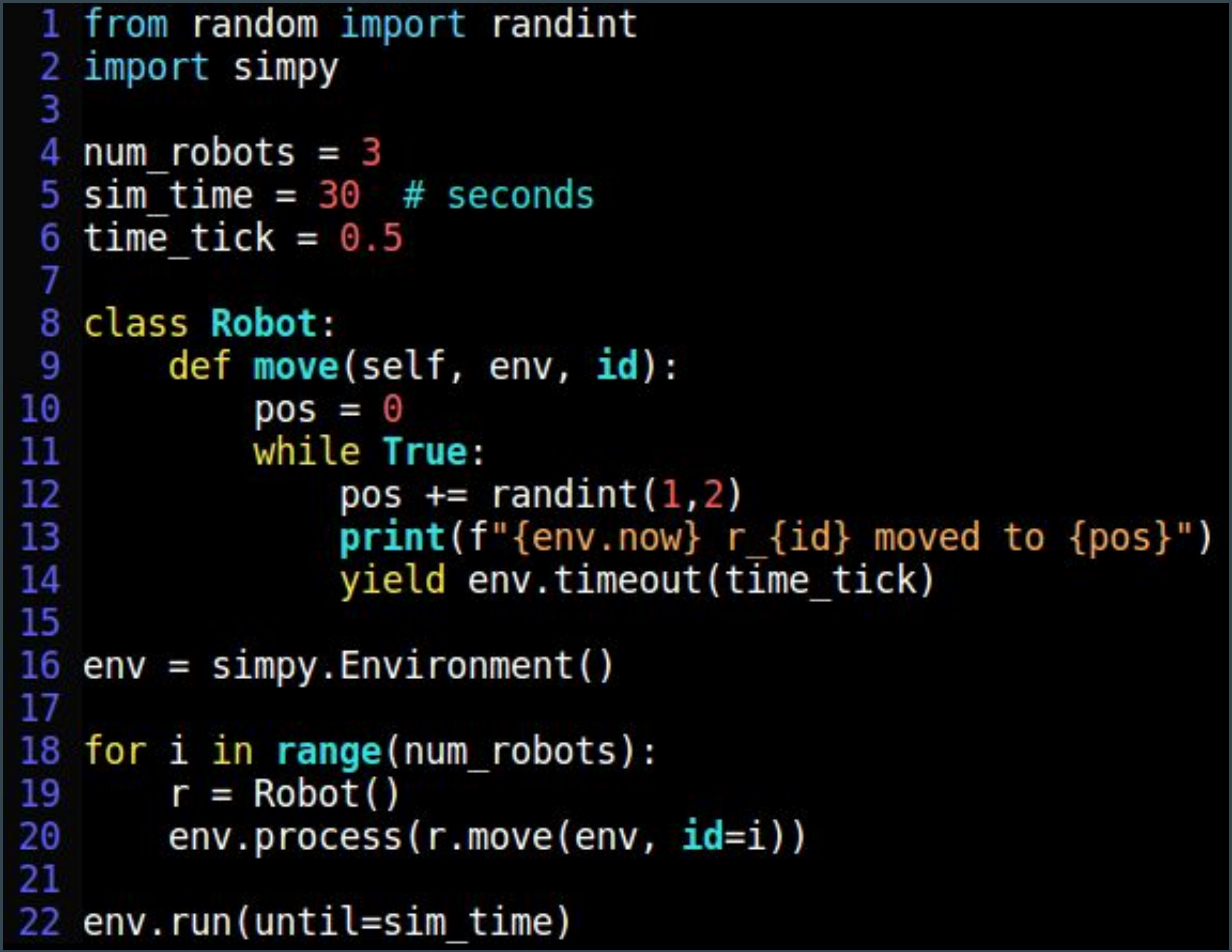
SimPy Overview

- Processes
  - Modeled by Python generators
  - All processes run in a single thread
- Environment
  - Can run in ‘real-time’ mode
  - Receives *initial_time* as parameter

SimPy Example - Robot Race

- A robot’s speed is about 2-4 meters/second





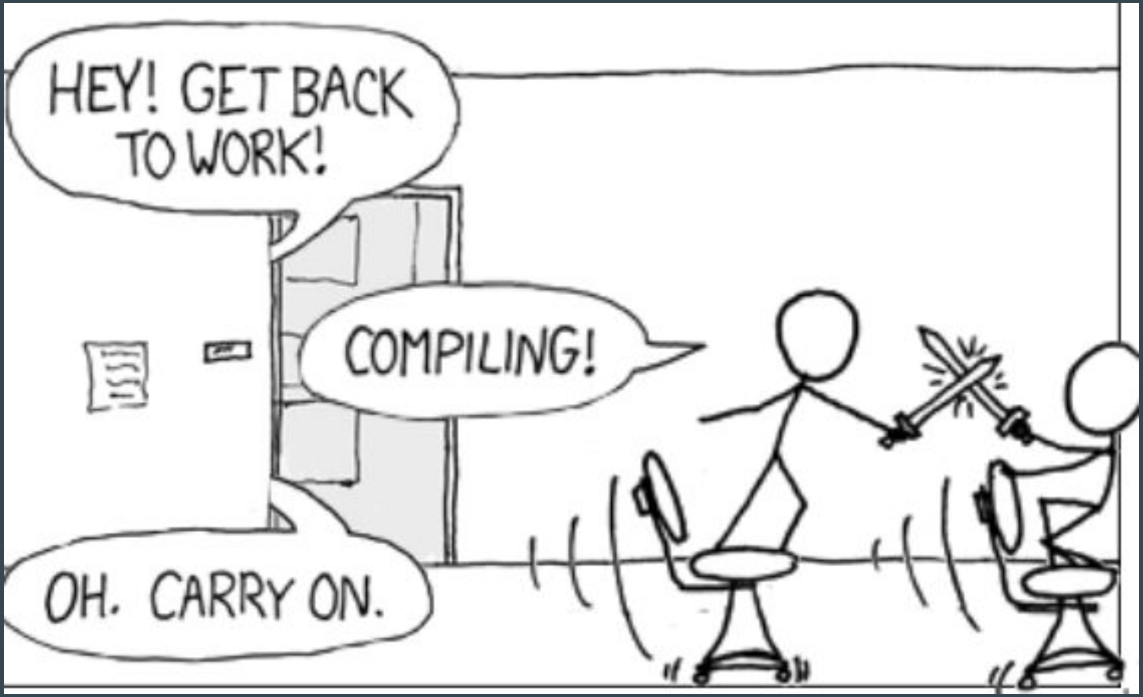
```python
from random import randint
import simpy

num_robots = 3
sim_time = 30  # seconds
time_tick = 0.5

class Robot:
    def move(self, env, id):
        pos = 0
        while True:
            pos += randint(1,2)
            print(f"{env.now} r_{id} moved to {pos}")
            yield env.timeout(time_tick)

env = simpy.Environment()

for i in range(num_robots):
    r = Robot()
    env.process(r.move(env, id=i))

env.run(until=sim_time)
```

SimPy Example - Robot Race

- SimPy code is simulative only
- Parameters that affect performance:
  - Number of simulated components
  - Time tick granularity

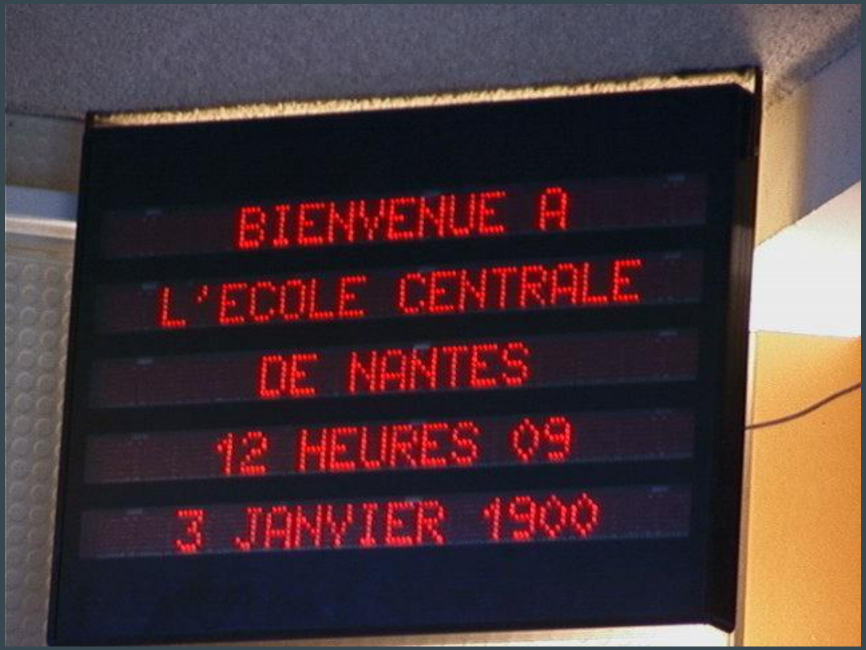
Benefits

- Accelerates development time and faster CI
- Realistic and deterministic simulation



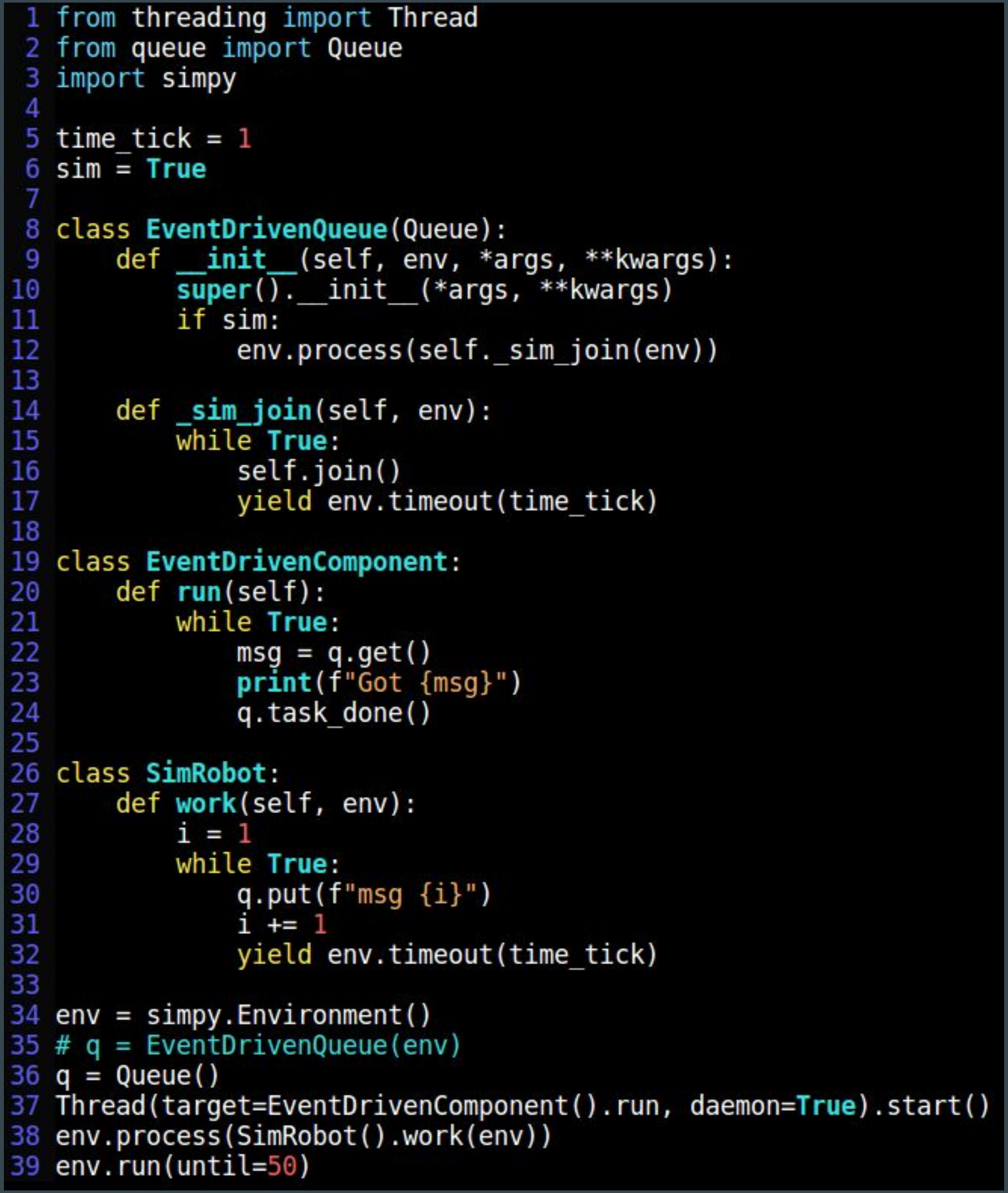
Benefits

- Feedback on code efficiency
- Simulate any date and time of the day (no panic before 'Y2K' bug)



Time Leak - Event-Driven Component

- Event-driven components are not naturally tied to time
- SimPy supports event-driven processes
- Not suitable for multi-threaded systems
- Solution: inherit from *Queue* and create a SimPy process that *joins* on itself in each time tick

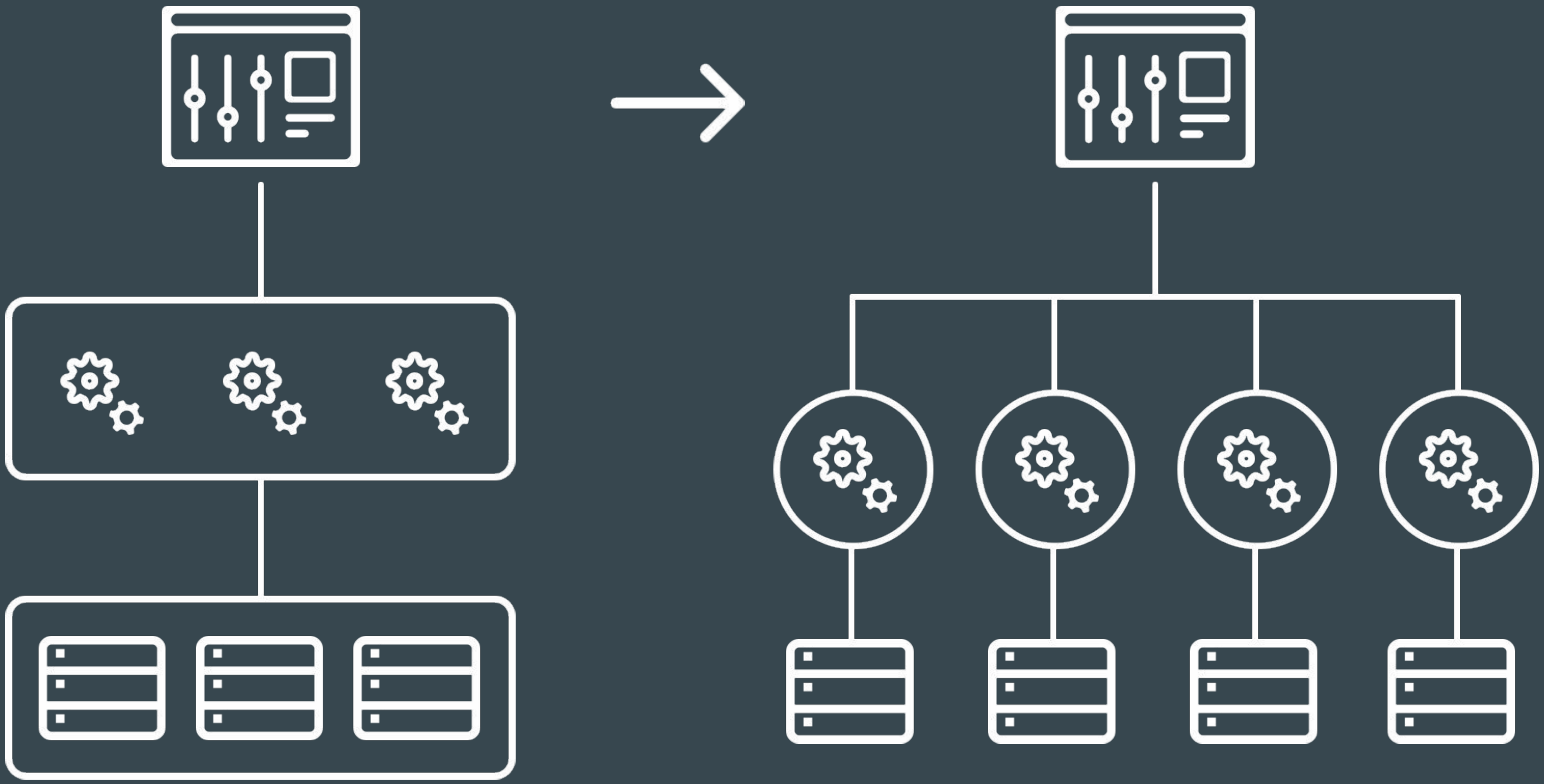


```python
from threading import Thread
from queue import Queue
import simpy

time_tick = 1
sim = True

class EventDrivenQueue(Queue):
    def __init__(self, env, *args, **kwargs):
        super().__init__(*args, **kwargs)
        if sim:
            env.process(self._sim_join(env))

    def _sim_join(self, env):
        while True:
            self.join()
            yield env.timeout(time_tick)

class EventDrivenComponent:
    def run(self):
        while True:
            msg = q.get()
            print(f"Got {msg}")
            q.task_done()

class SimRobot:
    def work(self, env):
        i = 1
        while True:
            q.put(f"msg {i}")
            i += 1
            yield env.timeout(time_tick)

env = simpy.Environment()
# q = EventDrivenQueue(env)
q = Queue()
Thread(target=EventDrivenComponent().run, daemon=True).start()
env.process(SimRobot().work(env))
env.run(until=50)
```

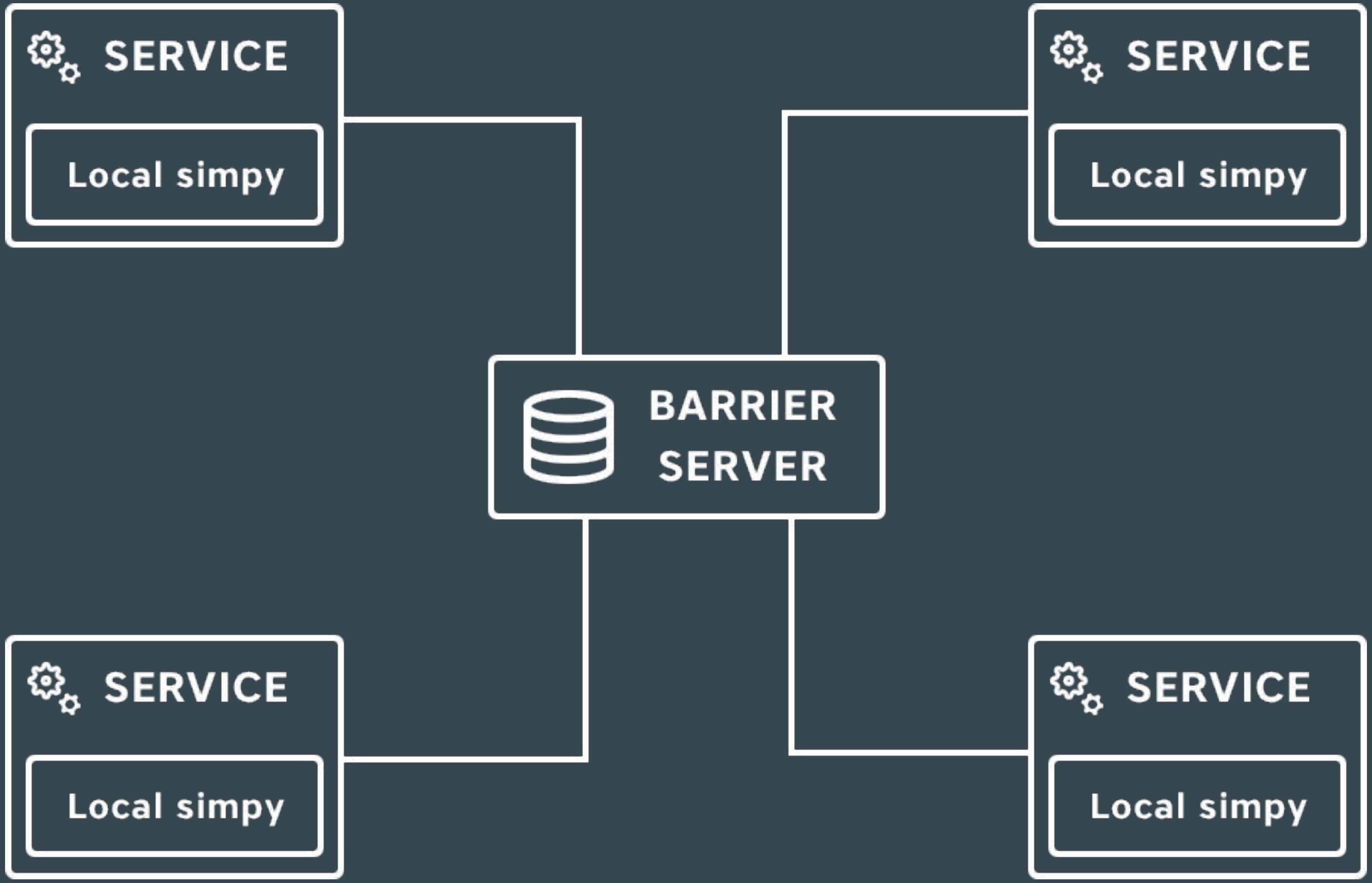
Implementation

- Can’t use the usual time-related functions. Wrapping time-related functionality in our own module
  - *datetime.now()*
  - *time.time()*
  - *time.sleep()*
  - …
- Debugging - simulation timestamp in log

Distributed Simulation



Distributed Simulation



SERVICE

Local simpy

SERVICE

Local simpy

BARRIER SERVER

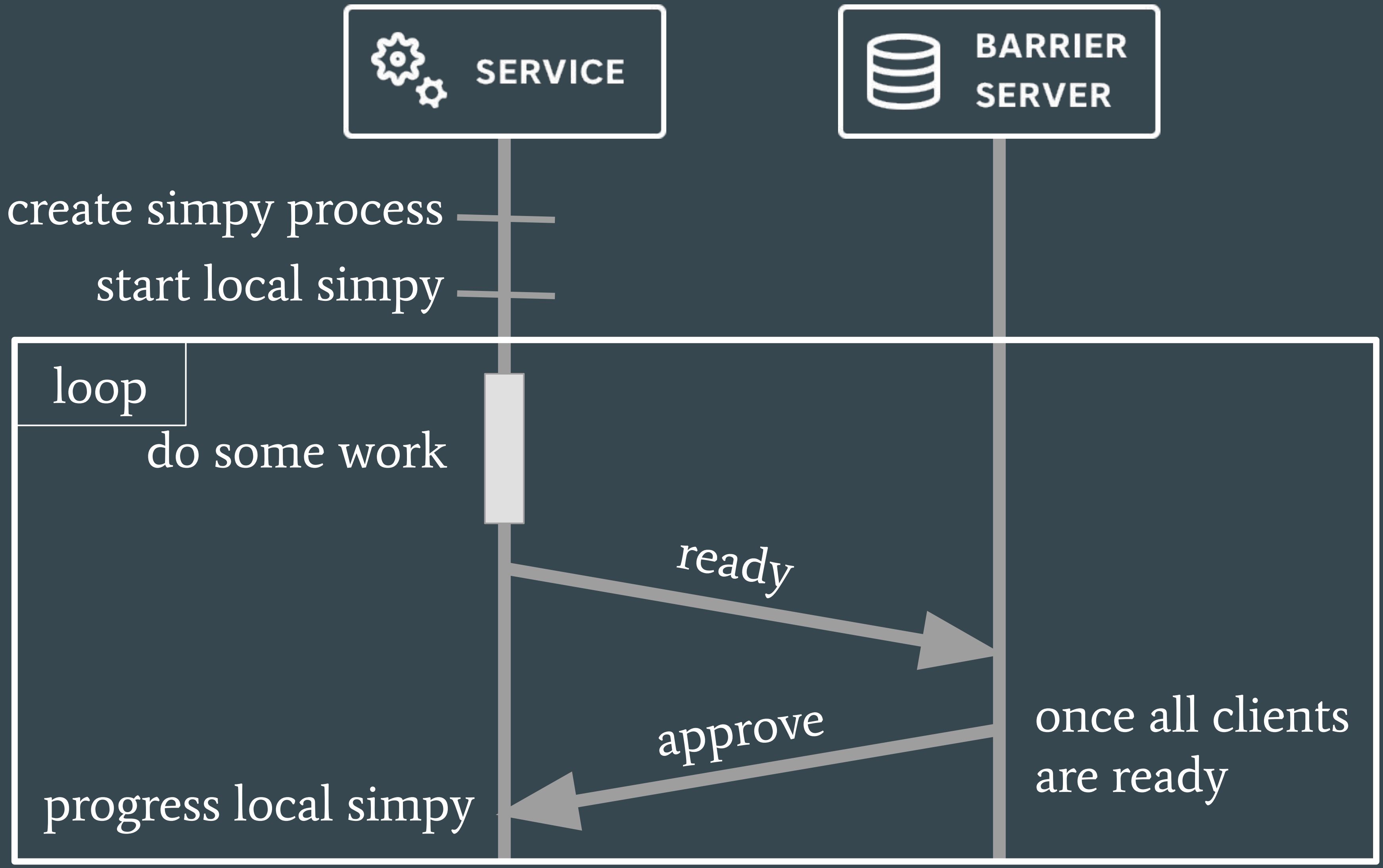
SERVICE

Local simpy

SERVICE

Local simpy

Distributed Simulation



SERVICE

BARRIER SERVER

create simpy process

start local simpy

loop

do some work

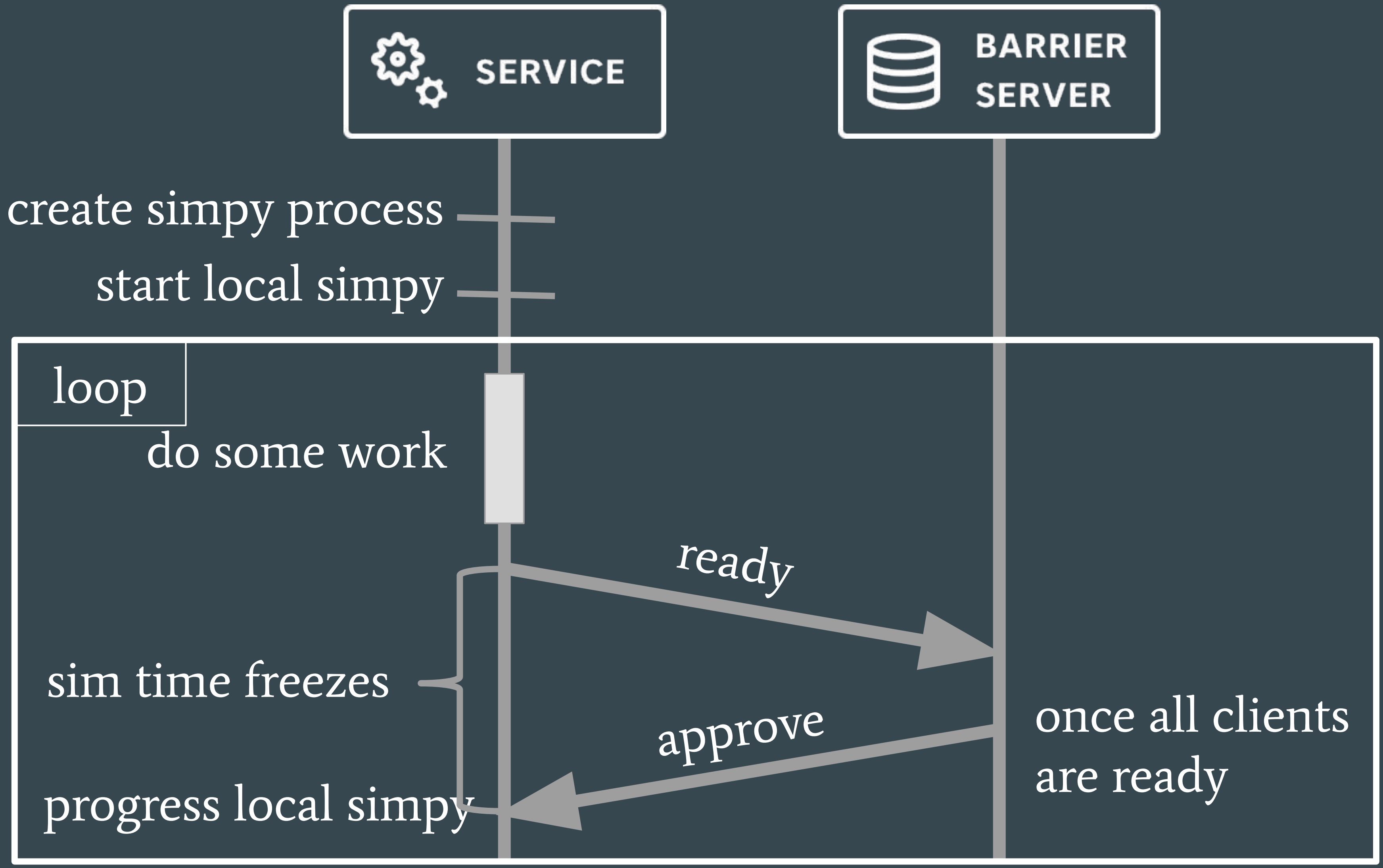
ready

approve

once all clients are ready

progress local simpy

Distributed Simulation



Summary

- Simulation is a powerful tool
- DES makes it more powerful
- SimPy is SimPle
- Time leak - synchronize all components time
- Easy to extend to a distributed simulation