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ISYE 6501
Week 6 Homework

Question 13.2

In this problem you, can simulate a simplified airport security system at a busy airport. Passengers arrive according to a Poisson distribution with λ1 = 5 per minute (i.e., mean interarrival rate μ1 = 0.2 minutes) to the ID/boarding-pass check queue, where there are several servers who each have exponential service time with mean rate μ2 = 0.75 minutes. [Hint: model them as one block that has more than one resource.] After that, the passengers are assigned to the shortest of the several personal-check queues, where they go through the personal scanner (time is uniformly distributed between 0.5 minutes and 1 minute).

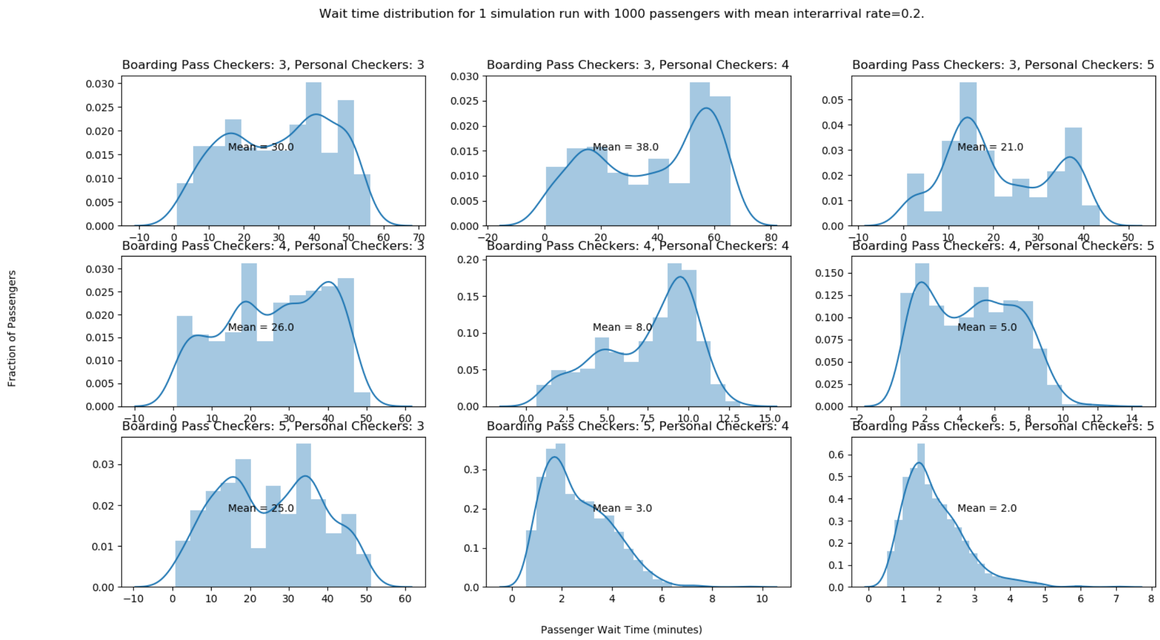
I used the Python package Simpy to complete this problem. The code is shown below.

```
import simpy
import numpy as np
from functools import partial, wraps
import matplotlib.pyplot as plt
import seaborn as sns

class Passenger(object):
    def __init__(self, env, name, bpc, pc, travel_time, board_pass_wait_time,
personal_check_wait_time):
        self.env = env

        self.name = name
        self.bpc = bpc
        self.pc = pc
        self.travel_time = travel_time
        self.board_pass_wait_time = board_pass_wait_time
        self.personal_check_wait_time = personal_check_wait_time

        # Start the begin_trip process everytime an instance is created.
        self.action = env.process(self.begin_trip())

    def begin_trip(self):

        # Simulate driving to the airport
        yield self.env.timeout(self.travel_time)

        start_time = self.env.now
        # Begin waiting in line for ID/boarding-pass check
        print('%s arriving at boarding-pass check queue at %d' % (self.name,
self.env.now))
        with self.bpc.request() as req:
            yield req

            # Begin ID/boarding-pass check
            print('%s starting boarding pass check at %s' % (self.name,
self.env.now))
            yield self.env.timeout(self.board_pass_wait_time)
            print('%s leaving the boarding pass check queue %s' % (self.name,
self.env.now))

        # Begin waiting in personal-check queue
```

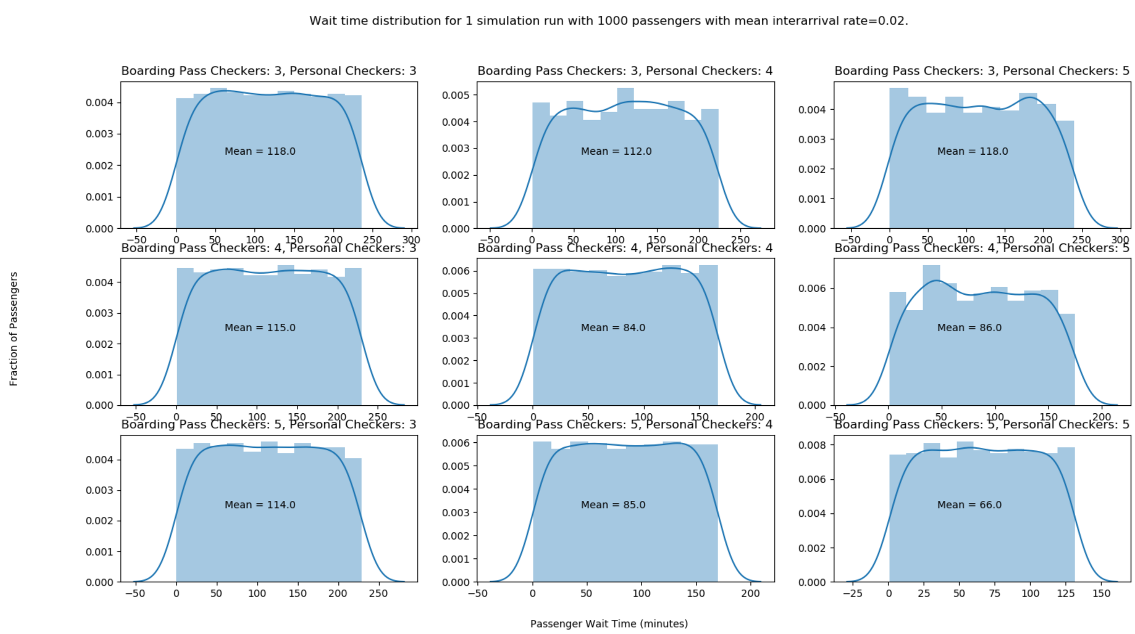
```
        with self.pc.request() as req:
            yield req

            # Begin personal-check
            print('%s starting personal-check at %s' % (self.name, self.env.now))
            yield self.env.timeout(self.personal_check_wait_time)
            print('%s leaving the personal-check queue %s' % (self.name,
self.env.now))

        end_time = self.env.now
        self.wait_time = end_time - start_time

def patch_resource(resource, pre=None, post=None):
    """Patch *resource* so that it calls the callable *pre* before each
    put/get/request/release operation and the callable *post* after each
    operation.  The only argument to these functions is the resource
    instance.
    """
    def get_wrapper(func):
        # Generate a wrapper for put/get/request/release
        @wraps(func)
        def wrapper(*args, **kwargs):
            # This is the actual wrapper
            # Call "pre" callback
            if pre:
                pre(resource)

            # Perform actual operation
            ret = func(*args, **kwargs)

            # Call "post" callback
            if post:
                post(resource)

            return ret
        return wrapper

    # Replace the original operations with our wrapper
    for name in ['put', 'get', 'request', 'release']:
        if hasattr(resource, name):
            setattr(resource, name, get_wrapper(getattr(resource, name)))

def monitor(data, resource):
    """This is our monitoring callback."""
    item = (
        resource._env.now,  # The current simulation time
        resource.count,  # The number of users
        len(resource.queue),  # The number of queued processes
    )
    data.append(item)

def run_airport_simulation(num_passengers, pass_mean_interarrival_rate,
num_board_pass_checkers, num_personal_check_checkers):
```

```
    data_bpc = []
    data_pc = []

    env = simpy.Environment()
    bpc = simpy.Resource(env, capacity=num_board_pass_checkers)
    pc = simpy.Resource(env, capacity=num_personal_check_checkers)

    bpc_monitor = partial(monitor, data_bpc)
    patch_resource(bpc, post=bpc_monitor)

    pc_monitor = partial(monitor, data_pc)
    patch_resource(pc, post=pc_monitor)

    passenger_list = []

    travtime = 0
    for i in range(num_passengers):
        bptime = np.random.exponential(scale=0.75)
        pctime = np.random.uniform(low=0.5, high=1.0)
        passenger_list.append(Passenger(env, 'Passenger %d' % i, bpc, pc, travtime,
bptime, pctime))
        travtime = travtime +
np.random.exponential(scale=pass_mean_interarrival_rate)
    env.run()

    return data_bpc, data_pc, passenger_list

num_passengers = 1000
pass_mean_interarrival_rate = 0.02
num_board_pass_checkers_list = [15, 16, 17]
num_personal_check_checkers_list = [15, 16, 17]

fig, axtuple = plt.subplots(len(num_board_pass_checkers_list),
len(num_personal_check_checkers_list), figsize=(18, 9))
plotnum = 0
for n0, num_board_pass_checkers in enumerate(num_board_pass_checkers_list):
    for n1, num_personal_check_checkers in
enumerate(num_personal_check_checkers_list):
        datbpc, datpc, pl = run_airport_simulation(num_passengers,
pass_mean_interarrival_rate, num_board_pass_checkers, num_personal_check_checkers)
        wait_time_list = [passenger_instance.wait_time for passenger_instance in pl]
        sns.distplot(wait_time_list, ax=axtuple[n0, n1])
        axtuple[n0, n1].set_title("Boarding Pass Checkers: {}, Personal Checkers:
{}".format(num_board_pass_checkers, num_personal_check_checkers))
        axtuple[n0, n1].text(0.35, 0.5, "Mean =
{}".format(round(np.mean(wait_time_list))), transform=axtuple[n0, n1].transAxes)

fig.text(0.5, 0.04, "Passenger Wait Time (minutes)", ha='center')
fig.text(0.04, 0.5, "Fraction of Passengers", va='center', rotation='vertical')
fig.suptitle('Wait time distribution for 1 simulation run with {} passengers with
mean interarrival rate={}.'.format(num_passengers, pass_mean_interarrival_rate))
```

The first analysis was completed with a mean passenger arrival rate of 5 passengers per minute (mean passenger interarrival time of 0.2 minutes). This was simulated for 1000 passengers with all 9 permutations of 3, 4 or 5 boarding-pass checkers and personal-checkers. Shown below are the plots of the distribution of wait times for all 1000 passengers for one run of each permutation.



From this we see that 4 boarding-pass checkers and 4 personal-checkers is the minimum required for the average wait time to be below 15 minutes. Let's take a look at how the wait time changes for these amounts of resources if we bump the passenger arrival rate to 50 passengers per minute (interarrival time of .02 minutes):



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It is clear that the 10x increase in passenger arrival rate has overrun the resource combinations which produced average wait times less than 15 minutes in the first scenario. In fact, with this higher arrival rate, the average wait time does not dip below 15 minutes until we supply the airport check in with 17 boarding-pass checkers and 17 personal-checkers. See below: