Semester assignments 2020: Airport traffic

The lab in TTM4110 consists of four parts (in total 60% of final grade);

- Lab 1 (10% of final grade): Simulation modelling [deadline 14.09 @ 12:00]
- Lab 2 (20% of final grade): Simulations implementation and experiments [deadline 05.10 @ 12:00]
- Lab 3 (15% of final grade): Performance modelling [deadline 02.11 @ 12:00]
- Lab 4 (15% of final grade): Dependability modelling [deadline 23.11 @ 12:00]

System description: Simulating an airport-environment

(The underlying system is the same for all parts of the lab, but the level of details and objective will be different for each part *)*

An airport has hired You to make a simulation of their traffic. Their daily schedules vary from day to day, but are always set up according to certain rules. However, delays may also occur, and they want You to investigate the correlation between delays and queuing, etc.

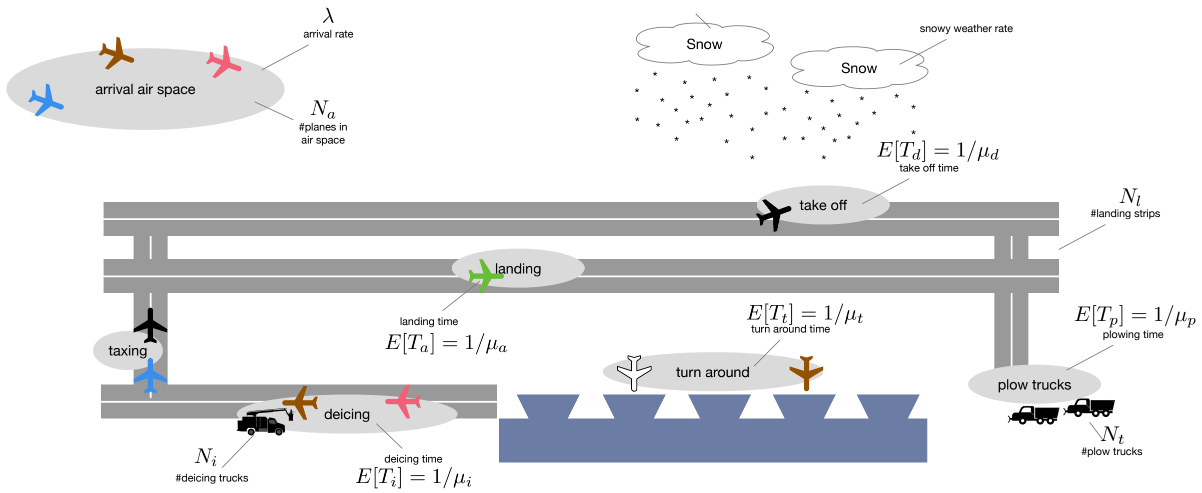

Figure 1: Airport traffic

We want to simulate the airport traffic, with the goal of studying the effect that delayed arrivals has on the overall performance. The airport has an arrival schedule of planes every day, which is set up such that no planes will arrive within the same time window called guard time. At arrival, the airplane requests the runway to initiate landing. If the runway is busy, it must circulate the airspace over the airport while waiting for the runway, initiating landing only when the runway is available. After landing, the plane has a turn-around time during which it offloads and onloads passengers and luggage, refuels etc., before it requests the runway again for take-of. When the runway is available, it departs from the airport again.

To generate a daily schedule, you will model arrivals according to a time-dependant Poisson process, with an inter arrival guard time. This means that the scheduled time between two planes is always set by

$$T_{\texttt{inter-arrival}}(t) = MAX[T_{\texttt{guard}}, T]$$

where the random variable $T \sim \texttt{n.e.d}(\lambda(t))$, with intensity $\lambda(t)$ dependent on the time of day t ($0 \leq t < 24$), according to Table 1.

Table 1: Arrival intensity

t:	00:00-05:00	05:00-08:00	08:00-11:00	11:00-15:00	15:00-20:00	20:00-00:00
λ	N/A	120	30	150	30	120

Unfortunately, planes may have been delayed, so the actual arrival time of planes will deviate from the schedule. The plane will be delayed with probability $P_{\texttt{delay}}$. If a plane is delayed, the delay will be sampled as:

$$X_{\texttt{delay}} \sim Erlang(3,\ \mu_{\texttt{delay}})$$

i.e. the delays are sampled from an Erlang-k distribution, with $k = 3$.

After initiating landing, the plane uses $T_{\texttt{landing}}$ time to complete the landing. After the plane has landed successfully, it also wishes to leave the airport again after a sampled turn-around time. The turn-around time is sampled as:

$$X_{\texttt{t.a.}} \sim Erlang(7,\ \mu_{\texttt{t.a.}})$$

Planes requesting the runway for take-off always has lower priority than planes requesting the runway for landing. However, once take-off is initiated, it must also be completed, which takes $T_{\texttt{take-off}}$ time. This means that arriving planes may still end up having to wait for a take-off to finish.

In Part II.c you should study the airport when it is cold weather. This means that the airplanes have to be deiced before they can take off. There is a limited number of deicing trucks (N_i), which means that an airplane might have to wait to be deiced. It might start snowing too, and then all runways will be closed when it has snowed for a certain amount of time, $T_{\texttt{snow}}$, and reopened again when the runway has been cleared for snow. If it is still snowing, the runways will again be closed after $T_{\texttt{snow}}$ time. The airport is served by N_t trucks.

Assumption A: A landing or take-off is always successful once initiated, i.e. there are no accidents.

Assumption B: The landing time for an airplane is $T_{\texttt{landing}}$, and is assumed to be constant.

Assumption C: The take-off time for an airplane is $T_{\texttt{take-off}}$, and is assumed to be constant

Assumption D: The inter arrival guard time is $T_{\texttt{guard}}$, and is assumed to be constant

Assumption E: The airport can be initialized as empty, i.e. there are no airplanes at the airport at the start of the day.

Assumption F: There are no arrivals between 00:00 and 05:00.

Assumption G: Time can be modelled discretely with a granularity of 1 second.

Assumption H: The time it takes a plow-truck to clear of the runway for snow is T_p, and is assumed to be constant.

PART II: Simulate System Performance

In this assignment, You will implement the models from part I. The objective is to study how delayed arrivals affects performance. To implement the simulation model, You may use either Simula and the DEMOS class, or Python and the SimPy library.

The simulations should be based on the models from lab I. If you need to make any changes from lab I, document the changes and explain why.

PART II.a: Simulating arrivals

As mentioned in part I, the modelling of the arrivals correctly is key to investigating the objective. Therefore, we start by implementing the generator, which generates arrivals.

1. Implement Your simulation model from part I.a with the parameters below, and plot the inter-arrival times.

Parameter	Expected Value
$T_{\texttt{guard}}$	60 seconds
$T \sim n.e.d(\lambda(t))$	Varies, see table 1
$P_{\texttt{delay}}$	0.5
$X_{\texttt{delay}} \sim Erlang(3,\, \mu_{\texttt{delay}})$	0 seconds

2. Run your simulation model again, while gradually increasing $\mu_{\texttt{delay}}$. Plot, and describe what you observe.

PART II.b: Simulate system in nice weather

We will now go on to simulate the whole system, without considering weather conditions. Use Your generator from part II.a. The objective is still to investigate how much delayed arrivals affects the landing, and take-off queue times.

1. Implement Your simulation model from part I.b and run it with the following additional parameters:

Parameter	Expected Value
$T_{\texttt{landing}}$	60 seconds
$T_{\texttt{take-off}}$	60 seconds
$X_{t.a.} \sim Erlang(7, \mu_{t.a.})$	45 minutes
N_l (number of landingstrips)	2

2. Run your simulation model, while changing $\mu_{\texttt{delay}}$ and $P_{\texttt{delay}}$ to study its effect on performance.
Comment on your results, and make a graph to visualize them.

PART II.c: Simulate system preformance in bad weather

In final part, you should study the airport when it is cold weather and deicing is necessary. Extend your simulator handle cold weather with deicing, and to include the effects of snow (it is not snowing all the time). The objective is again to study landing and take-off queue times. There are now considerably many more parameters to vary, so the discussion should be focused on finding the most important contributors to system congestion (i.e. what causes the most queue?).

1. Implement Your simulation model from part I.c. and run it with the following additional parameters:

Parameter	Expected Value
$T_{w1} \sim n.e.d(\lambda_1)$	1 hour
$T_{w2} \sim n.e.d(\lambda_2)$	2 hours
$T_{\texttt{snow}} \sim n.e.d(\lambda_{\texttt{snow}})$	45 minutes
N_t (Number of plow trucks)	1
N_i (Number of deicing trucks)	1
T_p	10 minutes
T_i	10 minutes

Some clarification: The whether is changing between snowing and not snowing. When it snows it does so for $T_{w1} \sim n.e.d(\lambda_1)$ time, until it stops. Then it takes $T_{w2} \sim n.e.d(\lambda_2)$ time until it starts snowing again. When it is snowing, the runways fill up with snow after $T_{\texttt{snow}} \sim n.e.d(\lambda_{\texttt{snow}})$. All runways fill up evenly, but will be cleared by a shared set of plow-trucks. If You feel that You need to make simplifications, do so, and argue why this simplification is justified.

2. Run your simulation model, while changing parameters such as expected delay, snow-intensity, plowing time and number of runways. Visualise your results and comment.