UCF Stands For Opportunity

CDA6530: Performance Models of Computers and Networks

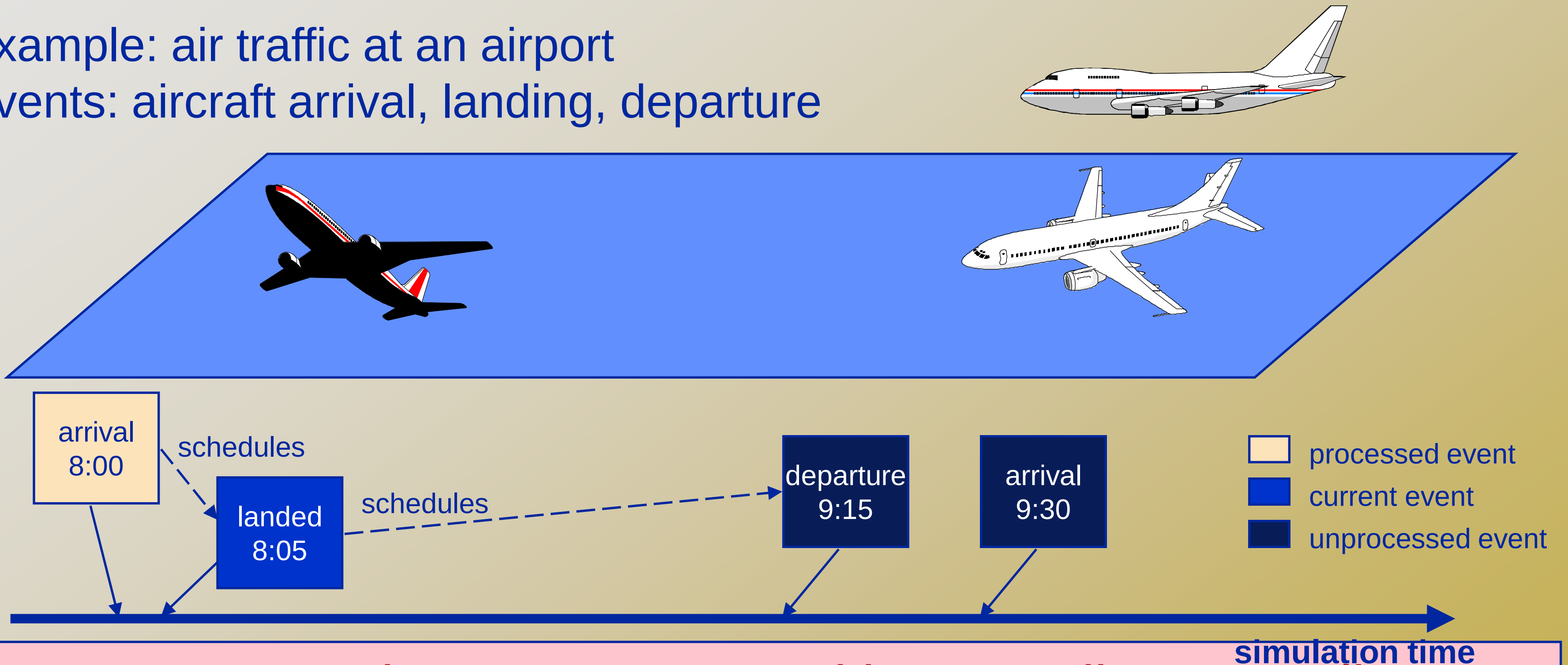
Chapter 9: Statistical Simulation ----- Discrete Event Simulation (DES)

Time Concept

- *physical time:* time in the physical system
  - Noon, Oct. 14, 2008 to noon Nov. 1, 2008
- *simulation time:* representation of physical time within the simulation
  - floating point values in interval [0.0, 17.0]
  - Example: 1.5 represents one and half hour after physical system begins simulation
- *wallclock time:* time during the execution of the simulation, usually output from a hardware clock
  - 8:00 to 10:23 AM on Oct. 14, 2008

Discrete Event Simulation Computation

example: air traffic at an airport
events: aircraft arrival, landing, departure



- Unprocessed events are stored in a pending event list
- Events are processed in time stamp order

From: http://www.cc.gatech.edu/classes/AY2004/cs4230_fall/lectures/02-DES.ppt

DES: No Time Loop

- Discrete event simulation has no time loop
  - There are events that are scheduled.
  - At each **run** step, the next scheduled event with the *lowest* time schedule gets processed.
    - The current time is then *that* time, the time when that event is supposed to occur.
- Accurate simulation compared to discrete-time simulation
- Key: We have to keep the list of scheduled events *sorted* (in order)

Variables

- Time variable t
  - Simulation time
  - Add time unit, can represent physical time
- Counter variables
  - Keep a count of times certain events have occurred by time t
- System state (SS) variables
- We focus on queuing systems in introducing DES

Interlude: Simulating non-homogeneous Poisson process for first T time

- Nonhomogeneous Poisson process:
  - Arrival rate is a variable λ(t)
  - Bounded: $\lambda(t) < \lambda$ for all t<T
- Thinning Method:
  1. t=0, I=0
  2. Generate a random number U
  3. t=t-ln(U)/λ. If t>T, stop.
  4. Generate a random number U
  5. If U$\leq$ $\lambda(t)/\lambda$, set I=I+1, S(I)=t
  6. Go to step 2
- Final I is the no. of events in time T
- S(1), $\cdots$, S(I) are the event times
- Remove step 4 and condition in step 5 for homogeneous Poisson

Subroutine for Generating T_s

- Nonhomogeneous Poisson arrival
  - T_s: the time of the first arrival after time s.

1. Let t =s
2. Generate U
3. Let $t=t-\ln(U)/\lambda$
4. Generate U
5. If $U \leq \lambda(t)/\lambda$, set $T_s=t$ and stop
6. Go to step 2

Subroutine for Generating T_s

- Homogeneous Poisson arrival
  - T_s: the time of the first arrival after time s.

1. Let t =s
2. Generate U
3. Let t=t-ln(U)/λ
4. Set T_s=t and stop

M/G/1 Queue

- Variables:
  - Time: t
  - Counters:
    - N_A: no. of arrivals by time t
    - N_D: no. of departures by time t
  - System state: n – no. of customers in system at t
  - eventNum: counter of # of events happened so far
- Events:
  - Arrival, departure (cause state change)
  - Event list: EL = t_A, t_D
    - t_A: the time of the next arrival after time t
    - T_D: departure time of the customer presently being served

- Output:
  - A(i): arrival time of customer i
  - D(i): departure time of customer I
  - SystemState, SystemStateTime vector:
    - SystemStateTime(i): i-th event happening time
    - SystemState(i): the system state, # of customers in system, right after the i-th event.

- Initialize:
  - Set $t=N_A=N_D=0$
  - Set SS $n=0$
  - Generate T_0, and set $t_A=T_0$, $t_D=\infty$
  - Service time is denoted as r.v. Y
    - $t_D= Y + T_0$

- If ($t_A \leq t_D$) (Arrival happens next)
  - $t = t_A$ (we move along to time t_A)
  - $N_A = N_A + 1$ (one more arrival)
  - $n = n + 1$ (one more customer in system)
  - Generate T_t, reset $t_A = T_t$ (time of next arrival)
  - If ($n=1$) generate Y and reset $t_D = t + Y$ (system had been empty before without t_D determined, so we need to generate the service time of the new customer)

- Collect output data:
  - $A(N_A)=t$ (customer N_A arrived at time t)
  - eventNum = eventNum + 1;
  - SystemState(eventNum) = n;
  - SystemStateTime(eventNum) = t;

- If ($t_D < t_A$) (Departure happens next)
  - $t = t_D$
  - $n = n-1$ (one customer leaves)
  - $N_D = N_D+1$ (departure number increases 1)
  - If ($n=0$) $t_D=\infty$; (empty system, no next departure time)

    else, generate Y and $t_D=t+Y$ (why?)

- Collect output data:
  - $D(N_D)=t$
  - eventNum = eventNum + 1;
  - SystemState(eventNum) = n;
  - SystemStateTime(eventNum) = t;

Summary

- Analyzing physical system description
- Represent system states
- What events?
- Define variables, outputs

- Manage event list
- Deal with each top event one by one