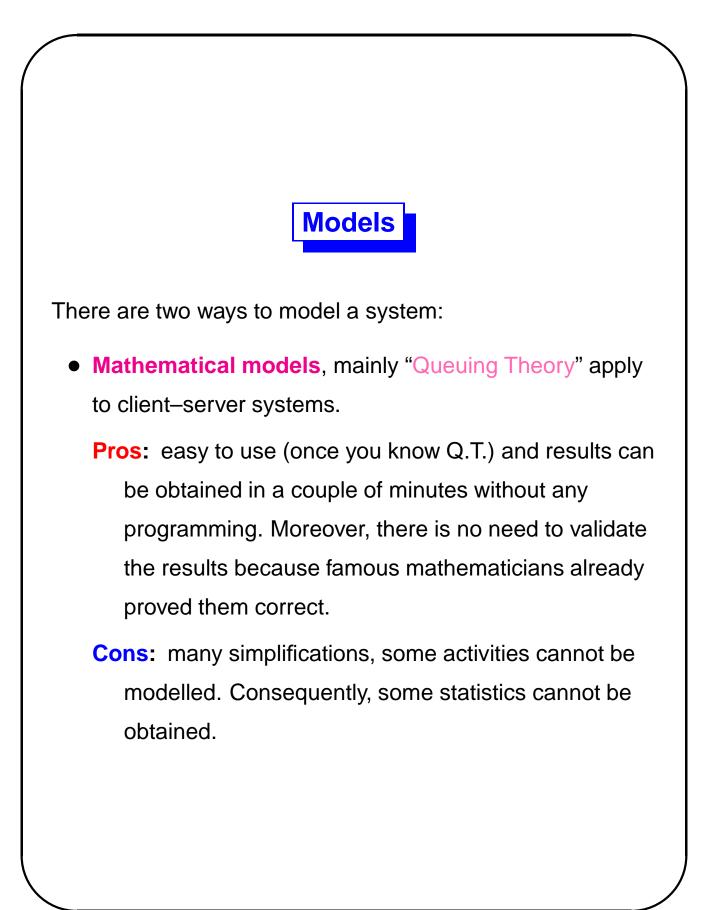
The system and its model

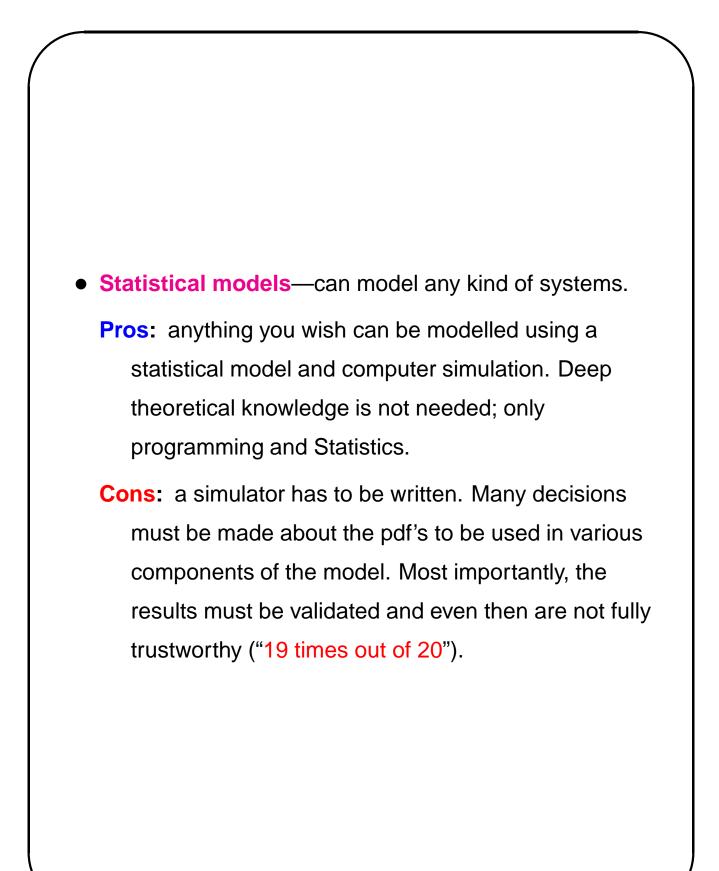
The standard assumption is that the "system" starts its operation at time 0 and works forever. Thus we will not know the true properties of the system until the end of time (whatever that means).

In a model, we use the information gathered as modelling time progresses, i.e. from time 0 to time T (T is just a symbolic notation).

The model yields some statistics; if the model was properly constructed, the larger T is, the closer these statistics are to the real ones.

If the model contains errors, its statistics will never converge to real values–this is a **serious problem** because a bad model looks as good as a good model until proven otherwise.



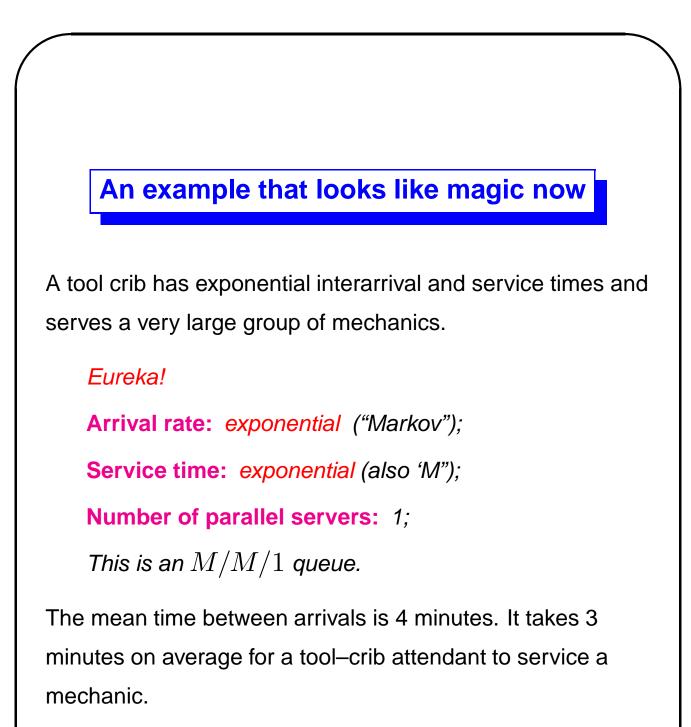


Queuing theory

QT models systems with servers and clients (presumably waiting in queues). Elements of the theory will be covered in greater detail at a later time; now is the time for a brief preview.

Notation: there are many standard symbols like $\lambda, \mu, \rho, A_n, W_n, L(t), L, L_Q, w, w_Q$ etc. These represent the **actual** properties of a system. There is no need to know the meaning of all of them now.

The interpretation is simple: a "hat" on top of a symbol, such as \widehat{L} says that this is an approximate value of L called an **estimator**. Note that the exact value of L will never be known to anyone.



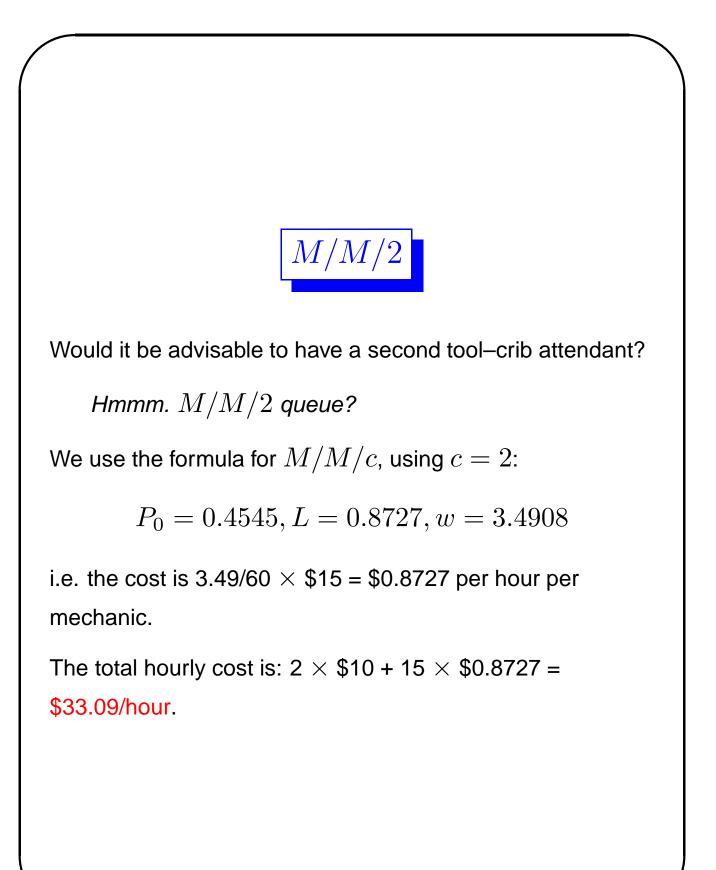
Aha.
$$\lambda = \frac{1}{4}, \mu = \frac{1}{3}$$
. $\lambda < \mu \rightarrow \rho = \frac{\lambda}{\mu} = \frac{3}{4}$

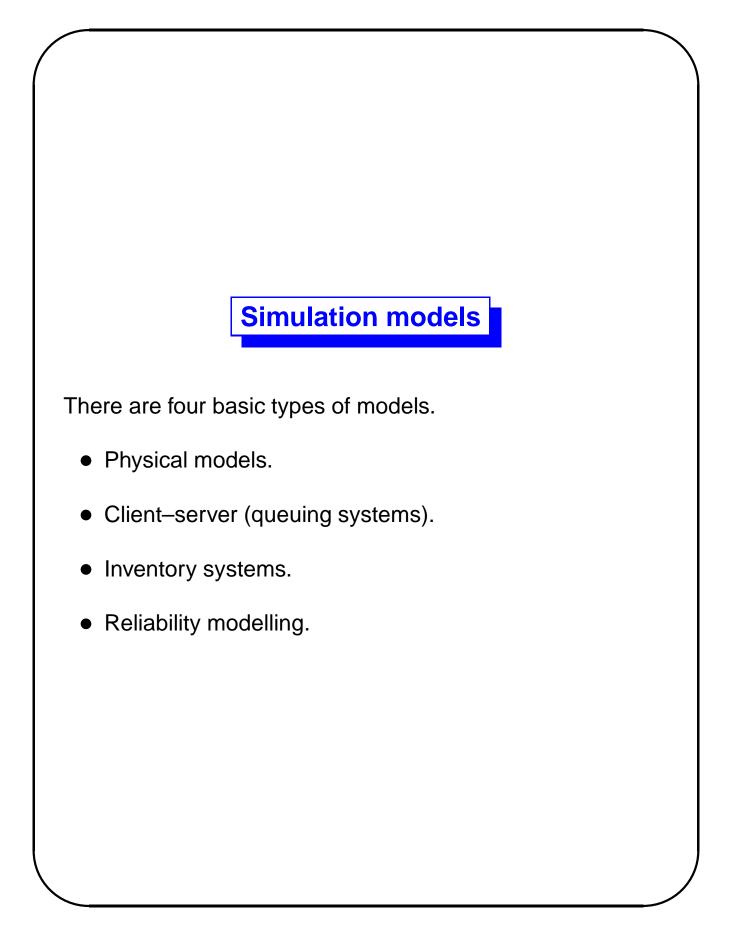


The tool crib is a system with one server. The average waiting time is $\frac{1}{\mu(1-\rho)}=12$ minutes.

12 minutes of a mechanic's time are worth \$3.

15 mechanics arrive per hour, hence the hourly cost of the system is: $10 + 15 \times 3 = \frac{55}{hour}$.



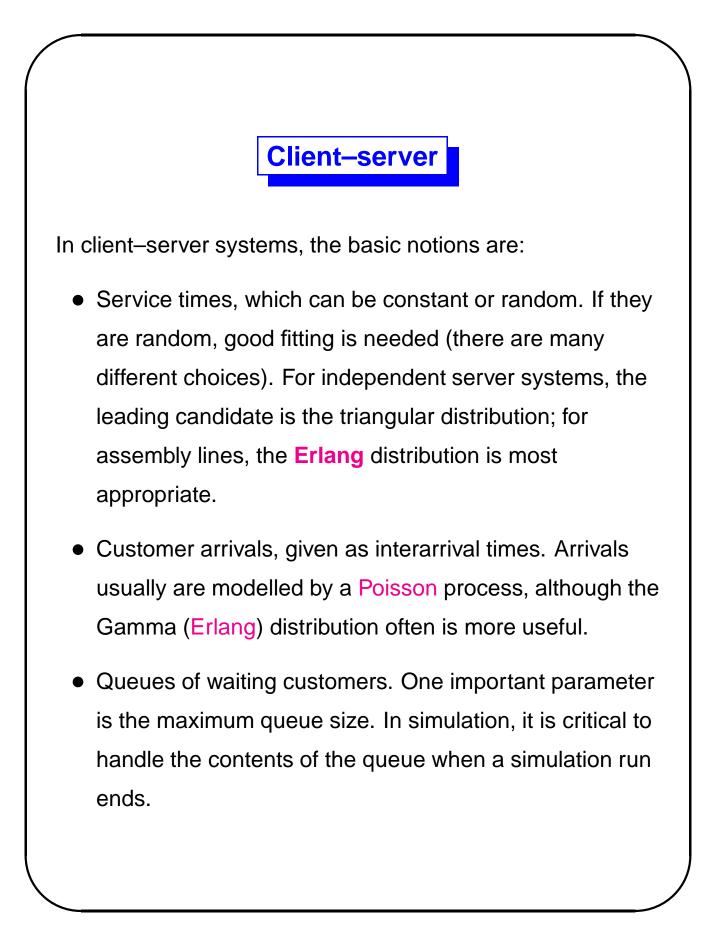


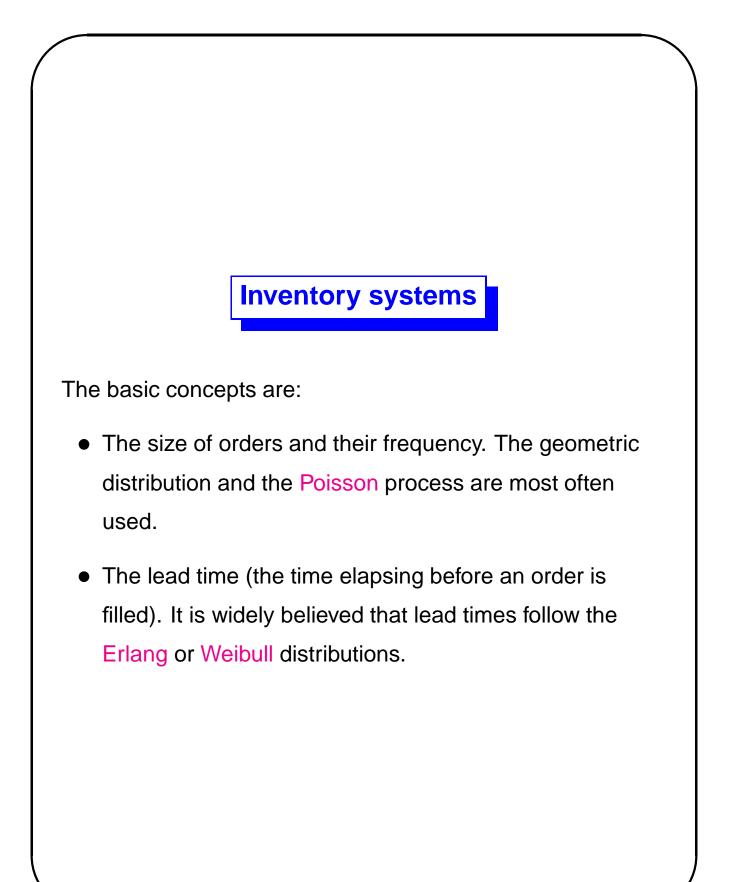
Physical models

This is a broad category of models of physical reality. Some examples:

- 1. Behaviour of an eco-system (as a function of time).
- 2. Mutations in organisms (as a function of generation).
- 3. Resistance of an object to external phenomena (CPU chip to temperature variations, etc.).
- 4. Properties of a digital signal sent over some carrier (SNR, attenuation, etc.).

some of these models are deterministic; other are stochastic.





Reliability

Reliability studies focus on determining the mean time between failures. They rely heavily on Statistics to model the elusive failure pdfs of the components of the system under investigation.

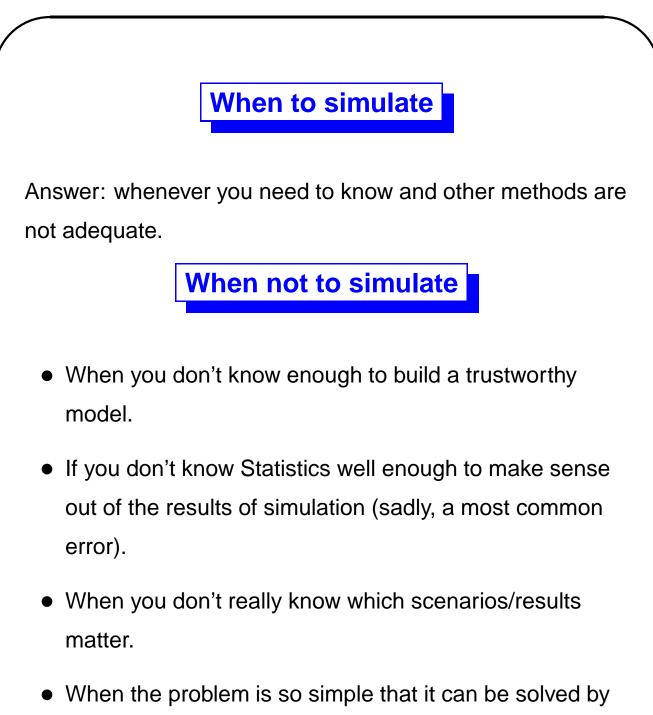
A large variety of distributions are used to model failing components and Queuing Theory is often used in modelling reliability. This is seldom correct because QT has no means of taking into account changes of conditions of operation such as temperature oscillations.

Simulation

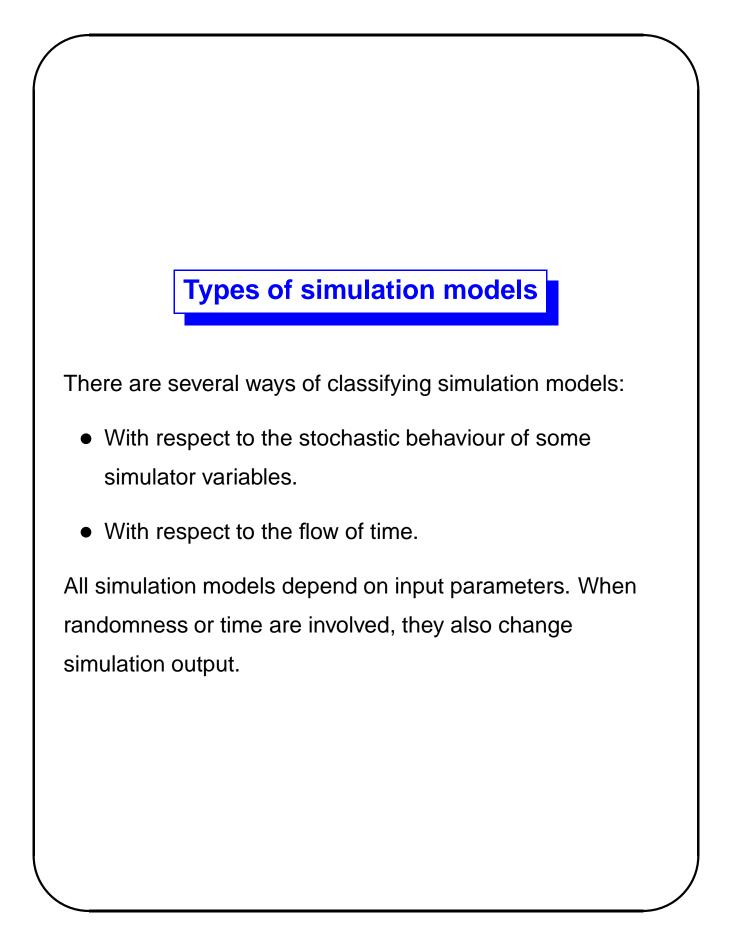
is the **imitation** of the operation of a real–world system.

Simulation is a form of modelling and offers all the other possibilities of making errors; it adds another aspect of uncertainty: when a simulator models the behaviour of a system, it gives only a finite number of **snapshots** of the states of the system being simulated. Even if these snapshots are perfect (seldom the case), they do not reflect the whole complexity of the system (e.g. try reconstructing the surface of the Moon based on *n* photographs, for different values of *n*).

Warning: simulation may be misleading and should be used with caution.



 When the problem is so simple that it can be solved by another method (prototype, some thinking, queuing theory, etc.). Other methods are always more trustworthy when they work.



Randomness

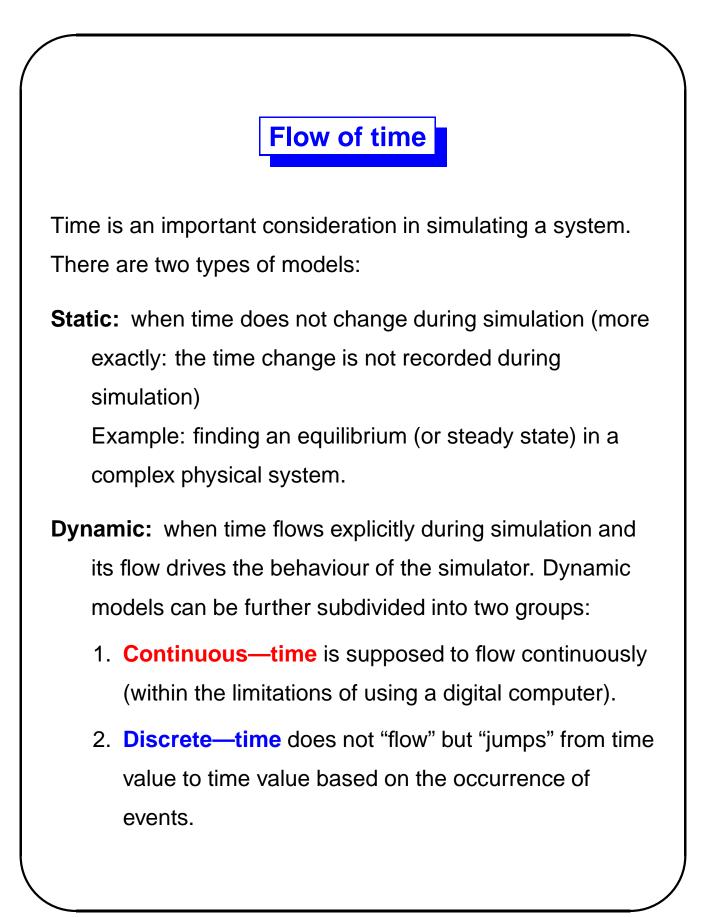
A simulation model may assume that all events occur according to a predetermined schedule or it may assume that some events are subject to random influences.

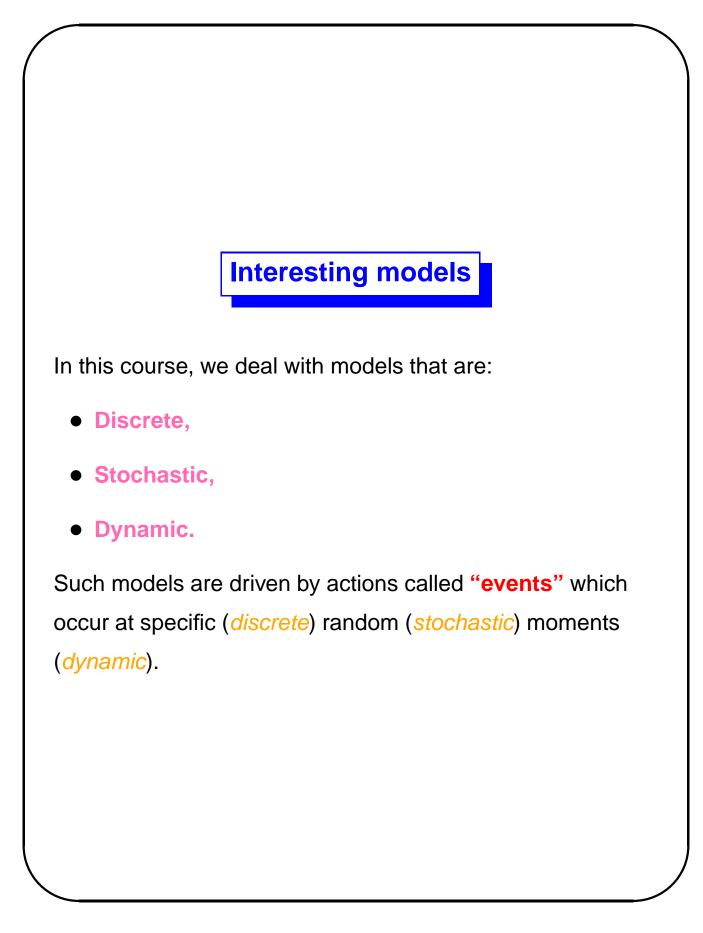
Deterministic: no randomness involved; the simulator output always the same.

An example would be to study the behaviour of a container port facility, where we assume that all the activities occur according to schedule and are looking for bottlenecks in the system.

Stochastic: Some simulator variables take as values random variates (drawn from appropriate probability distributions).

Any serious model involving servers and customers is stochastic, because customers arrive (somewhat) unpredictably and service times vary.







There are two approaches to dynamic simulation:

time-driven ("continuous") and event-driven ("discrete").

Continuous simulation is an attempt to mimic reality which has a dimension called **time** flowing "continuously" forward.

Continuous simulators are easier to write, but are often impractical, because of huge execution times.

Discrete simulators are more versatile, but less intuitive.

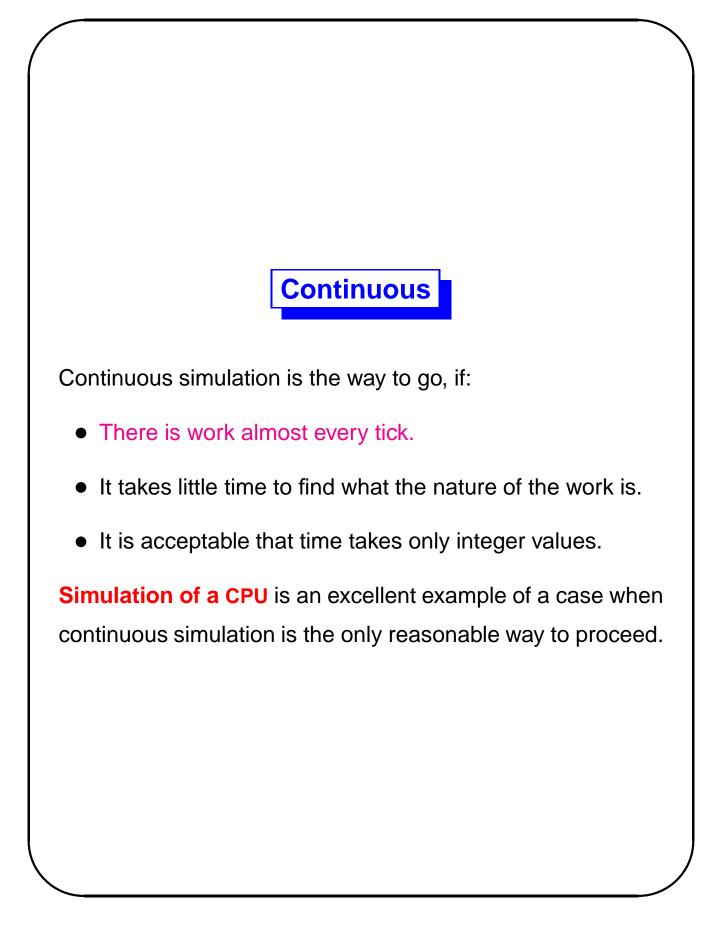
```
Continuous simulator
```

A time-driven simulator essentially simulates a real-life clock.

A "continuous" simulator has an integer variable representing the current time:

```
for( int clock = 0 ; clock < END ; clock++ ) {
    check if there is work at time "clock"
    if so, do what needed.
}</pre>
```

The constant **END** gives the duration of simulation expressed as a multiple of a unit called **tick** and the **clock** changes ("ticks") one tick at a time (second, hour, μ s).



Discrete simulation

Instead of simulating a clock, discrete simulation simulates the occurrence of events.

An event is an instantaneous occurrence that changes the state of the system (such as the arrival of a new customer).

Since the state of the system changes only as a result of an event, nothing changes at moments when no events occur. Such moments are skipped by the simulator and time advances not "continuously" (a tick at a time) but discretely jumps forward from the time of the occurrence of one event to the time of the occurrence of the next event.

It is critical to process events in order (keep time moving forward).

