Discrete Event Simulation

Tecniche di Programmazione – A.A. 2020/2021

Strategy

- Decision makers need to evaluate beforehand the impact of a strategic or tactical move
- But some process are just "too complex"
  - Mathematical models is too abstract
  - Building real systems with multiple configurations is too expensive

$\Rightarrow$ Simulation is a good compromise

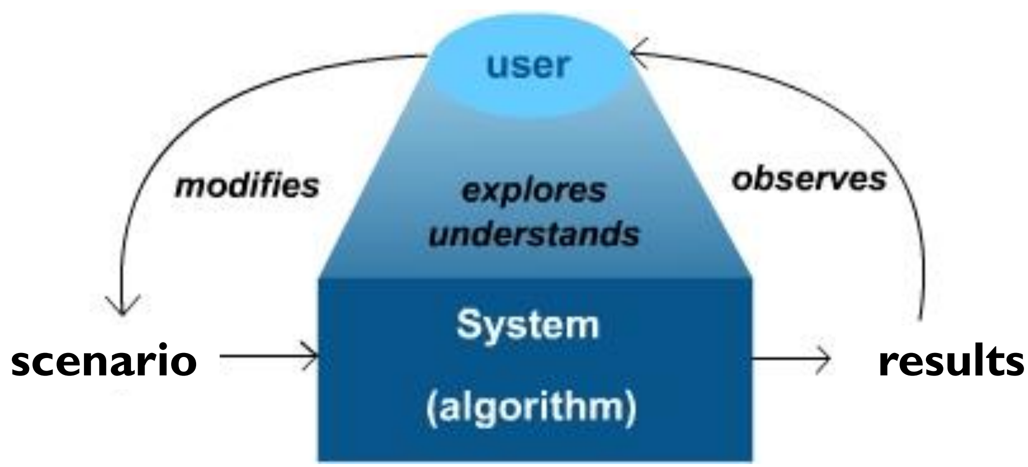
Simulation

Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of a system

– Shannon

What-if analysis

- A data-intensive simulation whose goal is to inspect the behavior of a complex system under some given hypotheses (called "*scenarios*")
- What-if analysis ≠ Forecasting



Disadvantages

- Simulation can be expensive and time consuming
- Each model is unique
- Managers must choose solutions they want to try in scenarios
- Overfitting vs. non-repeatability

Simulation tools

- Spreadsheets
  - Excel
  - Calc
  - Numbers
- Ad-hoc
  - Applix TM1
  - Powersim
  - QlikView
  - SAP BPS
  - SAS Forecast S.
  - …

Simulation tools

- Write your own simulator!
  - from scratch
  - in Java

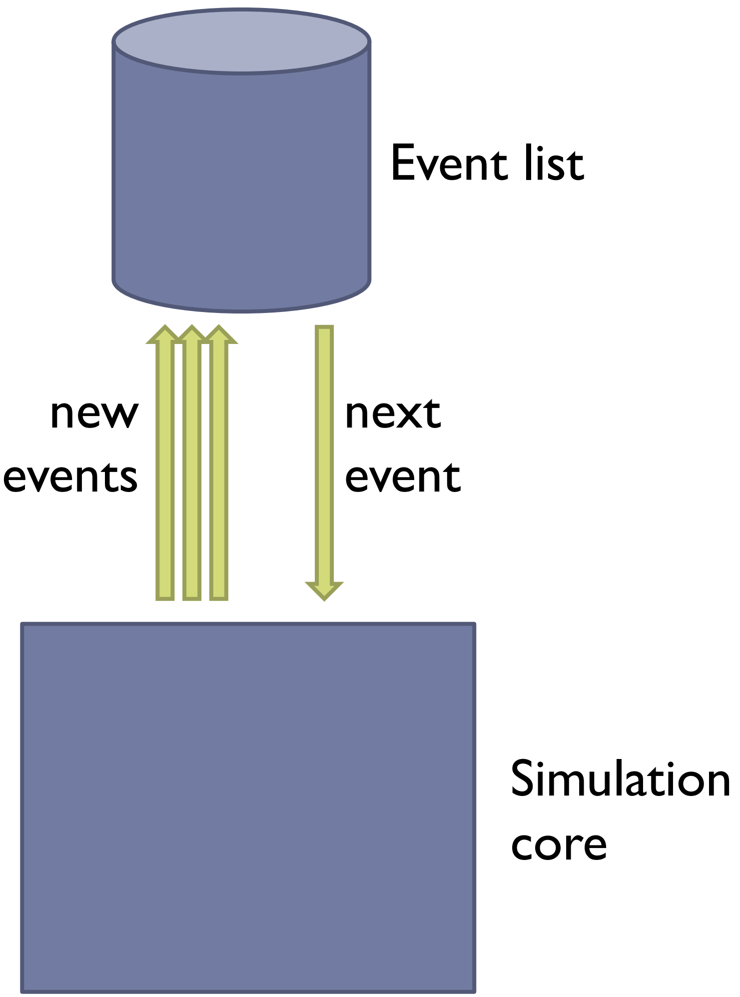
Taxonomy

- Deterministic or Stochastic
  - Does the model contain stochastic components?
- Static or Dynamic
  - Is time a significant variable?
- Continuous or Discrete
  - Does the system state evolve continuously or only at discrete points in time?

Discrete Event Simulation (DES)

- Discrete event simulation is **dynamic** and **discrete**
- It can be either deterministic or stochastic
- Changes in state of the model occur at discrete points in time
- The model maintains a list of events (“*event list*”)
  - At each step, the scheduled event with the lowest time gets processed (i.e., the event list is a *priority queue*)
  - The event is processed, new events are scheduled

Discrete Event Simulation (DES)



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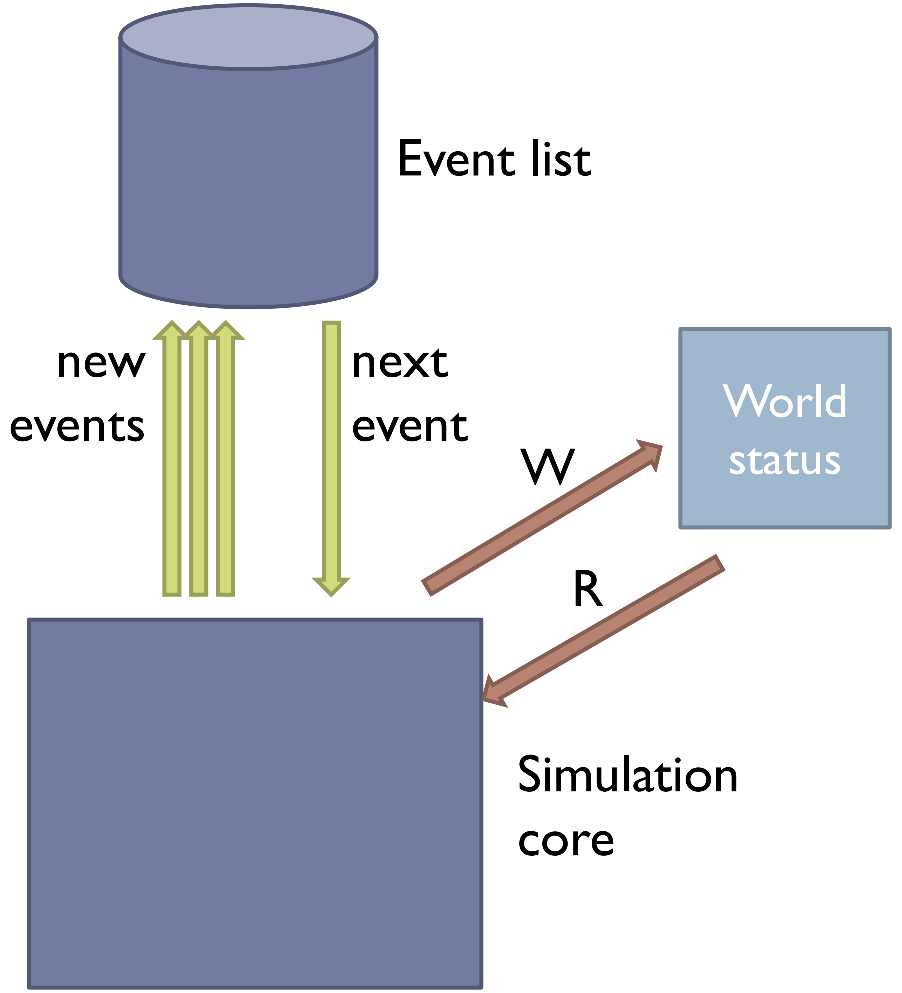

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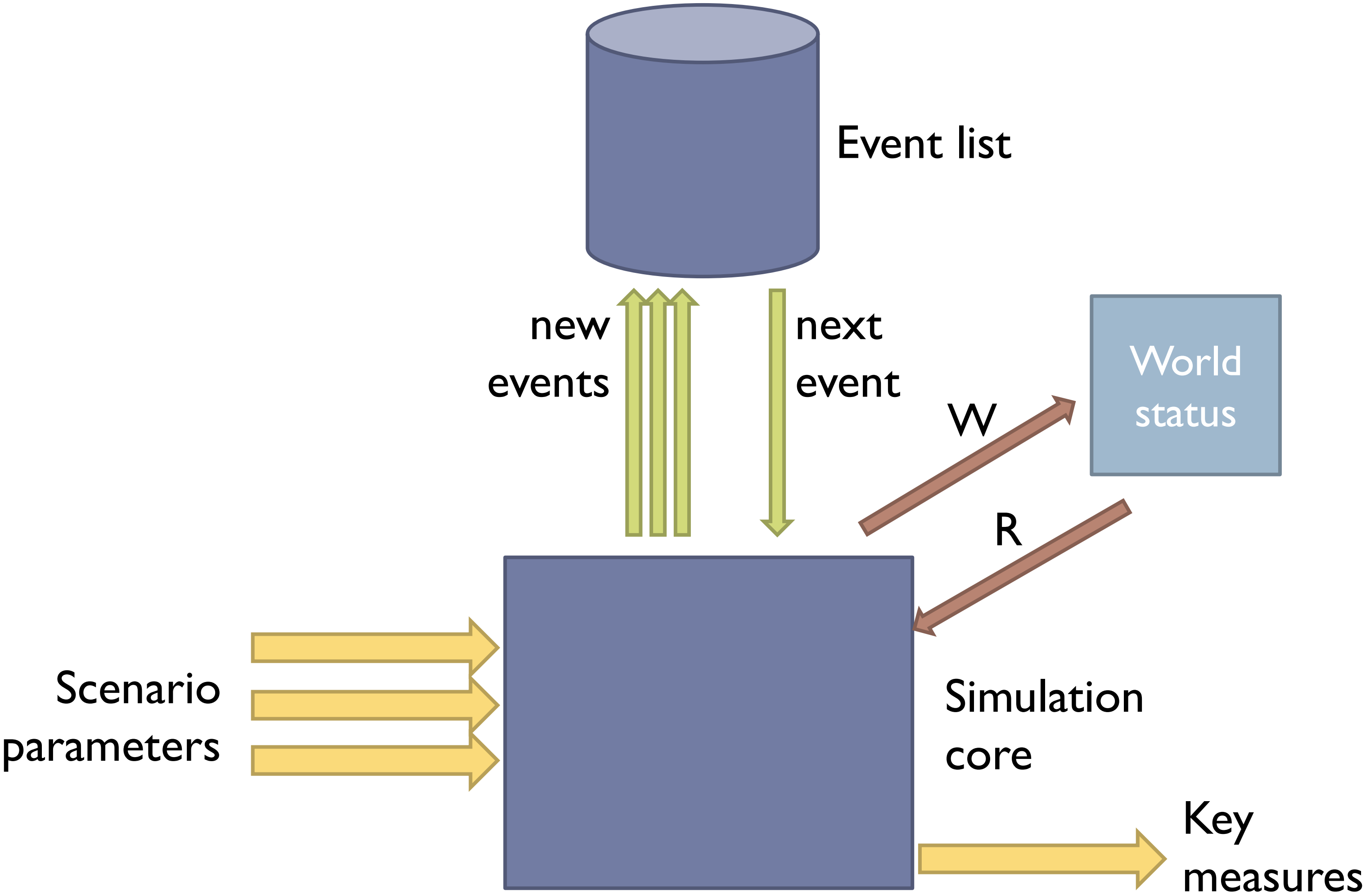
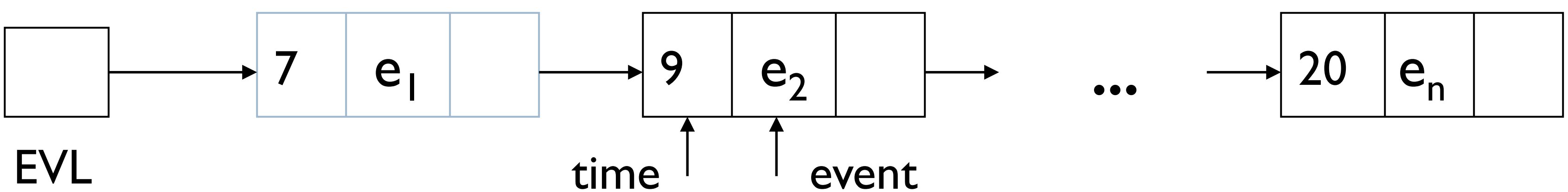


The event list

- An event contains at least two fields of information
  - time of occurrence (timestamp): time when the event should happen (in the "simulated future")
  - what the event represents



- Simulation terminates when the event list is empty
- Conceptually endless simulations, like weather, terminate at some arbitrary time

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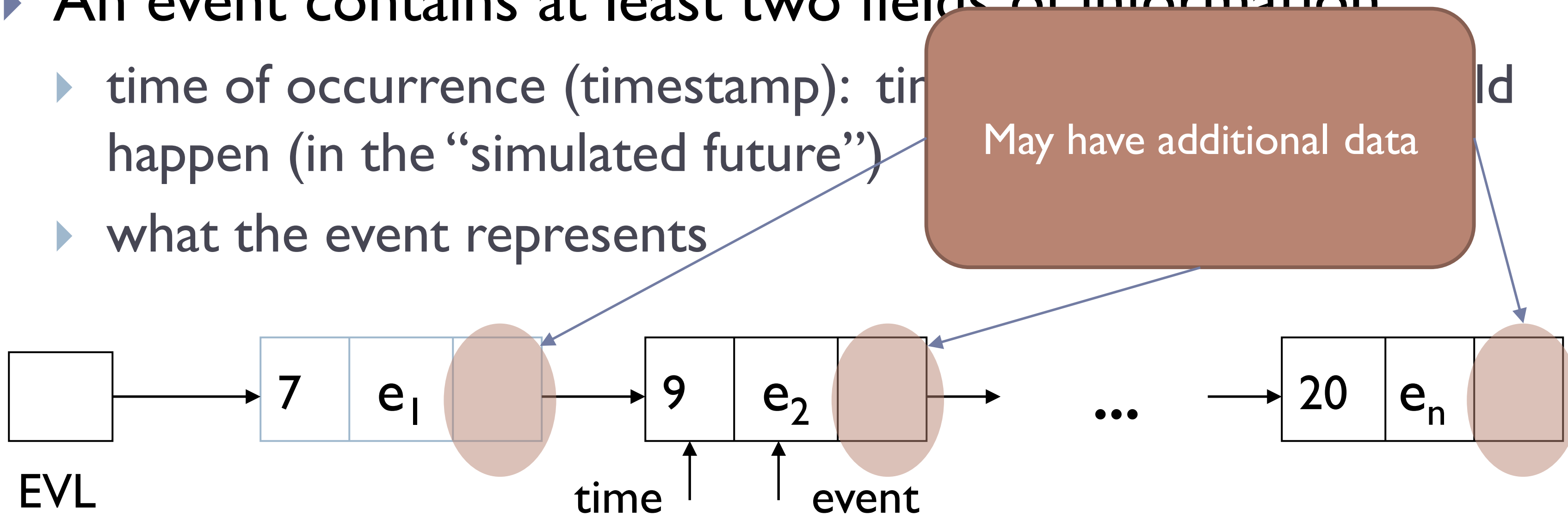

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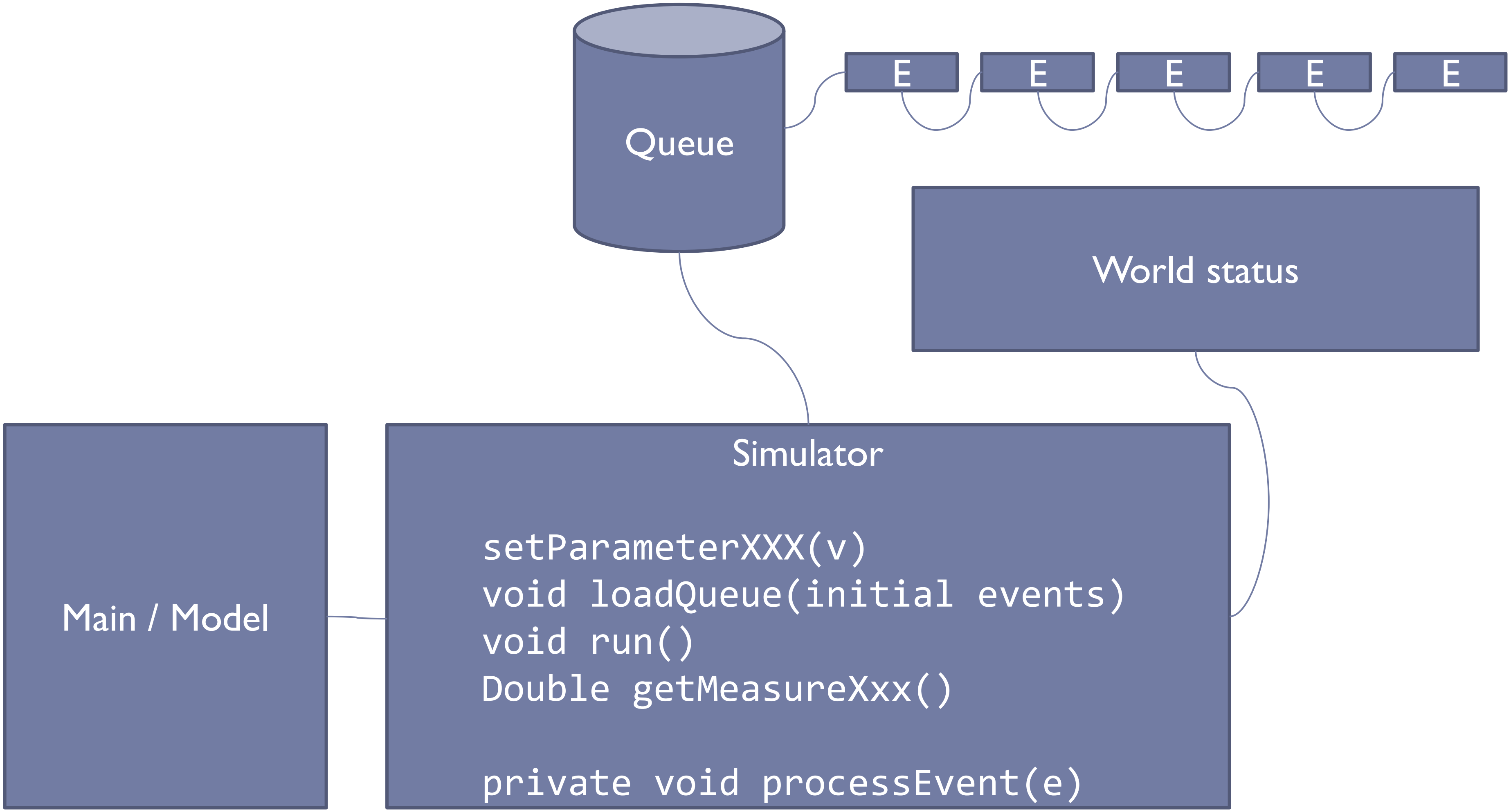
Simulator architecture



World Status

- A set of variables / collections / graphs / … that represent the current state (the *present*) of the simulation
- The simulation makes the world status evolve, through a series of events
- The world status may influence / constrain how the events are processed
- The world status includes the measures of interest.

General behavior: Simulator

- `setParameterXXX`: defines the simulation strategy and parameters, and initializes the World Status
  - Can also be in the Simulator constructor
- `loadQueue`: defines the initial contents of the simulation queue, *at time zero*
- `run`: executes the simulation loop
  - extract an event from the queue
  - `processEvent(e)`
- `getMeasureXXX`: allows to access the results of the simulated variables, after the completion of the loop

`processEvent(e)`

- Analyzes `e.getType()`
- Depending on:
  - The simulation parameters (constants) and strategy
  - The type of event
  - The value(s) associated with the event
  - The current world status
- It performs actions:
  - (Optional) updates the current world status
  - (Optional) generates and inserts new events (in the future)
  - (Optional) updates the measures of interest

Handling time

Synchronous

- Events (all/most/some) correspond to the passing of time
  - Easy to generate systematically (all at the beginning, or each one generates the next)
- When a new day/hour/months ticks, something needs to be done
- May be intermixed by other events, at arbitrary times

Asyncronous

- Something happens in the simulated world
- May happen at any time instant
- The simulated time will «jump» to the nearest interesting event

Handling Randomness

Deterministic

- All actions are purely deterministic (initial events, event processing)
- Repeating the simulation, with equal parameters, will yield the same result. Always.

Stochastic

- Random initial events (times, values, types)
- Randomness in event processing (eg. in 10% of the cases simulate a fault)
- Repeating the simulation will yield different measures
- Simulation should be repeated and the measures should be averaged

Example 1

Discrete Event Simulation

Example: Car Sharing

- We want to simulate a deposit of shared cars.
  - Initially we have NC cars
- A new client comes every T_IN minutes
  - If there are available cars, he lends one car, for a duration of T_TRAVEL minutes
  - If there are no cars, he is a dissatisfied client
- Compute the number of dissatisfied clients, at the end of the day, as a function of NC.
- T_IN = 10 minutes
- T_TRAVEL = random (1 hour, 2 hours, 3 hours)

Simulator data

Events

- Client arrives
- Client returns car

World model

- Number of total cars
- Number of available cars

- Number of clients served
- Number of dissatisfied clients

Variants

- Remember "who" is the client, at return time
- Model different kinds of cars (A, B, C).
  - A client wants one kind of car, but he may accept a "better" car (cost for the company)
- Model different car rental locations
  - A car is taken at location "x" and returned at location "y"

Example 2

Discrete Event Simulation

Example: Emergency

- We simulate the behavior of an **Emergency department** in an hospital.
- The department in organized in two sections
  - A single Triage, where patients are received, quickly examined, and assigned a severity code
  - A number NS of doctor studios, that operate in parallel. Each doctor will receive the next patient, act on him, and then release him
  - The severity code gives priority in accessing the doctors. Patients with the same severity, will be called in arrival order.

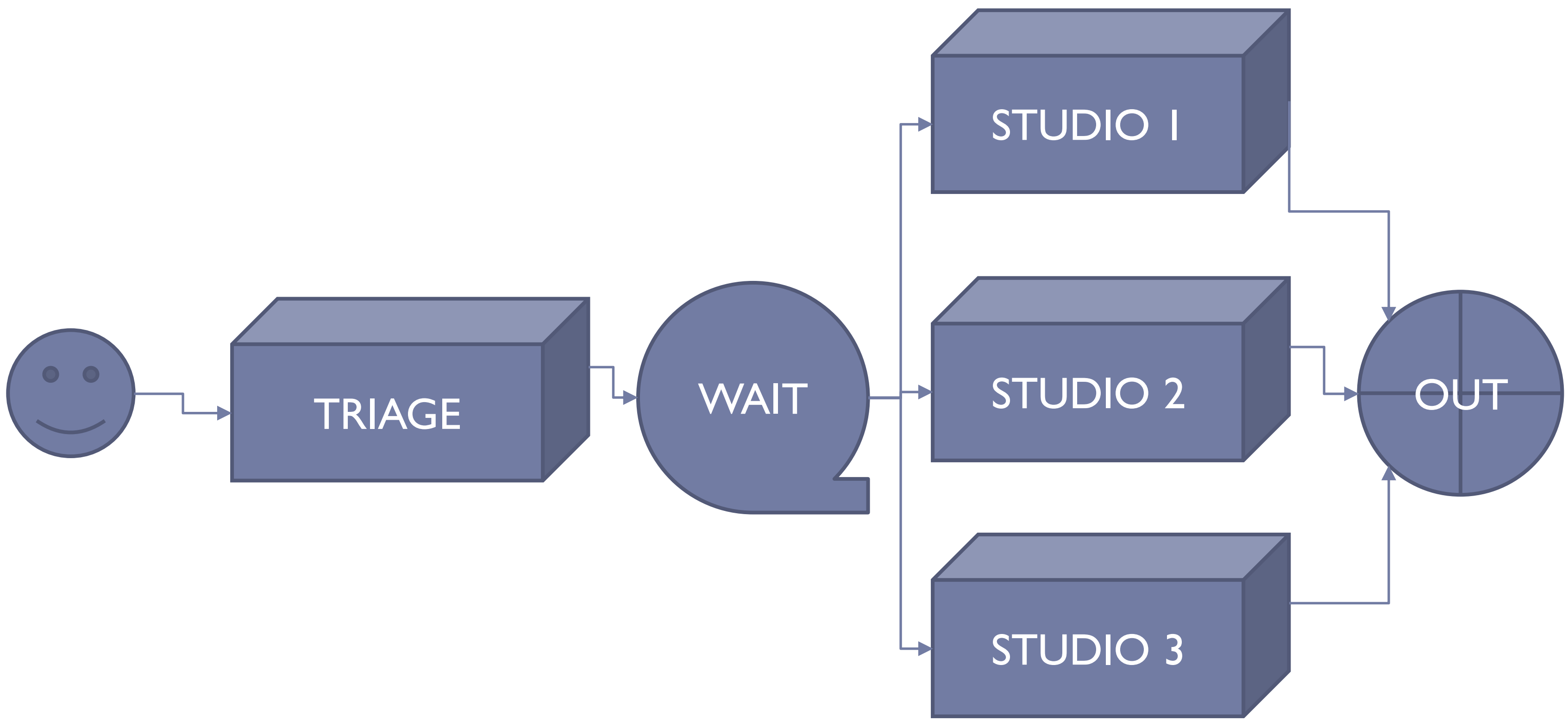
Severity codes

- WHITE: not urgent, may wait without problems
  - After WHITE_TIMEOUT, if not served, goes home
- YELLOW: serious but not urgent
  - After YELLOW_TIMEOUT, if not served, becomes RED
- RED: serious and urgent, risking life, must be served as soon as possible
  - After RED_TIMEOUT, if not served, becomes BLACK
- BLACK: dead. No need to be served.

Timing

Phase	Required time	Example
Triage	DURATION_TRIAGE	5 minutes
Handling a White patient	DURATION_WHITE	10 minutes
Handling a Yellow patient	DURATION_YELLOW	15 minutes
Handling a Red patient	DURATION_RED	30 minutes
Handling a Black patient	N/A	not needed

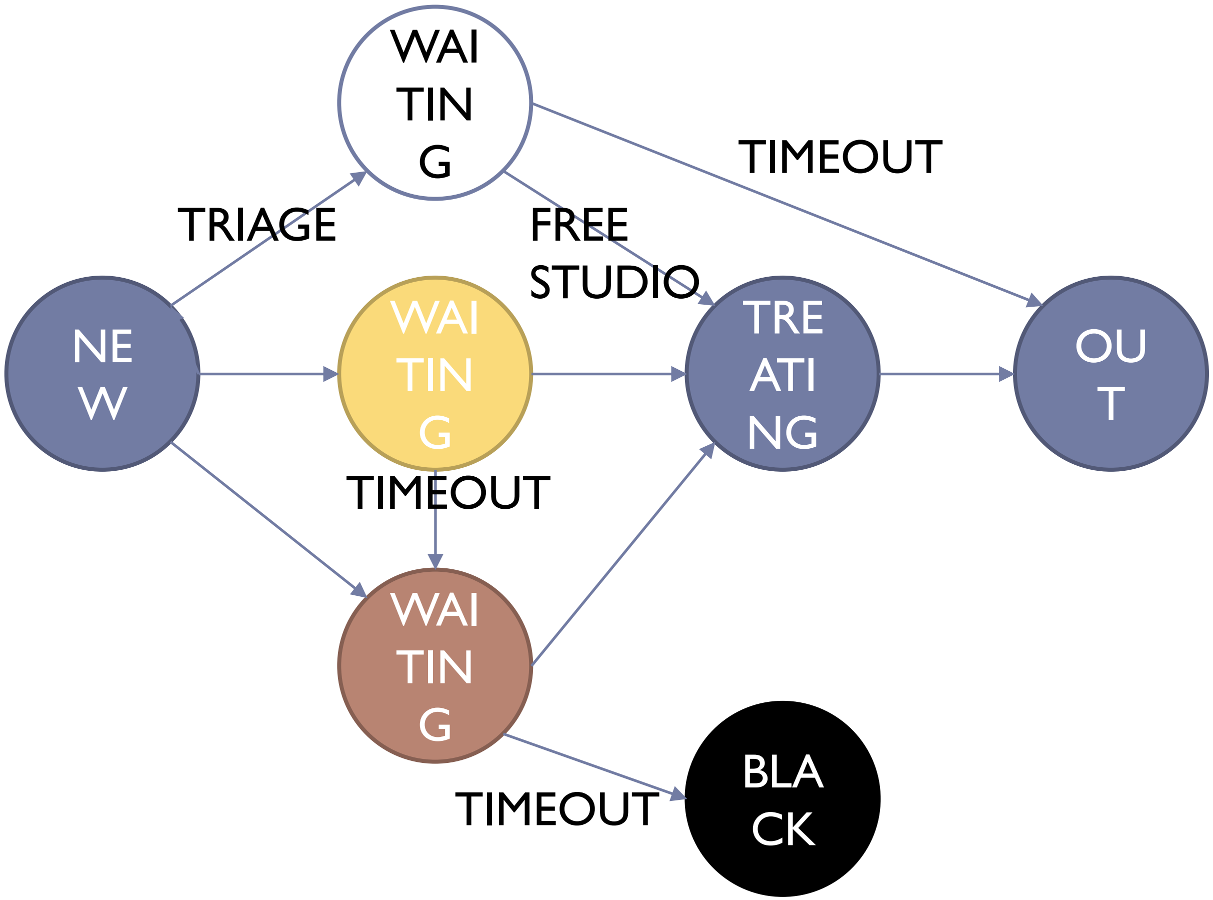
Patients workflow



World Model

- Collection of patients
- For each patient:
  - Patient status

Evolution of patient status



Simulation goals

Input

- Parameter: NS
- Initial events:
  - NP patients
  - arriving every T_ARRIVAL minutes
  - with a round-robin severity (white/yellow/red/white/…)
- Simulate from 8:00 to 20:00

Output

- Number of patients dismissed
- Number of patients that abandoned
- Number of patients dead

Randomizing

- Input arrival times every T_ARRIVAL ± random%
- Input severity probabilities (PROB_WHITE, PROB_YELLOW, PROB_RED)
- Variable processing time (DURATION_TRIAGE, DURATION_WHITE, DURATION_YELLOW, DURATION_RED ± random%)
- Etc…

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