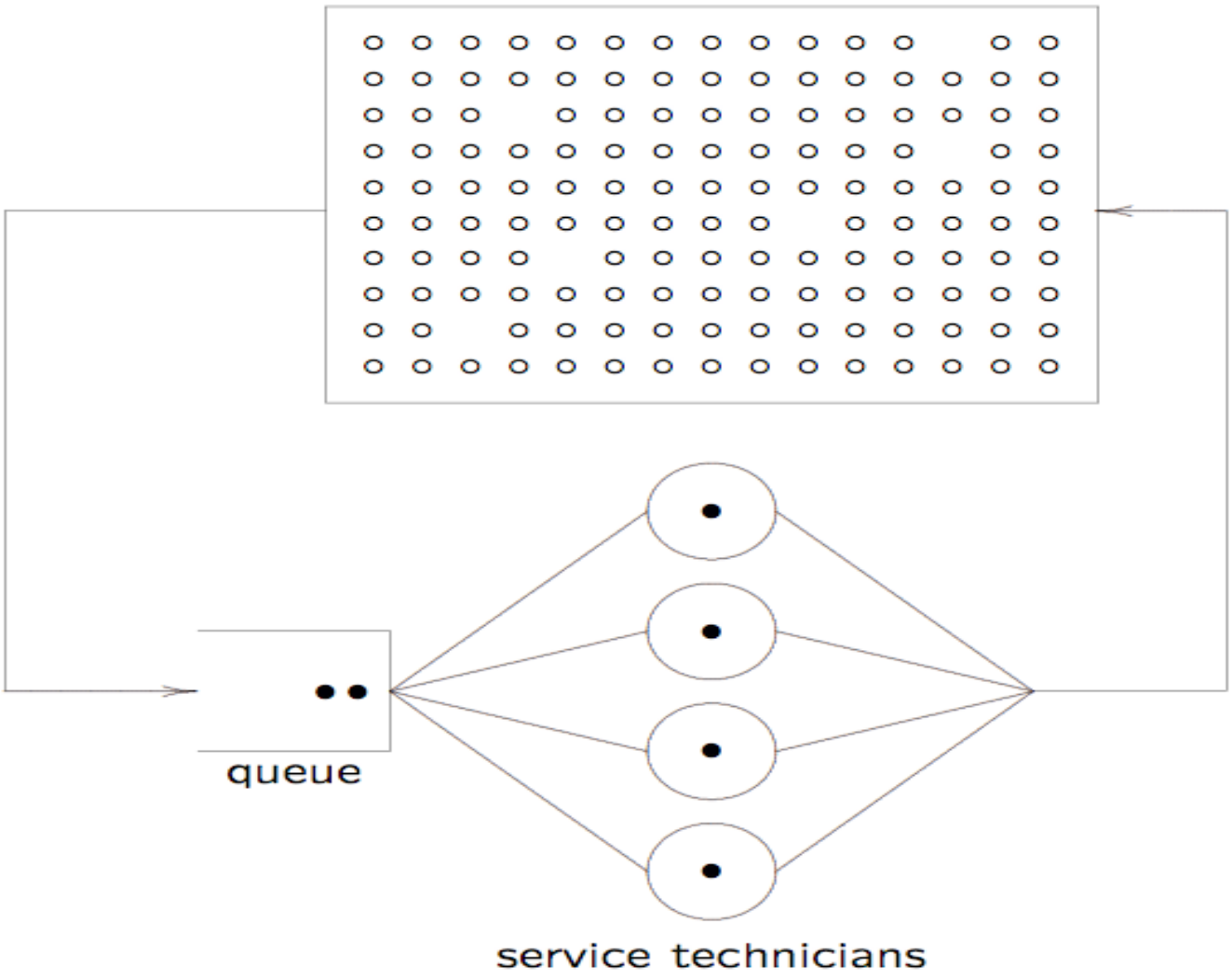
A Machine Shop Model

- 150 identical machines:
  - Operate continuously, 8 hr/day, 250 days/yr
  - Operate independently
  - Repaired in the order of failure
  - Income: $20/hr of operation
- Service technician(s):
  - 2-year contract at $52,000/yr
  - Each works 230 8-hr days/yr
- How many service technicians should be hired?

System Diagram



Steps in the Study

1) Goals and Objectives:
   - Find number of technicians for max profit
   - Extremes: one techie, one techie per machine
2) Conceptual Model:
   - State of each machine (failed, operational)
   - State of each techie (busy, idle)
   - Provides a high-level description of the system at any time
3) Specification Model:
   - What is known about time between failures?
   - What is the distribution of the repair times?
   - How will time evolution be simulated?

Steps cont.

4) Computational Model:
   - Simulation clock data structure
   - Queue of failed machines
   - Queue of available techies
5) Verify:
   - Software engineering activity
   - Usually done via extensive testing
6) Validate:
   - Is the computational model a good approximation of the actual machine shop?
   - If operational, compare against the real thing
   - Otherwise, use *consistency checks*

Machine Shop Model Applications

7) Design Experiments
   - Vary the number of technicians
   - What are the initial conditions?
   - How many replications are required?
8) Make Production Runs
   - Manage output wisely
   - Must be able to reproduce results exactly
9) Analyze Output
   - Observations are often correlated (not independent)
   - Take care not to derive erroneous conclusions

Application cont.

10) Make Decisions
- Graphical display gives optimal number of technicians and sensitivity
- Implement the policy subject to external conditions

11) Document Results
- System diagram
- Assumptions about failure and repair rates
- Description of specification model
- Software
- Tables and figures of output
- Description of output analysis

DES can provide valuable insight about the system

Programming Languages

- General-purpose programming languages
  - Flexible and familiar
  - Well suited for learning DES principles and techniques
  - E.g.: C, C++, Java
- Special-purpose simulation languages
  - Good for building models quickly
  - Provide built-in features (e.g., queue structures)
  - Graphics and animation provided
  - GPSS, SLAM, …

Simulation Examples

- Three steps:

(1) Determine the characteristics of each of the inputs (parameters) - usually modeled with discrete or continuous probability distributions

(2) Construct a simulation table containing the inputs and outputs for the problems at hand.

(3) Run through the simulation for some number of iterations generating new values for the inputs and then calculating the outputs

Example 1
- Grocery Store Checkout

Interarrival time distribution - uniform

Time between Arrivals	Probability	Cumulative Probability	Random Digit Assignment
1	0.125	0.125	001-125
2	0.125	0.250	126-250
3	0.125	0.375	251-375
4	0.125	0.500	376-500
5	0.125	0.675	501-625
6	0.125	0.750	626-750
7	0.125	0.875	751-875
8	0.125	1.000	876-000

Grocery Store Checkout

Service time distribution

Service Time	Probability	Cumulative Probability	Random Digit Assignment
1	0.10	0.10	01-10
2	0.20	0.30	11-30
3	0.30	0.60	31-60
4	0.25	0.85	61-85
5	0.10	0.95	86-95
6	0.05	1.000	96-00

Input and Output

- Input: Arrival Time
  Service Begin Time
  Service End Time
- Output: Delay time (waiting in the queue)

Time in System

Idle Time for Server

Simulation Table

Iteration	Inputs					Output
	X_{i1}	X_{i2}	X_{i3}	…	X_{ip}	Y_i
1 2 3 … n						

Generate Inputs

Cust	Random Number	Interarrival Time	Random Number	Service Time
1	-	-	84	4
2	913	8	10	1
3	727		24	
4	015		53	
5	948		17	
6	309		79	
7	922		91	
8	753		67	
9	235		89	
10	302		38	

Simulate for 10 customers

Cust	Random Number	Interarrival Time	Random Number	Service Time
1	-	-	84	4
2	913	8	10	1
3	727	6	24	4
4	015	1	53	3
5	948	8	17	2
6	309	3	79	4
7	922	8	91	5
8	753	7	67	4
9	235	2	89	5
10	302	3	38	3

Simulation Table

Customer	Interarriv-al Time	Arrival Time	Service Time	Service Begins	Delay Time	Service Ends	Time in System	Idle time of Server
1 2 3 4 5	0 8 6 1	0 8 14 15	4 1 4 3	0 8 14 18	0 0 0 3	4 9 18 21	4 1 4 6	0 4 5 0