General Purpose Simulation System (GPSS) (Part 7)

Dr.Çağatay ÜNDEĞER

Öğretim Görevlisi
Bilkent Üniversitesi Bilgisayar Mühendisliği Bölümü

e-mail : cagatay@undeger.com
cagatay@cs.bilkent.edu.tr

Discrete Event Simulations (Outline)

- Simulation Languages
- GPSS Simulation Language
- A Sample Simulation Model

Simulation Language

- Describes the operation of a simulation on a computer.
- There are two major types of simulation:
  – Discrete-event and
  – Continuous simulations.
- Some modern languages can handle combinations.

Some Discrete-Event Simulation Languages

- GPSS
- AutoMod
- eM-Plant
- Rockwell Arena
- GASP
- SimPy
- SIMSCRIPT II.5
- Simula
- Poses++

Some Continuous Simulation Languages

- Advanced Continuous Simulation Language (ACSL):
  - Supports textual or graphical model specification.
- SimApp:
  - Simple simulation of dynamic systems and control systems.
- Simgua:
  - A simulation toolbox and environment that supports Visual Basic.
- VisSim:
  - A visually programmed block diagram language.

Some Hybrid Simulation Languages

- AnyLogic:
  - Multi-method simulation tool, which supports System dynamics, Discrete event simulation, Agent-based modeling.
- Simio:
  - A software for discrete-event, continuous, and agent-based simulation.
- Modelica:
  - An open-standard object-oriented language for modeling of complex physical systems.
- Saber Simulator:
  - Simulates physical effects in different engineering domains (hydraulic, electronic, mechanical, thermal, etc.).

General Purpose Simulation System (GPSS)

- A discrete time simulation language,
  - Where a simulation clock advances in discrete steps.
- A system is modelled as transactions (processes) that;
  - Enter the system and
  - Are passed from one service (represented by blocs) to another.

General Purpose Simulation System (GPSS)

- Can be applied effectively and easily to a broad range of problems.
- Particularly well suited for problems such as a factory optimization.
- There are many versions such as:
  - GPSS/360, GPSS II, GPSS III, Flow Simulator, GPSS K, GPSS V, GPSS/PC, GPSS World.

General Purpose Simulation System (GPSS)

- Features a software package that is designed to simplify matters for the user.
- User translates his problem into a conceptual model, which is a block diagram.
- Then GPSS software package:
  - Processes this block diagram,
  - Executes the simulation run, and
  - Produces statistics.

Block

- The basic structural element (statement) of the simulation language.
- A GPSS model is given by its block diagram.
- Some blocks:
  - GENERATE
  - TERMINATE
  - ASSIGN
  - SEIZE
  - RELEASE
  - QUEUE
  - DEPART
  - ADVANCE
  - START
  - END

A block diagram sample

```
          GENERATE                  X$INTMEAN,FN$EXPO
          ASSIGN    1,V$CALCWAIT
RECALC    ASSIGN    4,V$NORMALVAR
          TEST GE   P4,5,RECALC
          TEST E    F$COMPUTER1,1,LETSWAIT
          TEST E    F$COMPUTER2,1,LETSWAIT
          TEST E    F$COMPUTER3,1,LETSWAIT
          TEST E    F$COMPUTER4,1,LETSWAIT
          TRANSFER                  V$DECIDE,,IMMEQUIT
LETSWAIT            ENTER           CHAIRS,1
          QUEUE     WAITING
          TRANSFER                  ,ENTCOM1
```

Transaction

- A process that represents the real-world system you are modeling.
- Executed by moving from block to block.
- Each transaction in the model is contained in exactly one block,
- But one block may contain many transactions.

```
100   GENERATE    10,2    ;Jobs of type 1 start here
110   SEIZE       MACHA
120   ADVANCE     4
130   RELEASE     MACHA
140   TERMINATE           ;Jobs of type 1 end here
150   ;--------------------------------------------------------
160   GENERATE    20,5    ;Jobs of type 2 start here
170   SEIZE       MACHB
180   ADVANCE     6
190   RELEASE     MACHB
200   TERMINATE           ;Jobs of type 2 end here
```


Operands of Blocks

- **Some blocks with their operands**
  - GENERATE A,B,C,D,E
  - SIEZE A
  - QUEUE A
  - ....

The Format of GPSS Computer Code

Line Number (old versions)	Label	Operation	Operands	Comments
100	NEW	GENERATE	10	;comments
100	NEW	GENERATE	, , ,10	; comments

Generating and Terminating Transactions

- GENERATE block generates transactions
- TERMINATE block destroys the transactions

```
GENERATE     300     ; creates a transaction every 300 time units
.....
.....
TERMINATE            ; terminates the transaction
```

GENERATE A,B,C,D,E

- Generates transactions.

A: Mean interval between generation of two transactions

B: Half width of uniform distribution or function modifier used to generate random interval between generation of transactions

C: Delay starting time

D: Limit on total transactions to be created

E: Priority level

GENERATE A,B,C,D,E

If only the A Operand is specified,
It is evaluated numerically and used as the time increment.

GENERATE 300 ; interval times = 300

GENERATE A,B,C,D,E

- If B does not specify a function,
  - both A and B are evaluated numerically and a random number between A-B and A+B is used as the time increment.

GENERATE 300,100 ; interval times = [200,400]

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GENERATE A,B,C,D,E

- When Operand B is an function,
  - It is a special case called a “function modifier”.
  - Time increment is calculated by multiplying the result of function by Operand A.

GENERATE 100, FN$EXPO

; interval times = exponential with mean 100

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TERMINATE A

- Destroys the active transaction.

A: Termination Count decrement (optional).

- The Termination Count of the simulation is set to 1 by a prior START Command.
- When the termination count reaches 0, the simulation ends

TERMINATE ; transaction ends
TERMINATE 1 ; simulation ends

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ADVANCE A,B

- Delays the progress of a transactions for a specified amount of simulated time.

A: The mean time increment.

B: Half width of uniform distribution or function modifier used to generate random delay

ADVANCE 100
ADVANCE 100, 50

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ASSIGN A,B,C

- Used to place or modify a value in a Transaction Parameter (Local variable).
- If no such Parameter exists, it is created.

A: Parameter number of the Active Transaction. Operand must be Name, Positive Integer, etc....

B: Value assigned.

C: Function number.

```
ASSIGN      200, 3
ASSIGN      200+, 3
ASSIGN      TEXT, ”Sample text”
ASSIGN      1, V$COMPUTE_WAIT
```


SAVEVALUE A,B

- Changes the value of a Savevalue Entity (Global variable).

A: Savevalue Entity number. Operand must be Name, Positive Integer, etc....

B: Value to be stored.

```
SAVEVALUE     10, 5
SAVEVALUE     CUSTOMERCOUNT+, 1
SAVEVALUE     TEXT, ”Sample text”
```

Using Facilities

- GPSS provides the *facility* modeling concept to represent limited availability of a service.
- A facility is a resource that can be used by only one transaction at a time.
- To request a facility transaction should enter in SEIZE block.
- Once a transaction has entered the SEIZE block, it owns the facility and other transactions are not allowed to enter this block.
- This is called blocking.

Using Facilities

- When a transaction no longer needs a facility,
  - It releases ownership of the facility, making it ready to be seized by other transactions.
- The RELEASE block is used for this purpose.

```
SEIZE     A     ; gets the ownership of A
....
....
RELEASE   A     ; release the ownership of A
```

SEIZE A

- Waits for or acquires ownership of a Facility Entity.

A: Facility name or number.

SEIZE Teller1
SEIZE Server1

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RELEASE A

- Releases ownership of a facility.

A: Facility name or number.

RELEASE Teller1
RELEASE Server1

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Blocking Sample

Only one transaction at a time is allowed to own the facility MECHANIC

```
GENERATE  300,20
SEIZE     MECHANIC
ADVANCE   280,200
RELEASE   MECHANIC
TERMINATE 1
```


Using Storages

- GPSS provides the *storage* modeling concept to represent a limited number of unit capacity.
- A storage is a resource that can be used by several transactions at a time until it becomes empty.
- To get units from a storage, transaction should call an ENTER block.
- To put units to a storage, transaction should call a LEAVE block.

ENTER A,B

- Attempts to enter an ENTER Block.
- Either takes or waits for a specified number of storage units.

A: Storage Entity name or number.
B: Number of units by which to decrease the available storage capacity.

Toolkit	STORAGE	6
	ENTER	Toolkit, 2

* If there are not enough storage units remaining in the storage entity, Transaction comes to rest on the delay chain.

LEAVE A,B

- Increases the accessible storage units at a storage entity.

A: Storage Entity name or number.
B: Number of units by which to increase the available storage capacity.

LEAVE	Toolkit, 3

* When storage becomes available, delay chain of the storage entitiy is examined in decreasing priority for transactions whose demands can now be met.

Collecting Time Statistics

- To collect data about how long it takes transactions to traverse a given segment of model,
  - Mark;
    - The beginning of the segment with a QUEUE block and
    - The end with a DEPART block.

```
QUEUE     A     ; A is name of queue
...
...
DEPART    A     ; A is name of queue
```


QUEUE A,B

- Updates queue entity statistics to reflect an increase in content.

A: Queue Entity name or number.

B: Number of units by which to increase the content of the Queue Entity. Default value is 1.

```
QUEUE     WaitingLine, 1
```

* The content of the Queue Entity named WaitingLine is increased by one and the associated statistics accumulators are updated.

DEPART A,B

- Register statistics, which indicates a reduction in the content of a Queue Entity.

A: Queue Entity name or number.

B: Number of units by which to decrease the content of the Queue Entity. Default value is 1.

DEPART WaitingLine, 1

* The content of the Queue Entity named WaitingLine is reduced by one and the associated statistics accumulators are updated.

Queue-Depart Sample

```
GENERATE  300,20
QUEUE     GARAGE     ;Store time trans. entered
SEIZE     MECHANIC
DEPART    GARAGE     ;Store time trans. left
ADVANCE   280,200
RELEASE   MECHANIC
TERMINATE 1
```

* When this program is run, GPSS collects data about the amount of time each transaction spends waiting for MECHANIC

Branching with Transfer

- To branch on random basis,
  – use TRANSFER block.

TRANSFER P, LabelA, LabelB
....
LabelA ....
....
LabelB ....
....

Jumps to location LabelB with probability P,
Jumps to LabelA with probability 1- P.

TRANSFER A,B,C,D

- Causes the Active Transaction to jump to a new Block location.

A: Transfer Block mode. Optional. The operand must be BOTH, ALL, PICK, FN, P, SBR, SIM, fraction, Name, Positive Integer, etc.
The meaning of operands B and C depend on the mode.
When Operand A is omitted,
TRANSFER Block operates in “Unconditional Mode”, and
Transaction always jumps to the location specified by B.

B: Block number or location. Parameter name or number when in P Mode.

C: Block number or location. Increment value in FN or P Mode.

D: Block number increment for ALL Mode. Default is 1.

TRANSFER Samples

```
; Jump to Place unconditionally.
TRANSFER     , Place

; Jump to Place with 75% probability, and
; Continue next blok with 25% probability.
TRANSFER     0.75, , Place
.... ; next block

; Jump to Place2 with probability in variable V$DECIDE, and
; Jump to Place1 with 1-probability in variable V$DECIDE.
TRANSFER     V$DECIDE, Place1, Place2
```


Branching with Test

- To branch on some condition of the system,
  - Use TEST block.

```
TEST      GE      C1, 10, ElseLabel
....
....
ElseLabel ....
....
```

Greater than or equal

Transaction continues to next sequential program block if test is successful,
Or jumps to location ElseLabel if test specified is unsuccesful.
Transaction is blocked if test is unsuccesful and label is omitted.

```
TEST      L       Q$GARAGE, 4
```

Continue to next block only if queue GARAGE has less than 4 entries. otherwise transaction is blocked (not allowed to leave TEST block).

TEST O A,B,C

- Compares values, and controls the destination of the active transaction based on the result of the comparison.

O: Relational operator. Relationship of Operand A to Operand B for a successful test. The operator must be E, G, GE, L, LE, or NE.

A: Test value.

B: Reference value that A is going to be compared.

C: Destination Block number.

Transaction continues to next sequential program block if test is succesful,
or jumps to location indicated by C if test is unsuccesful.

If test is unsuccesful and label is omitted, transaction is blocked until the test becomes successful.

Branching Sample

Program segment for a queuing system with limited rework time.
5% of repairs must be reworked.

```
        GENERATE      300,20
        QUEUE         REPAIRSYS
INPUTQ  SEIZE         REPAIRMAN
        ADVANCE       270,30
        RELEASE       REPAIRMAN
        TRANSFER      0.95, , GOOD     ;5% are reworked
        TEST    GE    M1, 700, INPUTQ  ;Test for time in process.
        DEPART        REPAIRSYS        ;Remove twice repaired
        TERMINATE                      ;and still bad parts.
GOOD    DEPART        REPAIRSYS
        TERMINATE     1
```

The TEST block only sends bad parts that have been in system for less than 700 time units to the repair queue.

M1: *Indicates how much time has passes since a transaction was generated.*

Some of The System Variables

- Blocks:
  - N$label — Count of transactions entered the block
  - W$label — Current # of transactions in the block
- Facilities:
  - F$facility — Current content (0 or 1)
- Queues:
  - Q$queue — Current content
  - QM$queue — Maximum content so far
- Transactions:
  - M1 — Time since current transaction was created
  - PR — Priority of transaction
- Storages:
  - R$storage — Available storage capacity
  - S$storage — Amount of storage currently in use

If Queue is long, refuse to enter

```
        GENERATE 500,50
        TEST LE Q$waiting, 10, REFUSE
        SEIZE waiting
        ADVANCE 200,10
        DEPART waiting
REFUSE  TERMINATE 1
```

Random Numbers

- RNi i is the index of a random number stream.
- Each RNi is independent of each other.
- Value of RN is between 0..9999
- If RN is used with a FUNCTION, its value is between 0..1

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Random Queue Processing

```
GENERATE 200,50
PRIORITY RN1   ; assigns a random priority to
               ; active transaction
SEIZE RANQ
ADVANCE 300
DEPART RANQ
TERMINATE 1
```

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Probability Distribution Functions

- FUNCTION statement is used to specify other probability distributions.

Label

Random Number Stream number 1 (function argument)

C for Continuous function using 6 points (D for discrete functions)

EXPO FUNCTION RN1,C6

0, 0 /.359,.445 /.638,1.016 /.838,1.82 /.958,3.164 /.999,7.559

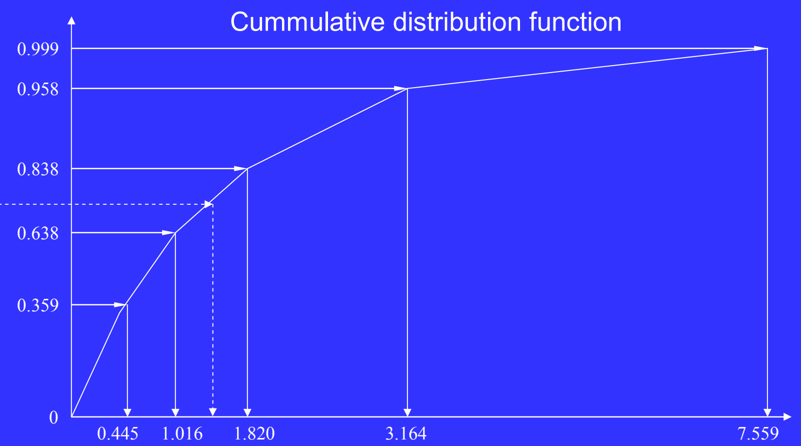
f(x) x Delimiter

Graphics Representation

EXPO FUNCTION RN1,c6

0,0/.359,.445/.638,1.016/.838,1.82/.958,3.164/.999,7.559

Cummulative distribution function



Discrete Functions

Value	4	5	6	7
Prob.	10%	40%	30%	20%

D for Discrete Functions

EXPO FUNCTION RN1,D6
.1,4 / .5,5 / .8,6 / 1.0,7

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Savevalues

- Using global variables
- INITIAL X$name, initialvalue
- SAVEVALUE name, value
- SAVEVALUE name+, value
- SAVEVALUE name-, value

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Variables

- Savevalues can only be set, increased or decreased.
- For complex functions, variables are used.

label VARIABLE function

(such as 5+Q$queue)

Exception : # is used for multiplication

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A Sample Simulation Model

- Problem: An internet cafe optimization

- Internet cafe having 4 computers and 6 waiting chairs.
- Customers arrive at the cafe in some intervals depending on the time of day.

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A Sample Simulation Model

- When a new customer arrives and there is any free computer,
  - He immediately starts to use one of the free computers and leave after some time.
- If there are not any free computers, but there are free chairs,
  - He may decide to wait for a limited period of time or immediately leave the cafe.
- If there are also no free chairs,
  - He immediately leaves without waiting.

A Sample Simulation Model

- If a customer uses a computer,
  - The price starts with 4 TL (opening price) and
  - Increases 1 TL for each 10 minutes of time (period of time).

Objective

- The Internet cafe owner wants to increase the profit of the cafe within a day by;
  - Either increasing the “opening price” or
  - Increasing the “period of time” without changing the cost of 1 hour for a customer (10 TL).

Objective

- The Internet cafe owner;
  - Wants to increase the profit of the cafe within a day by;
    - Either increasing the “opening price” or
    - Increasing the “period of time” without changing the cost of 1 hour for a customer (10 TL).
  - Also wonders how much the profit may increase if one more computer is added to the Internet cafe.

Objective

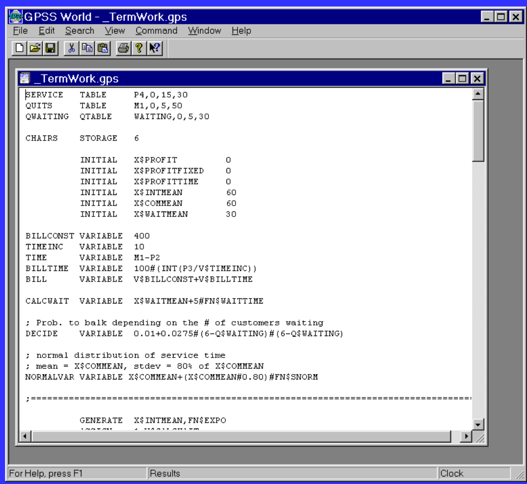
- The Internet cafe owner;
  - Wants to increase the profit of the cafe within a day by;
    - Either increasing the “opening price” or
    - Increasing the “period of time” without changing the cost of 1 hour for a customer (10 TL).
  - Also wonders how much the profit may increase if one more computer is added to the Internet cafe.

Solution

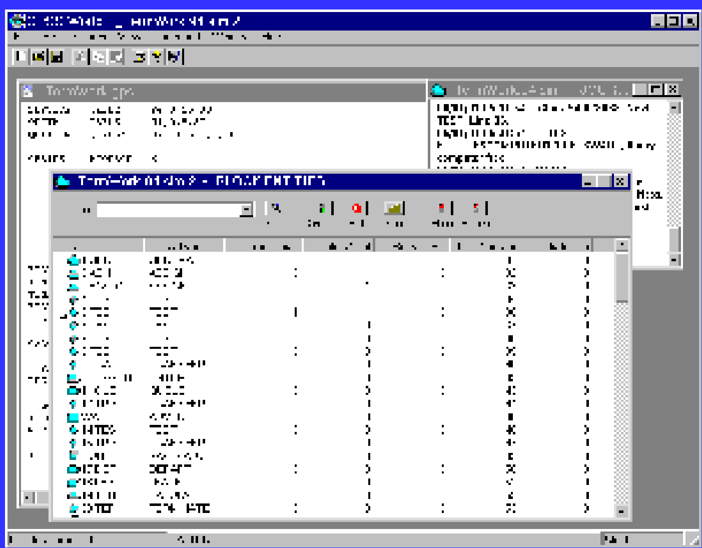
- One day of the internet cafe will be simulated by GPSS World (Student Addition), and
- The results will be analyzed.

GPSS World

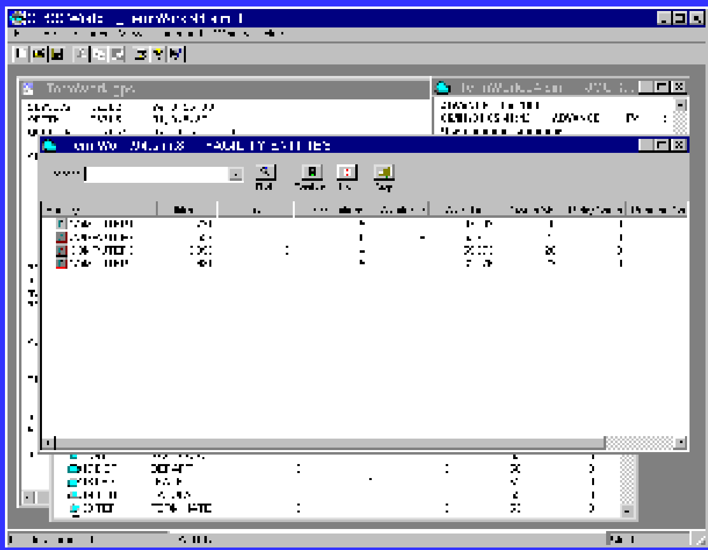
- A Minuteman Software product.



GPSS World (Blocks Window)



GPSS World
(Facilities Window)



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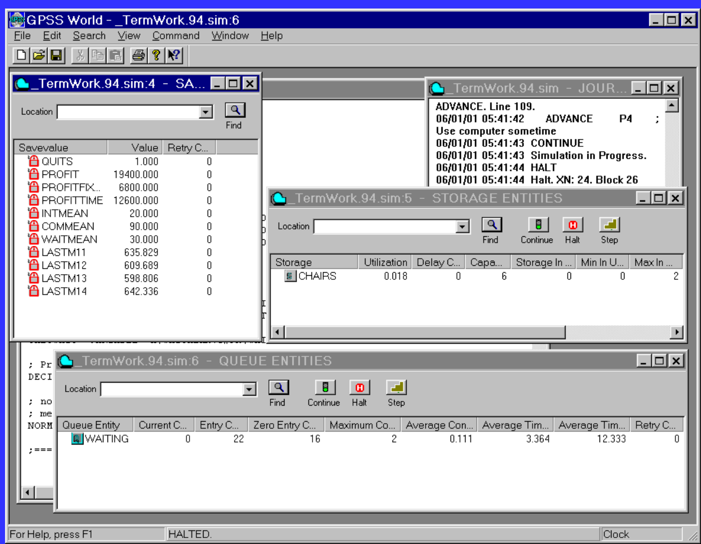
GPSS World
(Savevalues, Storages & Queus)



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Problem Details

- Internet cafe is opened at 9:00 in the morning and closed at 1:00 at night.
- The mean of inter-arrival times of customers;
  - Changes in various time of day,
  - Is usually less in the afternoon and evening, high in the morning and late at night.

Problem Details

- The mean service time is usually about 1.5 hours.
- In the morning and late at night, the mean reduces to 1 hour.

Problem Details

- There are totally 6 chairs.
- If all the chairs are full, the customer immediately leaves.
- A too much waited customer may decide to leave the cafe without using a computer.
- Sometimes customers do not wait although there are still free chairs.
- The probability of immediately leaving the cafe is proportional to the number of customers waiting in the queue.

Inter Arrival Times

- Inter-arrival time distribution is assumed to be exponential about the mean.
- Mean changes in different times of day in a discrete manner.

9:00 - 10:00	10:00 - 11:00	11:00 - 14:00	14:00 - 18:00	18:00-21:00	21:00-23:00	23:00-24:00	24:00-01:00
60 minutes	45 minutes	30 minutes	25 minutes	20 minutes	30 minutes	40 minutes	60 minutes

Inter Arrival Times

```
INITIAL       X$INTMEAN        60
....
GENERATE  X$INTMEAN,FN$EXPO  ————→ TIME = X$INTMEAN x FN$EXPO
....
....                                    A random number is taken
....                                    with exponential distribution
....
EXPO          FUNCTION  RN1,C24  ;Exponential Distribution
0,0/.1,0.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38/.8,1.6/.84
,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2/.97,3.5/.98,3.9/.99,
4.6/.995,5.3/.998,6.2/.999,7/.9997,8
```


Service Times

- There are 4 computers in the cafe.
- Because the customers give 4 TL in advance,
  - They don't usually leave early and
- The mean computer usage time;
  - Is about 1.5 hours in daytime, and
  - Reduces to 1 hour early in the morning and late at night.
- Service time distribution is assumed to be normal around the mean
  - With standard deviation = 80% of the mean.

09:00-11:00	11:00-23:00	23:00-01:00
60 minutes	90 minutes	60 minutes

Service Times

```
INITIAL       X$COMMEAN          60
              ....
NORMALVAR     VARIABLE   X$COMMEAN+(X$COMMEAN#0.80)#FN$SNORM
              ....
              GENERATE   X$INTMEAN,FN$EXPO
RECALC                   ASSIGN         4,V$NORMALVAR
              TEST GE            P4,5,RECALC
              ....
              SEIZE              COMPUTER1    ; Customer starts using computer
              ADVANCE    P4                ; Use computer sometime
              RELEASE    COMPUTER1    ; Customer leaves
              ....
SNORM         FUNCTION   RN4,C25  ;Standard normal dist. function
0,-5/.00003,-4/.00135,-3/.00621,-2.5/.02275,-2.06681,-1.5/.11507,-1.2/.15866,-1/
.21186,-.8/.27425,-.6.34458,-.4/.42074,-
.2/.5,0/.57926,.2/.65542,.4.72575,.6/.78814,.8/.84134,1/.88493,1.2/
.93319,1.5.97725,2/.99379,2.5/.99865,3/.99997,4/1,5
```

Loops until sevice time ≥ 5

Too Much Waited Customers

- After entering a queue by sitting on a chair,
  – the customer waits for a free computer.
- But if waiting time becomes so long,
  – Customer usually leaves the cafe.
- Mean waiting time for a customer is assumed to be 30 minutes.
- The distribution is assumed to be normal around the mean
  – With standard deviation = 5 minutes.

Too Much Waited Customers

```
CHAIRS       STORAGE              6
CALCWAIT     VARIABLE             X$WAITMEAN+5#FN$WAITTIME
             ....
             GENERATE    X$INTMEAN,FN$EXPO
             ASSIGN               1,V$CALCWAIT         ; max waiting time
             ....
LETSWAIT                 ENTER             CHAIRS,1
             TRANSFER    ,ENTCOM1
WAIT         ADVANCE              1
             TEST LE              M1,P1,QUIT           ; Enough wait?
             TRANSFER    ,ENTCOM1
QUIT         LEAVE                CHAIRS,1
             TERMINATE
             ....
             ....
ENTCOM1                  TEST E            F$COMPUTER1,0,ENTCOM2
             ....
ENTCOM2                  TEST E            F$COMPUTER2,0,ENTCOM3
             ....
ENTCOM3                  TEST E            F$COMPUTER3,0,ENTCOM4
             ....
ENTCOM4                  TEST E            F$COMPUTER4,0,WAIT
             ....
```

* M1 = Time since current transaction was created

Balking

- Many customers immediately leave the cafe without entering the queue (balking).
- There are 6 chairs to sit.
- So at most 6 customers can wait.
- Probability to balk = 0.01 + 0.0275 x Waitings^2

* Waitings = number of customers waiting in the queue
* If Waitings = 0, Probability to balk = 0.01
* If Waitings = 6, Probability to balk = 1.00

Balking

```
DECIDE  VARIABLE                        0.01+0.0275#Q$WAITING#Q$WAITING
        ....
        GENERATE        X$INTMEAN,FN$EXPO
        ASSIGN          1,V$CALCWAIT                ; max waiting time
RECALC  ASSIGN          4,V$NORMALVAR               ; service time
        TEST GE         P4,5,RECALC
        TEST E          F$COMPUTER1,1,LETSWAIT      ; If any computer free
        TEST E          F$COMPUTER2,1,LETSWAIT      ; don't think to balk
        TEST E          F$COMPUTER3,1,LETSWAIT
        TEST E          F$COMPUTER4,1,LETSWAIT
        TRANSFER        V$DECIDE,,IMQUIT            ; think for immediately balking
        ....
IMQUIT  TERMINATE                                   ; quit immediately
        ....
LETSWAIT        ENTER   CHAIRS,1
        QUEUE   WAITING
        ...
        DEPART  WAITING
        LEAVE   CHAIRS,1
        ...
```

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Calculating Bill

General Formula:

Bill = opening price +

payment increase x INT(usage time/period of time)

Formula for Default:

Bill = 4 + 1 x INT(usage time/10)

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Simulating Change in One Day

- A generate command is placed at the end of the program,
- Only generates one transaction in each day (within working hours).
- At the end of day, transaction is terminated decreasing the simulation counter by 1 (TERMINATE 1).

Simulating Change in One Day

```
ONEDAYGENERATE      961,,1        ; Internet Cafe Open, 16*60 Min  = 1 Day
       SAVEVALUE    INTMEAN,60    ; After 09:00 Inter Arrival Mean = 60 min
       SAVEVALUE    COMMEAN,60    ; Computer Usage Mean = 60 min
       ADVANCE      60            ; 1 Hours
       SAVEVALUE    INTMEAN,45    ; After 10:00 Inter Arrival Mean = 45 min
       ADVANCE      60            ; 1 Hours
       SAVEVALUE    INTMEAN,30    ; After 11:00 Inter Arrival Mean = 30 min
       SAVEVALUE    COMMEAN,90    ; Computer Usage Mean = 90 min
       ADVANCE      180           ; 3 Hours
       SAVEVALUE    INTMEAN,25    ; After 14:00 Inter Arrival Mean = 25 min
       ADVANCE      240           ; 4 Hours
       SAVEVALUE    INTMEAN,20    ; After 18:00 Inter Arrival Mean = 20 min
       ADVANCE      180           ; 3 Hours
       SAVEVALUE    INTMEAN,30    ; After 21:00 Inter Arrival Mean = 30 min
       ADVANCE      120           ; 2 Hours
       SAVEVALUE    INTMEAN,40    ; After 23:00 Inter Arrival Mean = 40 min
       SAVEVALUE    COMMEAN,60    ; Computer Usage Mean = 60 min
       ADVANCE      60            ; 1 Hours
       SAVEVALUE    INTMEAN,60    ; After 24:00 Inter Arrival Mean = 60 min
       ADVANCE      60            ; 1 Hours
       TERMINATE    1             ; Internet Cafe Closed At 01:00
```

Analyzing Results

- After running the simulation for 1 day,
  - Statistics of queue, facilities, balking and profit are examined.
- The total profit was 341 TL.
- 116 TL was from opening price, and
- 225 TL was from Internet usage time.

Analyzing Results

- Changed;
  - Opening price to 3 TL and
  - Period of time to 8.5 minutes.
- The cost of 1 hour didn't change.
- The total profit increased from 341 TL to 354 TL.

Analyzing Results

- Changed;
  - Opening price to 5 TL and
  - Period of time to 12 minutes.
- The cost of 1 hour didn't change again.
- The total profit increased from 341 TL to 331 TL.

- Decreasing the opening price increases the profit if the average service time remains the same (keep some opening price).

Analyzing Results

- Last attempt was to increase the number of computers by 1.
- The profit was 348 TL (7 TL increase).
- For one month,
  - Increase will be at most 210 TL.
- One computer costs about 1500 TL.
- The cafe has to work about 7 months to gain from 1 additional computer.
- Seems not worthed?