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| **Assignment** | |
| **Course Code** | CSC304A |
| **Course Name** | Computer Simulation |
| **Programme** | B.Tech |
| **Department** | CSE |
| **Faculty** | FET |

|  |  |
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| **Semester/Year** | 05/2019 |
| **Course Leader(s)** | Santhoshi Kumari |



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| Declaration Sheet | | | | | | | | |
| Student Name | Satyajit Ghana | | | | | | | |
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| Programme | B.Tech | | | | | Semester/Year | 05/2019 | |
| Course Code | CSC304A | | | | | | | |
| Course Title | Computer Simulation | | | | | | | |
| Course Date |  | | to |  | | | | |
| Course Leader | Santhoshi Kumari | | | | | | | |
| **Declaration**  The assignment submitted herewith is a result of my own investigations and that I have conformed to the guidelines against plagiarism as laid out in the Student Handbook. All sections of the text and results, which have been obtained from other sources, are fully referenced. I understand that cheating and plagiarism constitute a breach of University regulations and will be dealt with accordingly. | | | | | | | | |
| Signature of the Student | |  | | | | | Date |  |
| Submission date stamp  (by Examination & Assessment Section) | |  | | | | | | |
| Signature of the Course Leader and date | | | | | Signature of the Reviewer and date | | | |
|  | | | | |  | | | |

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# Question 1

Solution to Question No. 1 Part A

## Introduction to discrete-time and continuous-time simulation

## Identify and explain advantage and disadvantages of discrete event simulation and continuous event simulation of a system by taking suitable example

## Stance taken, justification and conclusion

# Question 2

Solution to Question 1 Part B

## Introduction

The given problem is a Monte-Carlo Simulation Method. The ‘Monte Carlo’ simulation technique involves conducting repetitive experiments on the model of the system under study, with some known probability distribution to draw random samples (observations) using random numbers. If a system cannot be described by a standard probability distribution such as normal, poisson, exponential, etc., an empirical probability distribution can be constructed.

The Probability Distribution for the rainfall when there was no rain the previous day, and also when there was rain on the previous day is given. The cumulative probability and the random digit assignment are determined for each of the table.

The Sequence of Random Numbers chosen for this 10-day simulation is:

{24, 59, 87, 22, 89, 96, 52, 24, 61, 21}

## Simulation Table

Table 1 Distribution if it rained on previous day

|  |  |  |  |
| --- | --- | --- | --- |
| Event | Probability | Cumulative Probability | Random Digit Assignment |
| No Rain | 0.50 | 0.50 | 01-50 |
| 1cm Rain | 0.25 | 0.75 | 51-75 |
| 2cm Rain | 0.15 | 0.90 | 76-90 |
| 3cm Rain | 0.05 | 0.95 | 91-95 |
| 4cm Rain | 0.03 | 0.98 | 96-98 |
| 5cm Rain | 0.02 | 1.00 | 99-100 |

Table 2 Distribution if it did not rain on previous day

|  |  |  |  |
| --- | --- | --- | --- |
| Event | Probability | Cumulative Probability | Random Digit Assignment |
| No Rain | 0.75 | 0.75 | 01-75 |
| 1cm Rain | 0.15 | 0.90 | 76-90 |
| 2cm Rain | 0.06 | 0.96 | 91-96 |
| 3cm Rain | 0.04 | 1.00 | 97-100 |

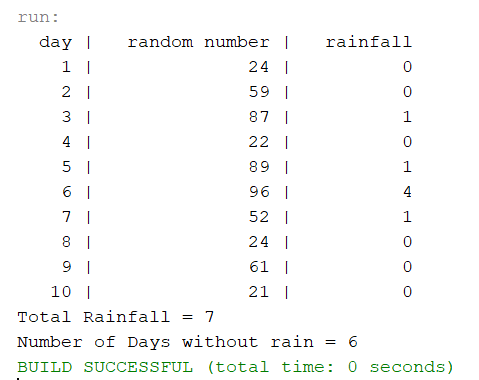


Figure 2‑1 Simulation Table for Rainfall

### Simulation Program in Java

**RAIN\_SIM.java**

/\*

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 \* To change this template file, choose Tools | Templates

 \* and open the template in the editor.

 \*/

package rain\_sim;

import java.util.Random;

/\*\*

 \*

 \* @author shadowleaf

 \*/

public class RAIN\_SIM {

    public static Integer[] gen\_rn(Double[] distr) {

        Integer[] rn = new Integer[distr.length];

        int temp = 0;

        for (int i = 0 ; i < distr.length; i++) {

            temp += distr[i]\*100;

            rn[i] = temp-1;

        }

        return rn;

    }

    public static void print\_arr(Integer[] arr) {

        for (Integer i : arr) {

            System.out.print(i+" ");

        }

        System.out.println();

    }

    /\*\*

     \* @param args the command line arguments

     \*/

    public static void main(String[] args) {

        Random rg = new Random();

        // if it rained the previous day

        Double prev\_rain\_distr[] = {0.50, 0.25, 0.15, 0.05, 0.03, 0.02};

        // if it did not rain on previous day

        Double no\_prev\_rain\_distr[] = {0.75, 0.15, 0.06, 0.04};

        // create the random\_no upper limit

        Integer[] prn\_rn = gen\_rn(prev\_rain\_distr);

        Integer[] nprn\_rn = gen\_rn(no\_prev\_rain\_distr);

//        print\_arr(prn\_rn);

//        print\_arr(nprn\_rn);

        // generate 10 random numbers from 10 to 100

        // testing Integer rn[] = {67, 63, 39, 55, 29, 78, 70, 6, 78, 76};

        Integer rn[] = new Integer[10];

        for (int i = 0 ; i < rn.length ; i++) {

            rn[i] = rg.nextInt(89) + 10;

        }

        // assuming it has not rained on previous day

        Boolean has\_rained\_prev = false;

        Integer[] rainfall = new Integer[rn.length];

        Integer n\_days\_without\_rain = 0;

        Integer total\_rain = 0;

        for (int i = 0 ; i < rn.length ; i++) {

            if (!has\_rained\_prev) {

                for (int j = 0 ; j < nprn\_rn.length ; j++) {

                    if (rn[i] <= nprn\_rn[j]) {

                        rainfall[i] = j;

                        break;

                    }

                }

            } else {

                for (int j = 0 ; j < prn\_rn.length ; j++) {

                    if (rn[i] <= prn\_rn[j]) {

                        rainfall[i] = j;

                        break;

                    }

                }

            }

            has\_rained\_prev = rainfall[i] != 0;

            if (!has\_rained\_prev) {

                n\_days\_without\_rain++;

            } else {

                total\_rain += rainfall[i];

            }

        }

//        print\_arr(rainfall);

        System.out.printf("%5s | %15s | %10s\n", "day", "random number", "rainfall");

        for (int i = 0 ; i < rainfall.length ; i++) {

            System.out.printf("%5d | %15d | %10d\n", i+1, rn[i], rainfall[i]);

        }

        System.out.printf("Total Rainfall = %d\nNumber of Days without rain = %d\n", total\_rain, n\_days\_without\_rain);

    }

}

## Result and Analysis

The Monte Carlo simulation technique consists of the following steps:

(1) Setting up a probability distribution for variables to be analyzed.

(2) Building a cumulative probability distribution for each random variable.

(3) Generating random numbers and then assigning an appropriate set of random numbers to represent value or range (interval) of values for each random variable.

(4) Conducting the simulation experiment using random sampling.

(5) Repeating Step – 4 until the required number of simulation runs has been generated.

(6) Designing and implementing a course of action and maintaining control.

From the Simulation Table constructed using the Monte-Carlo Method for the given problem we conclude that for the assumed Random Numbers in 2.1 the Total Rainfall is 7cm and the number of days without rain is 6, in total the simulation was performed for 10 days.

The highest rainfall was on Day 6 which was of 4cm.

Rainfall prediction done using this method is not so accurate since natural rain is so much dependent on many other factors such as geographical, ecological, global and local. Hence, we will be hardly successful in predicting the rainfall beyond a short term, such as predicting the rainfall for the next 50 years, the distribution is not complex enough to factor in all the variables that affect the rainfall.

The Random Numbers used in the simulation are generated using a LCG, which is pseudo-random number generator, the results for long term simulation hence will not be of any significance.

# Question 3

Solution to Question 2 Part B

## Introduction to problem solving approach

The problem is to implement an ATM Simulation System in Java for 12 hours, where the Service Time and Arrival Times are Random Integers from 1 to 6 and 1 to 4 respectively. The question specifies that one customer can take the service from the ATM, hence this is a Single Server Problem, and if another customer arrives, the customer is enqueued to the queue. When the current customer taking the service finishes the next customer is the front of the queue takes service.

This is a Single Server problem, with the Inter-Arrival-Time and the Service Time are generated Randomly, the total number of customers served is unknown before simulation, which can only be known after the simulation ends, which is determined by the total simulation time which is taken as input from the user before the simulation begins.

## Implementation

Refer to Appendix A for complete Implementation.

## Result and Analysis

Refer to Appendix B for complete Output.

Since the Average Service Time is greater than the Average Arrival Time in general, our server is busy most of the time, but this also means that the requests have to wait for a considerable amount of time before getting serviced, from the statistics we can see that the average wait time is 83 minutes, which is much higher, hence to reduce this multi-servers must be used.

A Total of 214 requests were processed in 720 minutes, so an average of 3.3644 minutes of system time was given to each of the request and the server processed, 0.297 requests were processed by the server every minute.

Some Analysis from the Output

Algorithms Used:

// Generates the next pseudo-random number.

**next(bits):**

1. do {

2. oldseed = seed.get()

3. nextseed = (oldseed \* MULTIPLIER + ADDEND) & MASK;

4. } while (!seed.compareAndSet(oldseed, nextseed))

5. return nextseed >>> (48-bits)

What this basically does is atomically update seed as

(seed \* 0x5DEECE66DL + 0xBL) & ((1L << 48) - 1)

This is a Linear Congruential Generator as defined by D. H. Lehmer and described by Donald E. Knuth in The Art of Computer Programming, Volume 3: Seminumerical Algorithms, section 3.2.1.

// Returns a pseduo-random number distributed int value between 0 (inclusive) and the specified value (exclusive)

**nextInt(bound):**

1. if (bound & -bound) == bound // bound is a power of 2

2. return (bound \* next(31)) >> 31

3. else

4. do {

5. bits = next(31)

6. val = bits % bound

7. } while (bits – val + bound – 1 < 0)

8. return val

The hedge "approximately" is used in the foregoing description only because the next method is only approximately an unbiased source of independently chosen bits. If it were a perfect source of randomly chosen bits, then the algorithm shown would choose int values from the stated range with perfect uniformity.

The algorithm is slightly tricky. It rejects values that would result in an uneven distribution (due to the fact that 2^31 is not divisible by n). The probability of a value being rejected depends on n. The worst case is n=2^30+1, for which the probability of a reject is 1/2, and the expected number of iterations before the loop terminates is 2.

The algorithm treats the case where n is a power of two specially: it returns the correct number of high-order bits from the underlying pseudo-random number generator. In the absence of special treatment, the correct number of low-order bits would be returned. Linear congruential pseudo-random number generators such as the one implemented by this class are known to have short periods in the sequence of values of their low-order bits. Thus, this special case greatly increases the length of the sequence of values returned by successive calls to this method if n is a small power of two. [1]

The OUTPUT of the program is attached in Appendix B of this Assignment.

# Bibliography

1. Java™ Platform, Standard Edition 7 API Specification, (2017). Class Random. [online] Available at: <https://docs.oracle.com/javase/8/docs/api/java/util/Random.html> [Accessed October 21, 2019].

# Appendix A

**ATM\_SIM.java**

/\*

 \* To change this license header, choose License Headers in Project Properties.

 \* To change this template file, choose Tools | Templates

 \* and open the template in the editor.

 \*/

package atm\_sim;

import java.util.ArrayList;

import java.util.Collections;

import java.util.HashMap;

import java.util.List;

import java.util.Map;

import java.util.OptionalDouble;

import java.util.Scanner;

/\*\*

 \*

 \* @author shadowleaf

 \*/

public class ATM\_SIM {

    /\*\*

     \* @param args the command line arguments

     \*/

    public static void main(String[] args) {

        Scanner input = new Scanner(System.in);

        System.out.print("Enter the total time to simulate for (minutes) : ");

        Integer T = input.nextInt();

        // seed the random number generator with the current system time in milli-seconds

        BromineRandom rand = new BromineRandom(System.currentTimeMillis());

        // map to store the simulation table

        Map<String, List<Integer>> SIM\_TAB = new HashMap<>();

        List<Integer> IAT = new ArrayList<>();

        List<Integer> ST = new ArrayList<>();

        // initialize the simulation table

        SIM\_TAB.put("IAT", IAT);

        SIM\_TAB.put("ST", ST);

        SIM\_TAB.put("SS", new ArrayList<>(Collections.nCopies(1, 0)));

        SIM\_TAB.put("AT", new ArrayList<>(Collections.nCopies(1, 0)));

        SIM\_TAB.put("SE", new ArrayList<>(Collections.nCopies(1, 0)));

        SIM\_TAB.put("WAIT", new ArrayList<>(Collections.nCopies(1, 0)));

        SIM\_TAB.put("IDLE", new ArrayList<>(Collections.nCopies(1, 0)));

        // start the simulatioin

        Integer SYS\_CLOCK = 0;

        SIM\_TAB.get("IAT").add(rand.nextInt(4)+1);

        SIM\_TAB.get("ST").add(rand.nextInt(6)+1);

        SIM\_TAB.get("AT").set(0, 0);

        for (int i = 1; SYS\_CLOCK <= T ; i++) {

            // IAT b/w 1-4 mins

            SIM\_TAB.get("IAT").add(rand.nextInt(4)+1);

            // ST b/w 1-6 mins

            SIM\_TAB.get("ST").add(rand.nextInt(6)+1);

            SIM\_TAB.get("AT").add(SIM\_TAB.get("AT").get(i - 1) + SIM\_TAB.get("IAT").get(i));

            if (SIM\_TAB.get("AT").get(i) >= SIM\_TAB.get("SE").get(i - 1)) {

                SIM\_TAB.get("SS").add(SIM\_TAB.get("AT").get(i));

            } else {

                SIM\_TAB.get("SS").add(SIM\_TAB.get("SE").get(i - 1));

            }

            SIM\_TAB.get("SE").add(SIM\_TAB.get("SS").get(i) + SIM\_TAB.get("ST").get(i));

            SIM\_TAB.get("WAIT").add(SIM\_TAB.get("SS").get(i) - SIM\_TAB.get("AT").get(i));

            SIM\_TAB.get("IDLE").add(SIM\_TAB.get("AT").get(i) - SIM\_TAB.get("SE").get(i-1) >= 0 ? SIM\_TAB.get("AT").get(i) - SIM\_TAB.get("SE").get(i-1) : 0);

            // set the sys\_time

            SYS\_CLOCK = SIM\_TAB.get("SE").get(i) + SIM\_TAB.get("ST").get(i);

        }

        // Print the simulation table

        System.out.println("REQNO\tIAT\tAT\tSS\tSE\tST\tWAIT\tIDLE");

        for (int i = 1; i < SIM\_TAB.get("IAT").size(); i++) {

            String out = i + "\t"

                    + SIM\_TAB.get("IAT").get(i) + "\t"

                    + SIM\_TAB.get("AT").get(i) + "\t"

                    + SIM\_TAB.get("SS").get(i) + "\t"

                    + SIM\_TAB.get("SE").get(i) + "\t"

                    + SIM\_TAB.get("ST").get(i) + "\t"

                    + SIM\_TAB.get("WAIT").get(i) + "\t"

                    + SIM\_TAB.get("IDLE").get(i);

            System.out.println(out);

        }

        // Avg WAIT, Avg. Ser, Avg. IAT

        OptionalDouble avgWAIT = SIM\_TAB.get("WAIT").stream().mapToDouble(a -> a).average();

        OptionalDouble avgService = SIM\_TAB.get("ST").stream().mapToDouble(a -> a).average();

        OptionalDouble avgIAT = SIM\_TAB.get("IAT").stream().mapToDouble(e -> e).average();

        System.out.println("Total Requests Processed : " + (SIM\_TAB.get("IAT").size()-1));

        System.out.println("Average WAIT : " + avgWAIT.getAsDouble());

        System.out.println("Averate Service Time : " + avgService.getAsDouble());

        System.out.println("Averate IAT : " + avgIAT.getAsDouble());

    }

**BromineRandom.java**

/\*

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 \* and open the template in the editor.

 \*/

package atm\_sim;

import java.util.concurrent.atomic.AtomicLong;

/\*\*

 \*

 \* @author shadowleaf

 \*/

public class BromineRandom {

    private final AtomicLong seed;

    private static final long MULTIPLIER = 0x5DEECE66DL;

    private static final long ADDEND = 0xBL;

    private static final long MASK = (1L << 48) - 1;

    public BromineRandom(long seed) {

        this.seed = new AtomicLong(initialScramble(seed));

    }

    private static long initialScramble(long seed) {

        return (seed ^ MULTIPLIER) & MASK;

    }

    /\*\*

     \* Generates the next pseudorandom number.

     \*

     \* @param bits random bits

     \* @return the next pseudorandom value from this random number generator's

     \* sequence

     \* @since 1.1

     \*/

    protected int next(int bits) {

        long oldseed, nextseed;

        AtomicLong \_seed = this.seed;

        do {

            oldseed = \_seed.get();

            nextseed = (oldseed \* MULTIPLIER + ADDEND) & MASK;

        } while (!\_seed.compareAndSet(oldseed, nextseed));

        return (int) (nextseed >>> (48 - bits));

    }

     \* @param bound the upper bound (exclusive). Must be positive.

     \* @return the next pseudorandom, uniformly distributed {@code int} value

     \* between zero (inclusive) and {@code bound} (exclusive) from this random

     \* number generator's sequence

     \* @throws IllegalArgumentException if bound is not positive

     \* @since 1.2

     \*/

    public int nextInt(int bound) {

        if (bound <= 0) {

            throw new IllegalArgumentException("Bad Bound");

        }

        int r = next(31);

        int m = bound - 1;

        if ((bound & m) == 0) // i.e., bound is a power of 2

        {

            r = (int) ((bound \* (long) r) >> 31);

        } else {

            for (int u = r;

                    u - (r = u % bound) + m < 0;

                    u = next(31))

                ;

        }

        return r;

    }

}

# Appendix B

OUTPUT for the ATM Simulation

run:

Enter the total time to simulate for (minutes): 720

REQNO IAT AT SS SE ST WAIT IDLE

1 4 4 4 9 5 0 4

2 2 6 9 15 6 3 0

3 3 9 15 18 3 6 0

4 3 12 18 23 5 6 0

5 4 16 23 26 3 7 0

6 2 18 26 27 1 8 0

7 4 22 27 33 6 5 0

8 4 26 33 35 2 7 0

9 3 29 35 36 1 6 0

10 2 31 36 39 3 5 0

11 4 35 39 41 2 4 0

12 1 36 41 42 1 5 0

13 3 39 42 43 1 3 0

14 3 42 43 47 4 1 0

15 3 45 47 52 5 2 0

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190 3 474 641 647 6 167 0

191 4 478 647 652 5 169 0

192 1 479 652 655 3 173 0

193 4 483 655 657 2 172 0

194 4 487 657 659 2 170 0

195 3 490 659 660 1 169 0

196 1 491 660 662 2 169 0

197 4 495 662 665 3 167 0

198 1 496 665 670 5 169 0

199 1 497 670 676 6 173 0

200 2 499 676 678 2 177 0

201 4 503 678 680 2 175 0

202 3 506 680 682 2 174 0

203 3 509 682 683 1 173 0

204 3 512 683 687 4 171 0

205 4 516 687 692 5 171 0

206 2 518 692 695 3 174 0

207 1 519 695 697 2 176 0

208 1 520 697 699 2 177 0

209 1 521 699 703 4 178 0

210 1 522 703 705 2 181 0

211 3 525 705 706 1 180 0

212 4 529 706 710 4 177 0

213 4 533 710 713 3 177 0

214 1 534 713 717 4 179 0

Total Requests Processed: 214

Average WAIT: 83.02325581395348 minutes

Average Service Time: 3.3209302325581396 minutes

Average IAT: 2.4976744186046513 minutes

BUILD SUCCESSFUL (total time: 2 seconds)