Special Assignment in lieu of Semester End Practical Examination May-June 2020
B.Sc. (Hons.) Computer Science Semester-VI
Paper Code: 32341601
Paper Name: Artificial Intelligence

Q1: Functional Extension of the work done earlier

Ans: I have added two new things (and an experimental thing) to the existing work.
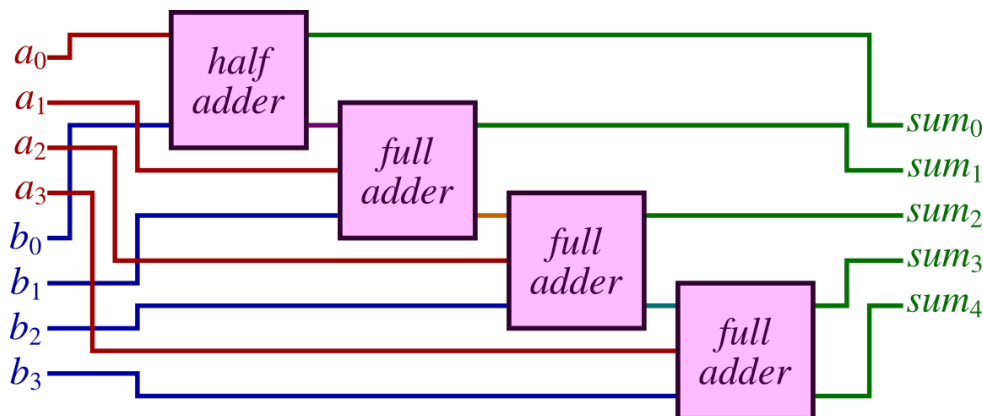
i) FOUR-BIT ADDER

ii) FOUR-BIT REGISTER

Experimental: iii) FOUR-BIT RAM

i) FOUR-BIT ADDER

Explanation of digram:

The a input (and the b input) will actually come into our circuit through four wires; we'll label the 1's bit of a as the a_0 wire, the 2's bit the a_1 wire, the 4's bit the a_2 wire, and the 8's bit the a_3 wire. (The system here is that a_i corresponds to the 2^i's bit from a.) We'll similarly do the same thing for b and for our output *sum* which will in fact be five wires, since the sum of two four-bit numbers may be a five-bit number (for example, $1111_{(2)}+1111_{(2)}$ is $11110_{(2)}$).

To build our complete circuit, we'll use a half adder to add the 1's bits a_0 and b_0. Then we'll use a full adder to add the 2's bits a_1 and b_1 along with the carry from the preceding column. And we'll continue with full adders, so that our complete four-bit adder is wired as follows.

The code that imitates the functioning of a FOUR-BIT ADDER has used the code that imitates the components mentioned above.

ii) FOUR-BIT REGISTER
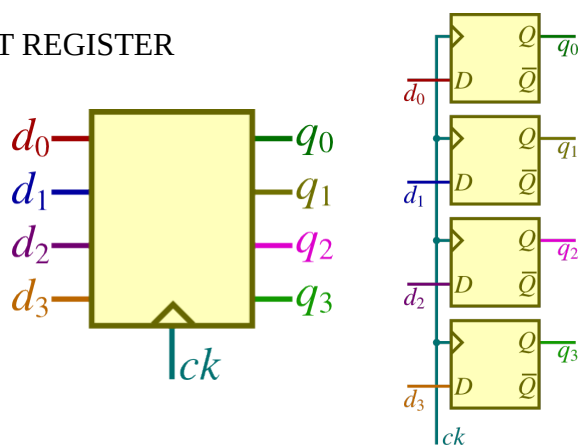
A **register** is a component for remembering several related bits. Aforementioned is a diagram of a four-bit register.
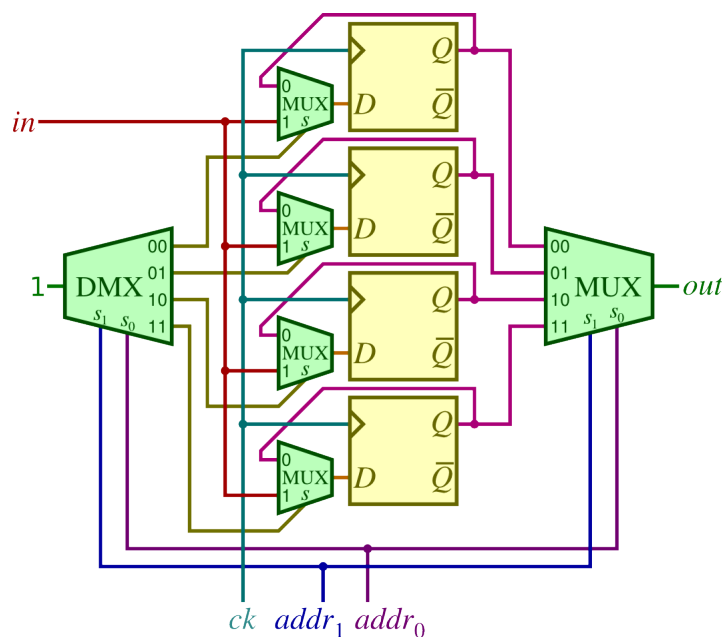
Explanation of diagram:
The outputs on the right continually emit the current contents of the register. The clock input, represented with a small triangle on the component's lower edge, tells the register when to alter its value. When this input changes from 0 to 1, the register changes its remembered bits to the values existing on the data bits on the register's left side.

Building a register is a straightforward task: It's just a matter of putting several D flip-flops together, sharing the same *ck* input, as in the below diagram of a four-bit register's internals.

The code that imitates the functioning of a regsiter has been made using the code that imitates the behaviour of a D flip-flop.

EXPERIMENTAL: iii) FOUR-BIT RAM

Mentioned below is the diagram fo the structure of a FOUR-BIT Memory.

Explanation of diagram:
This 4-bit memory will have its four memory locations indexed by the binary numbers 00, 01, 10, 11, and so the *addr* input will be 2 bits long. The *in* input and *out* output will be just a single wire each, since each memory location holds only one bit.

Our implementation includes four D flip-flops, corresponding to each of the four bits of memory. We employ a demultiplexer and a multiplexer to route *in* and *out* to the flip-flop identified by the current *addr* input. You can also see that each flip-flop has its own 2-to-1 multiplexer.

The easy part of this circuit is the right-hand side for reading a value from the selected flip-flop to be *out*. We send each of the flip-flops' values into a 4-to-1 multiplexer, and we use *addr* to select which of these the multiplexer should send into the *out* output.

The part on the left side, which stores *in* into the selected flip-flop, is more complex. Each of the flip-flops has its *D* input coming from a 2-to-1 multiplexer. This small multiplexer will route either the flip-flop's current value (if *s* is 0) or the value of the *in* input (if *s* is 1). The 1-to-4 demultiplexer will send 1 to the *s* input of the 2-to-1 multiplexer identified by the *addr* input, so that this flip-flop is the only one that sees the *in* input; the other 2-to-1 multiplexers would receive 0 for the *s* input, so they would see just the flip-flop's current value. When *ck* changes from 0 to 1, all flip-flops update (since *ck* is wired to the clock of all flip-flops), but the ones that aren't indicated by *addr* will simply update to the same value that they already held, since *s* is 0 for each of these flip-flop's 2-to-1 multiplexers. The one that is indicated by *addr* would see the value of *in* on its *D* input, so it would update to this value.

The code that imitates the functioning of this four-bit memory has been made using the code that imitates the behaviour of the components as shown in the diagram.

Q2: Epidemic Modelling
Ans:
(a): I have made the model from human perspective as to how the infection spreads. I have chosen to model this from human perspective beacause it can help us predict our present situation because of the COVID-19 Pandemic. Also, this model can help us understand our shortcomings in dealing witht the Pandemic and can help us to be better prepared for future.

(b.i & b.ii): This model mainly includes how many people were intitally infected and how the infection has spread. We find out that the spread of infection follows an exponential pattern and hence we can use an exponential model for calculation of rate of spread of infection.

Now let's consider the spread of infection in a city, let's say Delhi, with the population of 2 crore (2,00,00,000).

The city is divided into 9 regions based on the population density of those regions:-
15% in extreme congestion zone (ECZ)
30% in high congestion zone (HCZ)
35% in moderate congestion zone (MOCZ)
10% in mild congestion zone (MICZ)
7% in moderately spaced zone (MSZ)
2% in safe space zone (SSZ)
0.8% in ideal space zone (ISZ)
0.1% in sparse zone (SPZ)
0.1% in dispersed zone (DZ)

Zones have the following description:-

Zone	Average inter-person space (radial) in Dwelling Units (DU)
ECZ	<=0.5 meters
HCZ	More than 0.5 but < 1 meter
MOCZ	1 to 1.5 meters
MICZ	1.5 to 2 meters

MSZ	2 to 2.5 meters
SSZ	2.5 to 3 meters
ISZ	3 to 5 meters
SPZ	5 to 8 meters
DZ	>8 meters

Distributing the population according to the percentage given. So, the total number of people living in each region is:

$$
\begin{array}{ll}
\text{ECZ:} & 3 \times 10^6 \\
\text{HCZ:} & 6 \times 10^6 \\
\text{MOCZ:} & 7 \times 10^6 \\
\text{MICZ:} & 2 \times 10^6 \\
\text{MSZ:} & 1.4 \times 10^6 \\
\text{SSZ:} & 4 \times 10^5 \\
\text{ISZ:} & 1.6 \times 10^5 \\
\text{SPZ:} & 2 \times 10^4 \\
\text{DZ:} & 2 \times 10^4 \\
\end{array}
$$

Assuming a random distribution of initial carriers (i.e. carrier exists in a set of people with a very small probability, but uniformly – say there is one carrier per r persons (e.g. r = 1 million). Therefore, the number of infected people in each region given by (population of that region / 10,00,000) is:

$$
\begin{array}{l}
\text{DZ: } 0.02 \approx 0 \\
\text{SPZ: } 0.02 \approx 0 \\
\text{ISZ: } 0.16 \approx 0 \\
\text{SSZ: } 0.4 \approx 0 \\
\text{MSZ: } 1.4 \approx 1 \\
\text{MICZ: } 2 \\
\text{MOCZ: } 7 \\
\text{HCZ: } 6 \\
\text{ECZ: } 3 \\
\end{array}
$$

We have been given the conditions of transmission:
"The transmission of infection is possible with probability 0.7 if carrier is within 2 meter radius on another person for 5 seconds or more."

We have also been given the following three levels of daily Mobility of Population (MOP):
1. Static (S) – eveyone stays at home
2. Dynamic (D) – normal movement for work etc.
3. Sensitive (SN) – only sick (possibly infected) stay at home/quarantine

Case 1: Static Mobility of Population (Best Case Scenario)
In this case, the infected people are quarantined at home and no one is outside. The pathogen can't spread to many people and actually dies out after a while being exposed to the outside environment.

Since the probability of transmission of pathogen depends on two conditions:

1) if carrier is within 2 meter radius of another person
2) the duration is more than 5 seconds.

These four regions namely DZ, SPZ, ISZ and SSZ won't be affected by the pathogen since:-
1. The random distribution of initial carriers show there are no infected people in these regions.
2. The Average inter-person space (radial) for these four regions is more than 2.5 m and the city is already on complete lockdown which prevents people from meeting with each other.

As for the rest of regions, we have the count of inital carriers in each region. Given the conditions for the spread of the pathogen, and the fact that the *'Static Mobility Level'* ensures that eveyone stays at home, we can say that the rate of transmission of pathogen is very slow.

Assumption: Let's assume that each initially infected person, infects 2 new people every day.

Justification: We can safely assume that this rate of spread of 2 new people every day is unifom throughout the city, even though the count of initial carriers in different zones is varied, because <u>our mobility level ensures that everyone is staying in their homes. And hence, even though the initial carrier count in different zones is varied, the rate of spread will be almost uniform.</u>

Now, calculating the the total number of cases in each zone:

Day 0:
  MSZ: 1
  MICZ: 2
  ECZ: 3
  HCZ: 6
  MOCZ: 7

Total cases on Day 0: 19

Day 1:
  Now these 19 people will infect 2 people each. 19(2)=38
  Total cases on Day 1: 19+38=57

Day 2:
  Now these 57 people will infect 2 people each. 57(2)=114
  Total cases on Day 2: 57+114=171

Day 3:
  Now these 171 people will infect 2 people each. 171(2)=342
  Total cases on Day 3: 171+342=513

We get a series of total number of patients on each Day: 19,57,171,513.....
On closer inspection we find that we have a geometric progression that is of the form:

$$a, ar^2, ar^3 ...... ar^{n-1}$$

where, a=19 and r=3

Using the formula to calculate the Nth term of a Geometric Progression, we can find on what day

will a certain percentage of the population be under the infection, that indicates the rate of spread of infection.

The time needed for X% population to be infected can be calculated as:

(X / 100) x population affected

Note that since there are 4 zones that won't be affected by the pathogen, the Population affected is:

Population Affected = Total population – the population of zones not affected

$\qquad\qquad\qquad$ = 2,00,00,000 – 6,00,000

$\qquad\qquad\qquad$ = 1,84,00,000

Since the sequence is in GP with a = 19 and r = 3, n = days, can be calculated using the Nth term of GP

$\qquad$ $a(r)^{n-1}$ = X% of population affected

=> $19(3)^{n-1}$ = (X/100) * 1,84,00,000

=> $(3)^{n-1}$ = (X/100) * (1,84,00,000/19)

=> $(3)^{n}$ = (X/100) * (1,84,00,000/19) * 3

=> $\log_3 (3^n)$ = $\log_3 (X * 29052.6315)$

=> $n = \log_3 (X * 29052.6315)$

Since, we can't directly compute $\log_3$ prolog, we use $\log_{10}$ to obtain our answer using the formula:

$\qquad$ **$n = \log_{10}(X * 29052.6315) / \log_{10}(3)$**

The value that we obtain is in decimals and we can round it off to the next number to give us an approx. number of days.

Case 2: Dynamic Mobility of Population (Worst Case Scenario)

In this case, the infected people are not in Quarantine. They are roaming freely and spreading the pathogen. Also, breaking the city into regions does not work here since there is no restriction on movement of people. Therefore, the whole city is considered as a single unit.

Number of people initialy infected can be calculated as:

=> Total population / 10,00,000

=> 2,00,00,000 / 10,00,000

=> 20 people.

Assumption: Given the Mobilty level, and the conditions of spread of the virus, we can assume that each person infects 20 people.

Justification: We can safely assume this value and consider it unifom throughout the city because our mobility level ensures that infected people are not staying in their homes. And since we have already established that the city is considered a single unit, there is no scope of different rate of spread.

Now, calculating the the total number of cases each day:

Day 0:

$\qquad$ Total cases on Day 0: 20

Day 1:

Now these 20 people will infect 20 people each.   20(20)=400
Total cases on Day 1: 20+400=420

Day 2:
Now these 420 people will infect 20 people each.   420(20)=8400
Total cases on Day 2: 420+8400=8820

Day 3:
Now these 8820 people will infect 20 people each. 8820(20)=176400
Total cases on Day 3: 8820+176400=185220

We get a series of total number of patients on each Day: 20,420,8820,185220 .....
On closer inspection we find that we have a geometric progression that is of the form:

$$a, ar^2, ar^3 ...... ar^{n-1}$$

where, a=20 and r=21

Using the formula to calculate the Nth term of a Geometric Progression, we can find on what day will a certain percentage of the population be under the infection, that indicates the rate of spread of infection.
The time needed for X% population to be infected can be calculated as:
(X / 100) x population affected

Since the sequence is in GP with a = 20 and r = 21, n = days, can be calculated using the Nth term of GP
   $a(r)^{n-1}$ = X% of population affected
=> $20(21)^{n-1}$ = (X/100) * 2,00,00,000
=> $(21)^{n-1}$ = (X/100) * (2,00,00,000/20)
=> $(21)^{n}$ = (X/100) * (2,00,00,000/20) * 21
=> $\log_{21}(21^n)$ = $\log_{21}$(X * 2,10,000)
=> n = $\log_{21}$ (X * 2,10,000)

Since, we can't directly compute $\log_{21}$ prolog, we use $\log_{10}$ to obtain our answer using the formula:

n= $\log_{10}$(X * 2,10,000) / $\log_{10}$ (21)

The value that we obtain is in decimals and we can round it off to the next number to give us an approx. number of days.

Case 3: Sensitive Mobility of Population
In this case, only the possibly infected people are staying in. To explain this case, we have made a set of different assumptions than the previous two cases.

In this case, the city of Delhi having a population of 2 crores is considered to be divided in 4 regions that have an equal number of people living in that region. But, the Average inter-person space (radial) in Dwelling Units (DU) is different such that:

Zone	Average inter-person space (radial) in Dwelling Units (DU)
Zone 4	<=0.5 meters
Zone 3	More than 0.5 but < 1 meter

| Zone 2 | 1 to 1.5 meters |
| Zone 1 | 1.5 to 2 meters |

So, 2 crores/4= 50 lakh.
Each region is assumed to house 50 lakh people.
Considering r = 1 million (=10 lakh), initally infected people in all the regions equal 5.

Given that only possibly infected people are staying in and other people are freely going outside, and that there is difference in average inter-person space in the zones, we can assume that each zone has a different rate of spread of infection. The people can move from one zone to the other but considering that possibly infected people are staying in, we can consider the 4 zones as disjoint entities with their own rate of spread. The total number of people infected, however, is calculated by adding the number of infected people in that zone.

We know from the previous 2 cases that the spread follows a geometric progression, but since in this case we have different rate of spread, it is safe to assume that we will have 4 different geometric progressions, each of one zone.

According to the values assumed for the Avergae inter-person space and the inital count of infected people, we can assume that:-

For Zone 1, $a=5$ $r=4$
For Zone 2, $a=5$ $r=6$
For Zone 3, $a=5$ $r=8$
For Zone 4, $a=5$ $r=10$

Now to find out how long will it take for X% of the population to be infected, we can find the sum of the values obtained from the 4 G.P.s that gives us the total number of infected people in the city (since each individual G.P. gives us the number of infected people in that zone).

Note that we have 4 different G.P.s contributing to the total number of infected people, therefore, we can not use the method that has been used in the previous 2 cases.

Hence, the code for this Case is different from the other two cases and involves recursion to find out in how many days (rounded of value) will a certain percentage of the population be suffering from the disease caused by the pathogen.

We calculate the total population that has fallen ill because of the pathogen at each step of the recursion, the movement we get a value that is greater than that of the number required (according to the percentage), the count of days stop. **The last message printed tells us the final count of the number of days it takes for X% of the total population to be fallen ill.**

(b.iii): The purpose of this whole model is to understand out mistakes with dealing with the ongoing Pandemic COVID-19, so that we can refrain from making the same mistakes in future and can better prepare ourselves for a similar outbreak.

In my opinion, the situation can be made better by containment of infection and isolating the infected individuals as soon as they are identified. Special medical wards can be set up in remote places where infected people can stay during infection so that the infection does not spread from one person to another either direcly or indirectly. And since we already know from this outbreak of COVID-19, the symptoms can take upto 20 days to be visible, therefore, everyone should take the

disease seriously and practice best preventive measures.

Obviously, the rate of infection wouldn't become 0 altogether but it will start to decrease and be withing a manageable range.

So, in this case the rate of spread becomes 0, that is no new people will be infected.
And as for infected people, they will stay under isolation untill they are completely healthy.