Project Report

Deadlock Detector

Submitted to
Prof. Muktikanta Sahu
Department of Computer Science & Engineering
IIIT Bhubaneswar

By

Amit Jena
B417007

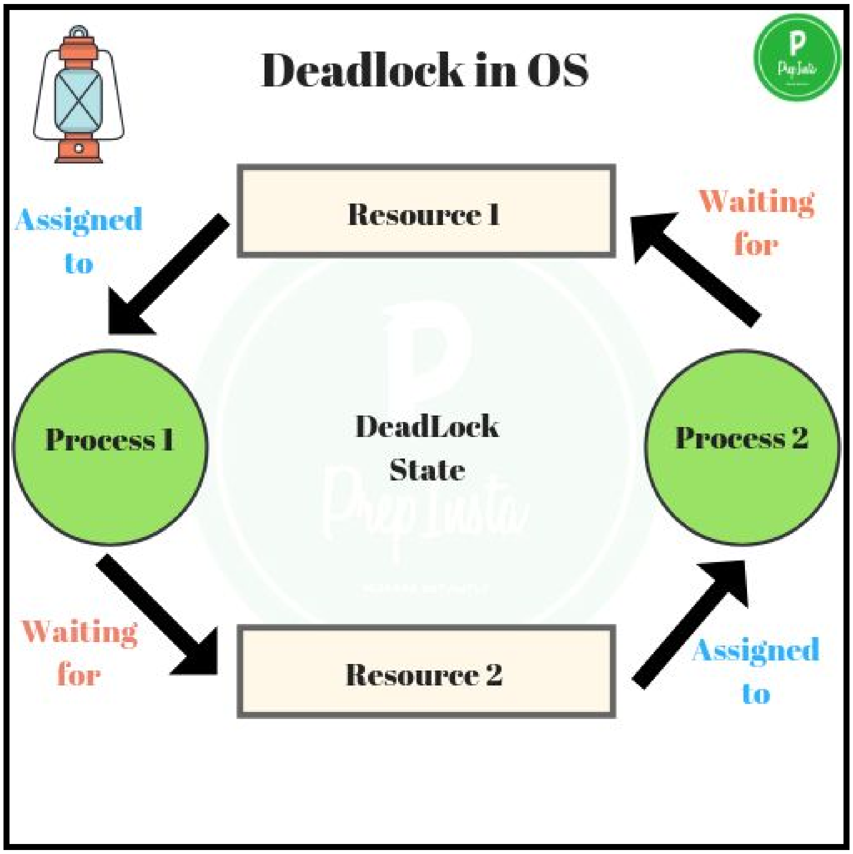
Shubham Sharma
B417043

Description

A process in operating systems uses different resources and uses resources in the following way:
1) Requests a resource
2) Use the resource
3) Releases the resource

Deadlock is a situation where a set of processes are blocked because each process is holding a resource and waiting for another resource acquired by some other process.

Consider an example when two trains are coming toward each other on the same track and there is only one track, none of the trains can move once they are in front of each other. Similar situation occurs in operating systems when there are two or more processes holding some resources and waiting for resources held by other(s). For example, in the below diagram, Process 1 is holding Resource 1 and waiting for resource 2 which is acquired by process 2, and process 2 is waiting for resource 1.



1. If resources have single instance:
   In this case for Deadlock detection we can run an algorithm to check for cycles in the Resource Allocation Graph. Presence of cycle in the graph is the sufficient condition for deadlock.

   In the above diagram, resource 1 and resource 2 have single instances. There is a cycle R1 → P1 → R2 → P2. So, Deadlock is Confirmed.
2. If there are multiple instances of resources:
   Detection of the cycle is necessary but not sufficient condition for deadlock detection, in this case, the system may or may not be in deadlock depending on different situations.

In order to recover the system from deadlocks, either OS considers resources or processes.

For Resource

Preempt the resource

We can snatch one of the resources from the owner of the resource (process) and give it to the other process with the expectation that it will complete the execution and will release this resource sooner. Well, choosing a resource which will be snatched is going to be a bit difficult.

Rollback to a safe state

System passes through various states to get into the deadlock state. The operating system can rollback the system to the previous safe state. For this purpose, the OS needs to implement check pointing at every state.

The moment we get into a deadlock, we will rollback all the allocations to get into the previous safe state.

For Process

Kill a process

Killing a process can solve our problem but the bigger concern is to decide which process to kill. Generally, the Operating system kills a process which has done the least amount of work until now.

Kill all process

This is not a suggestible approach but can be implemented if the problem becomes very serious. Killing all processes will lead to inefficiency in the system because all the processes will execute again from starting.

If a system does not employ either a deadlock prevention or deadlock avoidance algorithm then a deadlock situation may occur. In this case-

- Apply an algorithm to examine the state of the system to determine whether a deadlock has occurred or not.
- Apply an algorithm to recover from the deadlock.

Algorithm

1. We have simulated a software which is used to detect the deadlock in an office environment.The operator of the software is a resource administrator and checks for availability of resources based on the resources available at the current time.

2. There are multiple instances of resources available in the office and there are 4 employees in the office using the resources.

3. They are requesting the use of resources at any given time which the administrator knows and enters it at as input to the software.

4. The software at that time randomly distributes the resources i.e. the resources on hold by employees based on the total number of resources available.We have used rand() to randomly distribute the resources among the employees.

5. After that we calculate the resources available and take the resources requested by users as input and check for possibility of assigning the resources by taking counters if the resources requested by a particular person is less i.e. the number of printers,scanners,tape drive,fax then the counter value is increased till 4.If the counter value turns out to be 4 then resources are assigned to the person and the total resources available at that time is added upon by the person's resources in the available matrix. If the counter does not go upto 4 in any case then deadlock is detected.

6. Now coming to different matrices we have used:

   - fraction[]->It is used for randomly storing the number of resources allocated at any time
   - request[]->It is used for storing the resources requested by users at any time.
   - srand()->It is used for generating a seed at a particular time otherwise if we use rand() in c++ directly then it will always return the same random numbers after executing multiple times.So by using srand() we will be generating random numbers.
   - available[]->It is used to check for the resources available by subtracting the total number of resources available with total number of resources on hold.

Software and Hardware Requirements

Software used to develop the simulator:

Languages: C++14 and Python 3.7.4

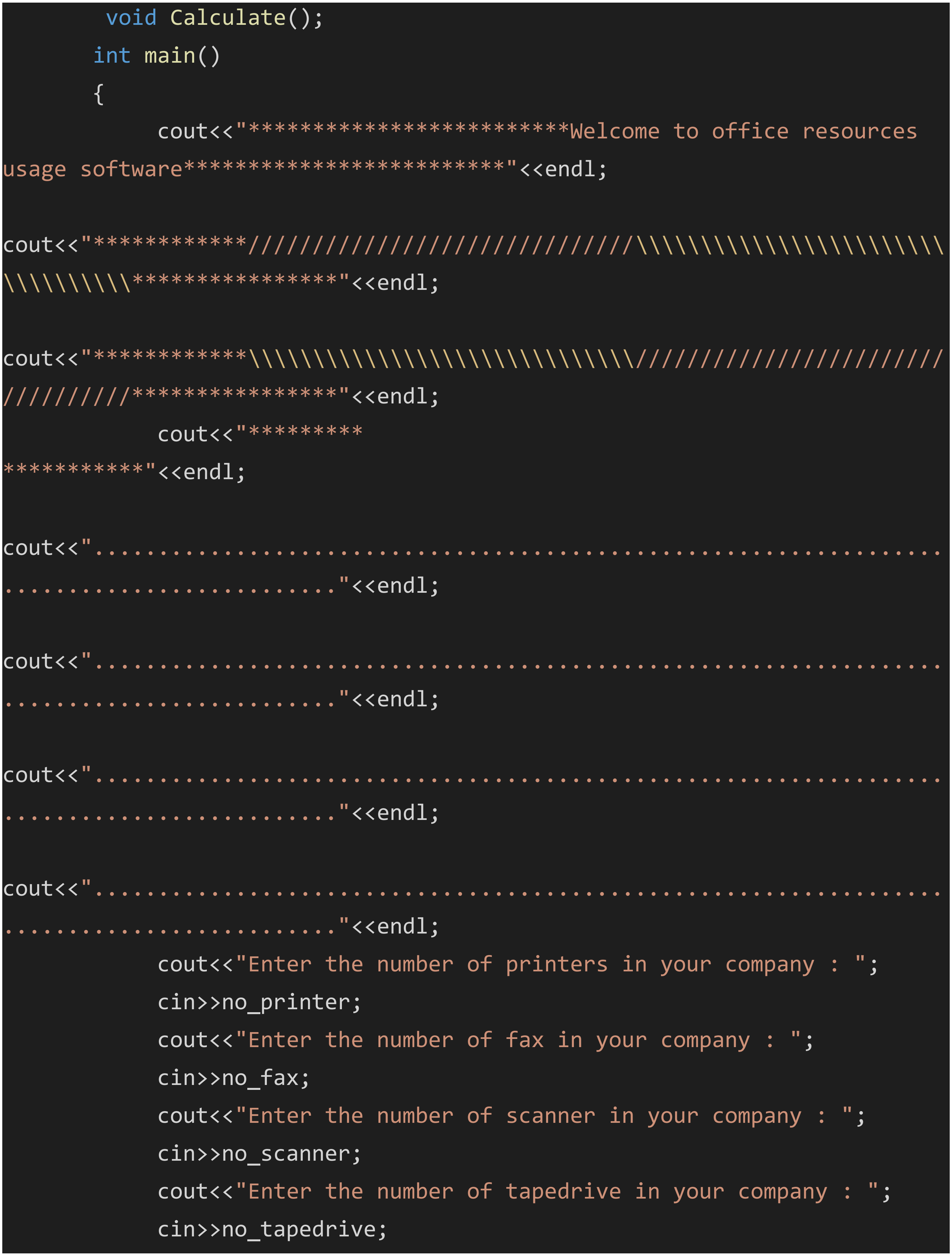
- **Visual Studio Code** is a source-code editor developed by Microsoft for Windows, Linux and macOS
- **Code Runner VSCode Extension:** Executing code snippet or code file for multiple languages: C, C++
- **Spyder:**Spyder is an open source cross-platform integrated development environment for scientific programming in the Python language.
- **Matplotlib:** It's a plotting library for the Python programming language

Hardware Requirements(Recommendation):

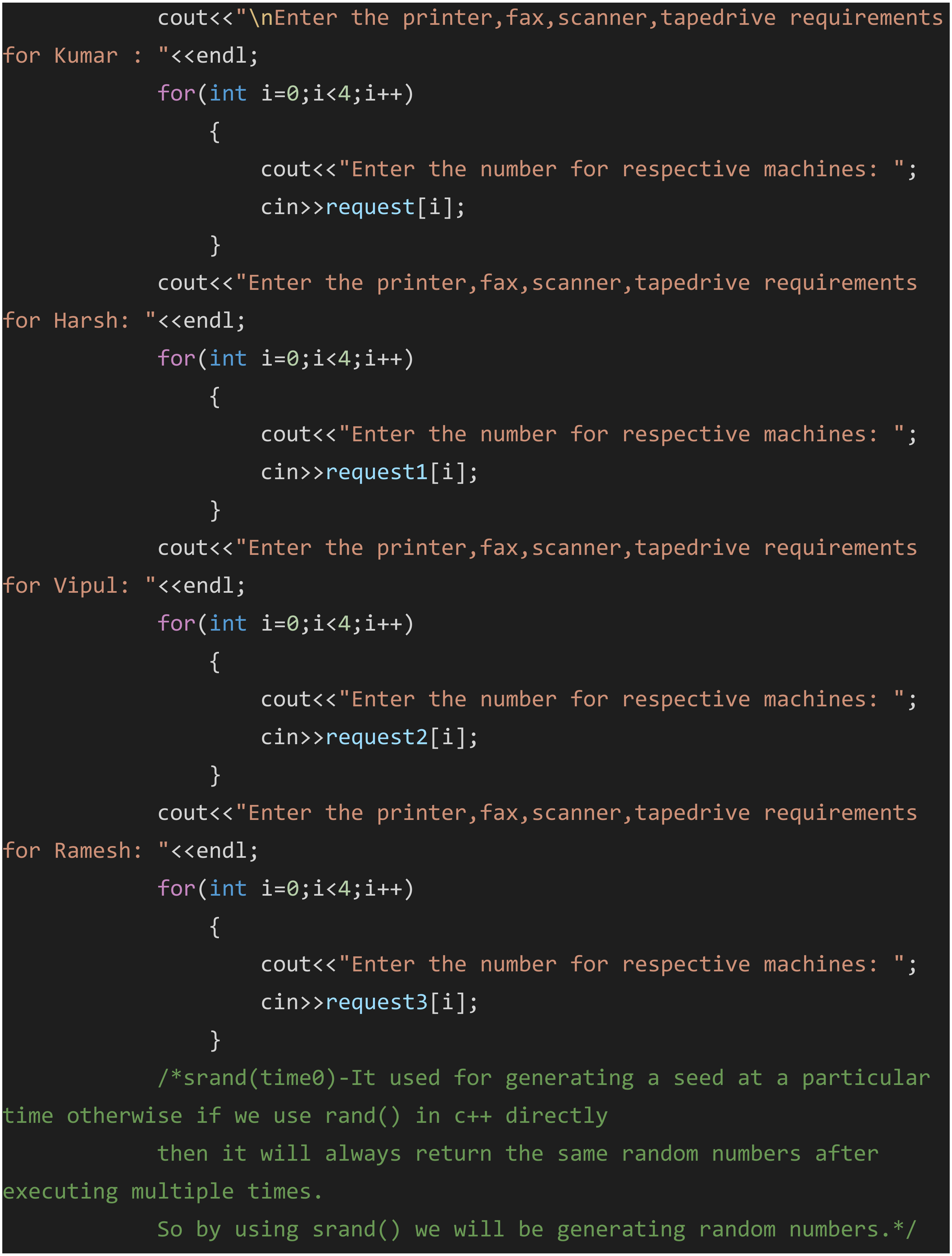
- 1.6 GHz or faster processor
- 1 GB of RAM
- 64Mb Graphics Card
- Processors: Intel Atom® processor or Intel® Core™ i3 processor
- Disk space: 1 GB
- Operating systems: Windows* 7 or later, macOS, and Linux

Source Code

```
#include<stdio.h>
#include<stdlib.h>
#include<iostream>
#include<math.h>
#include<time.h>
using namespace std;
//Variable for number of printers,fax,scanner and tapedrive
        int no_printer,no_fax,no_scanner,no_tapedrive;
//Used for calculating the random assignment of resources
        int sum=0,sum1=0,sum2=0,sum3=0;
//Variable for number of printers,fax,scanner and tapedrive on hold by
users
        int r1,r2,r3,r4;
//fraction[]->It is used for randomly storing the number of resources
allocated at any time
       int fraction[4];
       int fraction1[4];
       int fraction2[4];
       int fraction3[4];
//request[]->It is used for storing the resources requested by users at
any time.
       int request[4];
       int request1[4];
       int request2[4];
       int request3[4];
/*available[]->It is used to check for the resources available by
substracting the total number of resources available
with total number of resources on hold.*/

       int available[4];
```

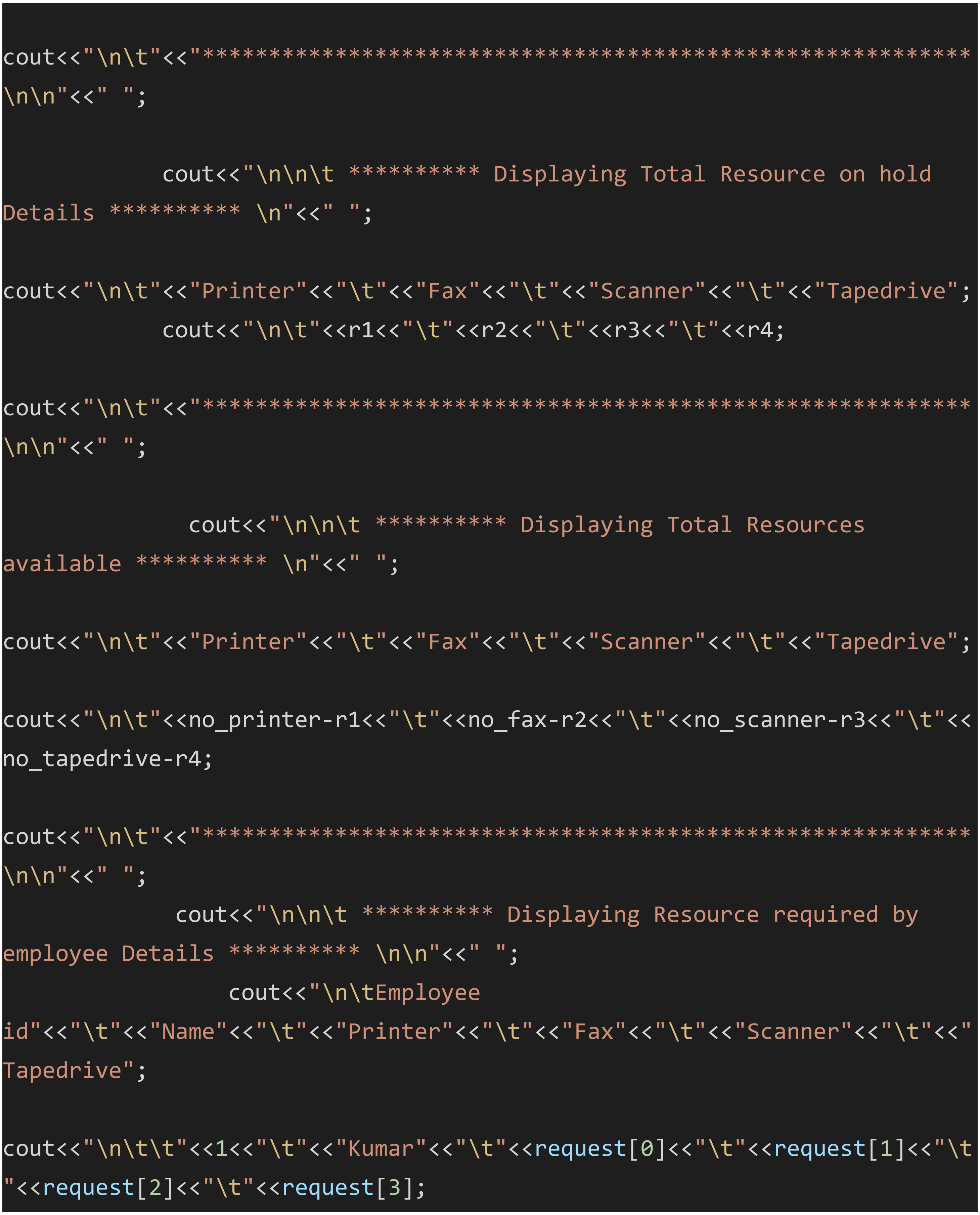


```
        void Calculate();
       int main()
       {
            cout<<"*************************Welcome to office resources usage software*************************"<<endl;

cout<<"************//////////////////////////////\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\****************"<<endl;

cout<<"************\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\//////////////////////////////////****************"<<endl;
            cout<<"*********
***********"<<endl;

cout<<"............................................................................................"<<endl;

cout<<"............................................................................................"<<endl;

cout<<"............................................................................................"<<endl;

cout<<"............................................................................................"<<endl;
            cout<<"Enter the number of printers in your company : ";
            cin>>no_printer;
            cout<<"Enter the number of fax in your company : ";
            cin>>no_fax;
            cout<<"Enter the number of scanner in your company : ";
            cin>>no_scanner;
            cout<<"Enter the number of tapedrive in your company : ";
            cin>>no_tapedrive;
```

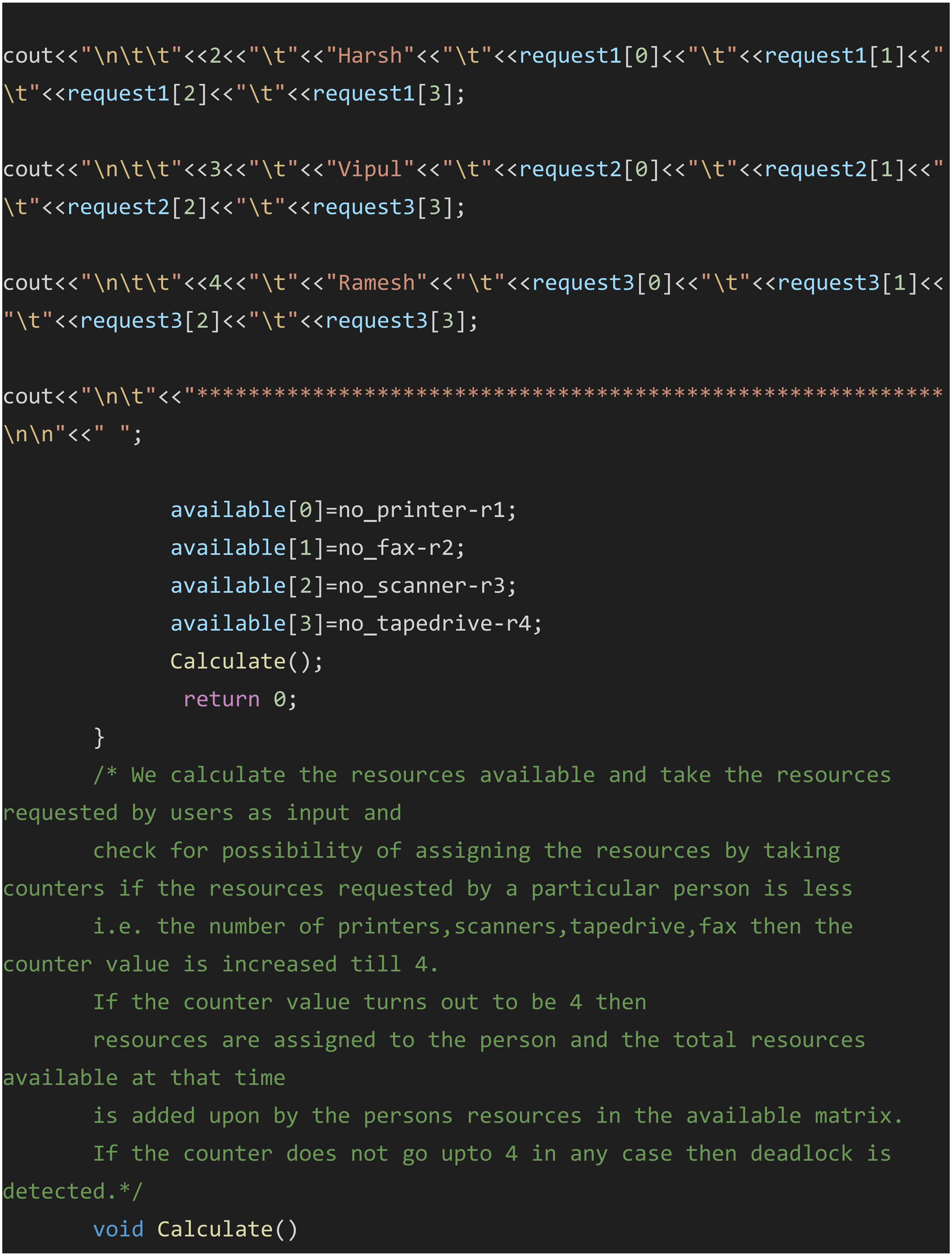


```
            cout<<"\nEnter the printer,fax,scanner,tapedrive requirements
for Kumar : "<<endl;
            for(int i=0;i<4;i++)
                {
                    cout<<"Enter the number for respective machines: ";
                    cin>>request[i];
                }
            cout<<"Enter the printer,fax,scanner,tapedrive requirements
for Harsh: "<<endl;
            for(int i=0;i<4;i++)
                {
                    cout<<"Enter the number for respective machines: ";
                    cin>>request1[i];
                }
            cout<<"Enter the printer,fax,scanner,tapedrive requirements
for Vipul: "<<endl;
            for(int i=0;i<4;i++)
                {
                    cout<<"Enter the number for respective machines: ";
                    cin>>request2[i];
                }
            cout<<"Enter the printer,fax,scanner,tapedrive requirements
for Ramesh: "<<endl;
            for(int i=0;i<4;i++)
                {
                    cout<<"Enter the number for respective machines: ";
                    cin>>request3[i];
                }
            /*srand(time0)-It used for generating a seed at a particular
time otherwise if we use rand() in c++ directly
            then it will always return the same random numbers after
executing multiple times.
            So by using srand() we will be generating random numbers.*/
            srand(time(0));
            int randnum[4];
            int randnum1[4];
            int randnum2[4];
            int randnum3[4];
            //for loop Used for generating random numbers within the max 
limit
            for (int i = 0; i < 4; i++)
                {
                randnum[i]=((double) rand() / (RAND_MAX))*no_printer;
                randnum1[i]=((double) rand() / (RAND_MAX))*no_fax;
                randnum2[i]=((double) rand() / (RAND_MAX))*no_scanner;
                randnum3[i]=((double) rand() / (RAND_MAX))*no_tapedrive;
                sum+=randnum[i];
                sum1+=randnum1[i];
                sum2+=randnum2[i];
                sum3+=randnum3[i];
                }

               //for loop used for random distribution of resources
              for (int i = 0; i < 4; i++)
              {
                fraction[i]=(no_printer*randnum[i]/sum);
                fraction1[i]=(no_fax*randnum1[i]/sum1);
                fraction2[i]=(no_scanner*randnum2[i]/sum2);
                fraction3[i]=(no_tapedrive*randnum3[i]/sum3);
               }
                 cout<<"\n\n\t ********** Displaying Total Resource 
Details ********** \n"<<" ";

cout<<"\n\t"<<"Printer"<<"\t"<<"Fax"<<"\t"<<"Scanner"<<"\t"<<"Tapedrive";
```

```
cout<<"\n\t"<<no_printer<<"\t"<<no_fax<<"\t"<<no_scanner<<"\t"<<no_tapedrive;

cout<<"\n\t"<<"**********************************************************\n\n"<<" ";
                 cout<<"\n\n\t ********** Displaying Resource on hold by employee Details ********** \n\n"<<" ";
                 cout<<"\n\tEmployee id"<<"\t"<<"Name"<<"\t"<<"Printer"<<"\t"<<"Fax"<<"\t"<<"Scanner"<<"\t"<<"Tapedrive";

cout<<"\n\t\t"<<1<<"\t"<<"Kumar"<<"\t"<<fraction[0]<<"\t"<<fraction1[0]<<"\t"<<fraction2[0]<<"\t"<<fraction3[0];

cout<<"\n\t\t"<<2<<"\t"<<"Harsh"<<"\t"<<fraction[1]<<"\t"<<fraction1[1]<<"\t"<<fraction2[1]<<"\t"<<fraction3[1];

cout<<"\n\t\t"<<3<<"\t"<<"Vipul"<<"\t"<<fraction[2]<<"\t"<<fraction1[2]<<"\t"<<fraction2[2]<<"\t"<<fraction3[2];

cout<<"\n\t\t"<<4<<"\t"<<"Ramesh"<<"\t"<<fraction[3]<<"\t"<<fraction1[3]<<"\t"<<fraction2[3]<<"\t"<<fraction3[3];

cout<<"\n\t"<<"**********************************************************\n\n"<<" ";

                r1=fraction[0]+fraction[1]+fraction[2]+fraction[3];
                r2=fraction1[0]+fraction1[1]+fraction1[2]+fraction1[3];
                r3=fraction2[0]+fraction2[1]+fraction2[2]+fraction2[3];
                r4=fraction3[0]+fraction3[1]+fraction3[2]+fraction3[3];
```

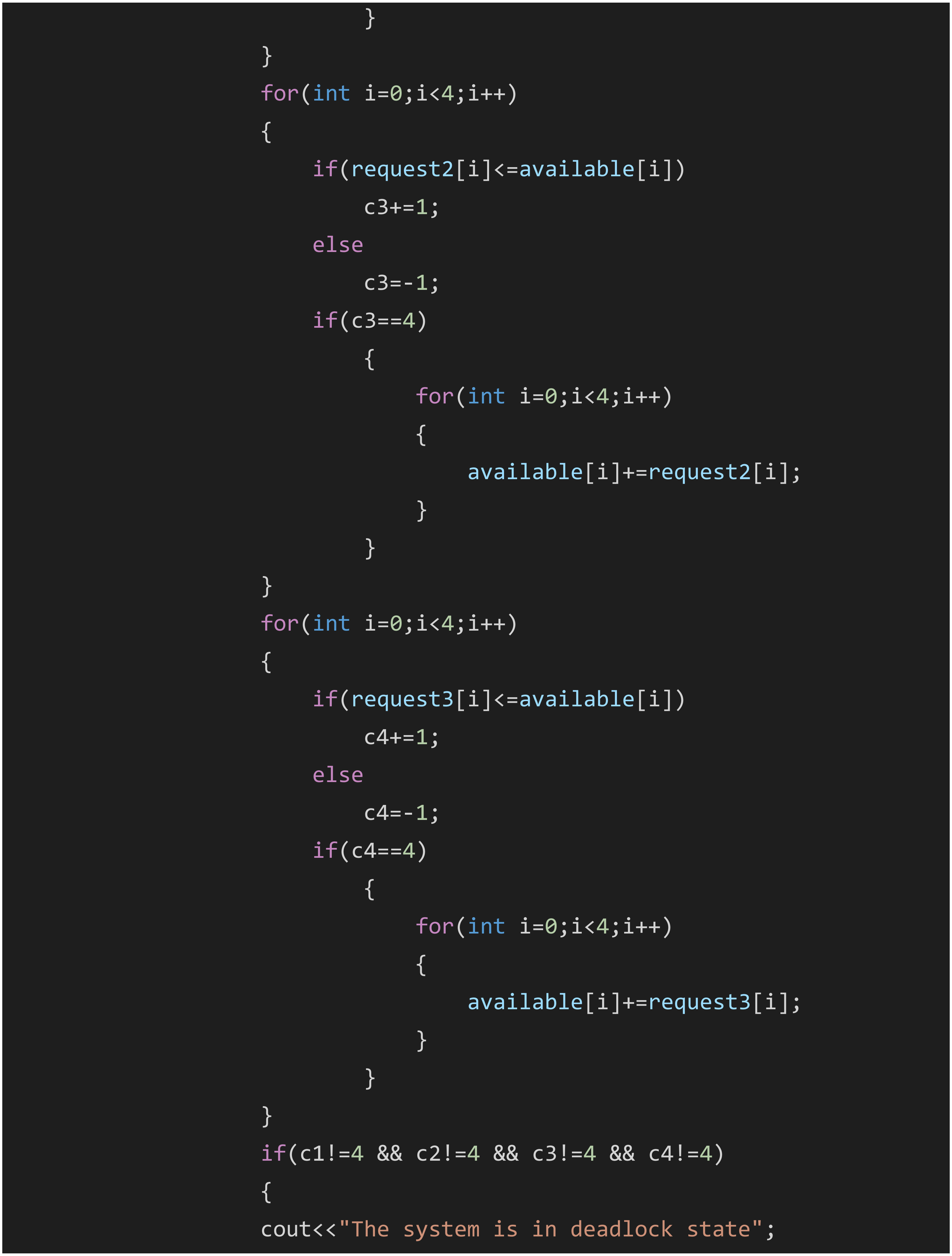


```
cout<<"\n\t"<<"**********************************************************
\n\n"<<" ";

            cout<<"\n\n\t ********** Displaying Total Resource on hold
Details ********** \n"<<" ";

cout<<"\n\t"<<"Printer"<<"\t"<<"Fax"<<"\t"<<"Scanner"<<"\t"<<"Tapedrive";
            cout<<"\n\t"<<r1<<"\t"<<r2<<"\t"<<r3<<"\t"<<r4;

cout<<"\n\t"<<"**********************************************************
\n\n"<<" ";

              cout<<"\n\n\t ********** Displaying Total Resources
available ********** \n"<<" ";

cout<<"\n\t"<<"Printer"<<"\t"<<"Fax"<<"\t"<<"Scanner"<<"\t"<<"Tapedrive";

cout<<"\n\t"<<no_printer-r1<<"\t"<<no_fax-r2<<"\t"<<no_scanner-r3<<"\t"<<
no_tapedrive-r4;

cout<<"\n\t"<<"**********************************************************
\n\n"<<" ";
             cout<<"\n\n\t ********** Displaying Resource required by
employee Details ********** \n\n"<<" ";
                 cout<<"\n\tEmployee
id"<<"\t"<<"Name"<<"\t"<<"Printer"<<"\t"<<"Fax"<<"\t"<<"Scanner"<<"\t"<<"
Tapedrive";

cout<<"\n\t\t"<<1<<"\t"<<"Kumar"<<"\t"<<request[0]<<"\t"<<request[1]<<"\t
"<<request[2]<<"\t"<<request[3];
```



```
cout<<"\n\t\t"<<2<<"\t"<<"Harsh"<<"\t"<<request1[0]<<"\t"<<request1[1]<<"\t"<<request1[2]<<"\t"<<request1[3];

cout<<"\n\t\t"<<3<<"\t"<<"Vipul"<<"\t"<<request2[0]<<"\t"<<request2[1]<<"\t"<<request2[2]<<"\t"<<request3[3];

cout<<"\n\t\t"<<4<<"\t"<<"Ramesh"<<"\t"<<request3[0]<<"\t"<<request3[1]<<"\t"<<request3[2]<<"\t"<<request3[3];

cout<<"\n\t"<<"**********************************************************\n\n"<<" ";

             available[0]=no_printer-r1;
             available[1]=no_fax-r2;
             available[2]=no_scanner-r3;
             available[3]=no_tapedrive-r4;
             Calculate();
              return 0;
       }
       /* We calculate the resources available and take the resources requested by users as input and
       check for possibility of assigning the resources by taking counters if the resources requested by a particular person is less
       i.e. the number of printers,scanners,tapedrive,fax then the counter value is increased till 4.
       If the counter value turns out to be 4 then
       resources are assigned to the person and the total resources available at that time
       is added upon by the persons resources in the available matrix.
       If the counter does not go upto 4 in any case then deadlock is detected.*/
       void Calculate()
```

```
{
    int c1,c2,c3,c4;
    c1=0,c2=0,c3=0,c4=0;
     do
     {
         c1=0,c2=0,c3=0,c4=0;

             for(int i=0;i<4;i++)
             {
                 if(request[i]<=available[i])
                     c1+=1;
                 else
                     c1=-1;
                 if(c1==4)
                     {
                         for(int i=0;i<4;i++)
                         {
                             available[i]+=request[i];
                         }
                     }
             }
             for(int i=0;i<4;i++)
             {
                 if(request1[i]<=available[i])
                     c2+=1;
                 else
                     c2=-1;
                 if(c2==4)
                     {
                         for(int i=0;i<4;i++)
                         {
                             available[i]+=request1[i];
                         }
```



```
        }
}
for(int i=0;i<4;i++)
{
    if(request2[i]<=available[i])
        c3+=1;
    else
        c3=-1;
    if(c3==4)
        {
            for(int i=0;i<4;i++)
            {
                available[i]+=request2[i];
            }
        }
}
for(int i=0;i<4;i++)
{
    if(request3[i]<=available[i])
        c4+=1;
    else
        c4=-1;
    if(c4==4)
        {
            for(int i=0;i<4;i++)
            {
                available[i]+=request3[i];
            }
        }
}
if(c1!=4 && c2!=4 && c3!=4 && c4!=4)
{
cout<<"The system is in deadlock state";
```

```
                    break;
                    }
                    else{
                    cout<<"The system is not in deadlock";
                    break;
                    }
            }while(c1==4||c2==4||c3==4||c4==4);
       }
```

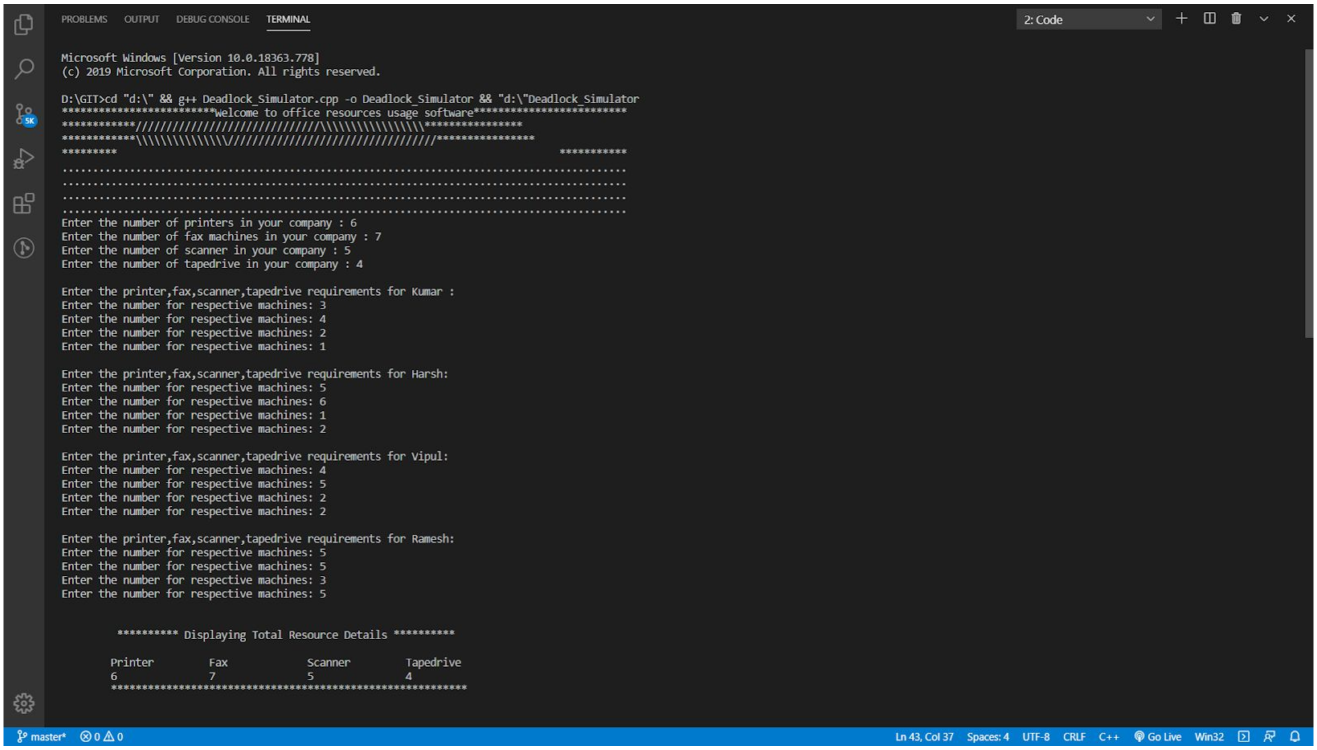
Code for generating Discrete distribution as horizontal bar chart

```
import numpy as np
import matplotlib.pyplot as plt


category_names = ['Resource hold by Kumar', 'Resource hold by Harsh',
                  'Resource hold by Vipul', 'Resource hold by Ramesh', 'Resource available']
results = {
    'Printer': [1,1,1,0,1],
    'Fax':[2,0,0,0,2],
    'Scanner':[1,1,0,1,1],
    'TapeDrive':[1,1,0,1,1]

}


def Resource(results, category_names):

    labels = list(results.keys())
    data = np.array(list(results.values()))
    data_cum = data.cumsum(axis=1)
    category_colors = plt.get_cmap('RdYlGn')(
        np.linspace(0.15, 0.85, data.shape[1]))
    fig, ax = plt.subplots(figsize=(9.2, 5))
    ax.invert_yaxis()
    ax.xaxis.set_visible(False)
    ax.set_xlim(0, np.sum(data, axis=1).max())

    for i, (colname, color) in enumerate(zip(category_names,
category_colors)):
        widths = data[:, i]
        starts = data_cum[:, i] - widths
        ax.barh(labels, widths, left=starts, height=0.5,
                label=colname, color=color)
        xcenters = starts + widths / 2

        r, g, b, _ = color
        text_color = 'white' if r * g * b < 0.5 else
'darkgrey'
        for y, (x, c) in enumerate(zip(xcenters, widths)):
            ax.text(x, y, str(int(c)), ha='center',
va='center',
                    color=text_color)
    ax.legend(ncol=len(category_names), bbox_to_anchor=(0,
1),
              loc='lower left', fontsize='small')

    return fig, ax


Resource(results, category_names)
plt.show()
```

TEST CASES

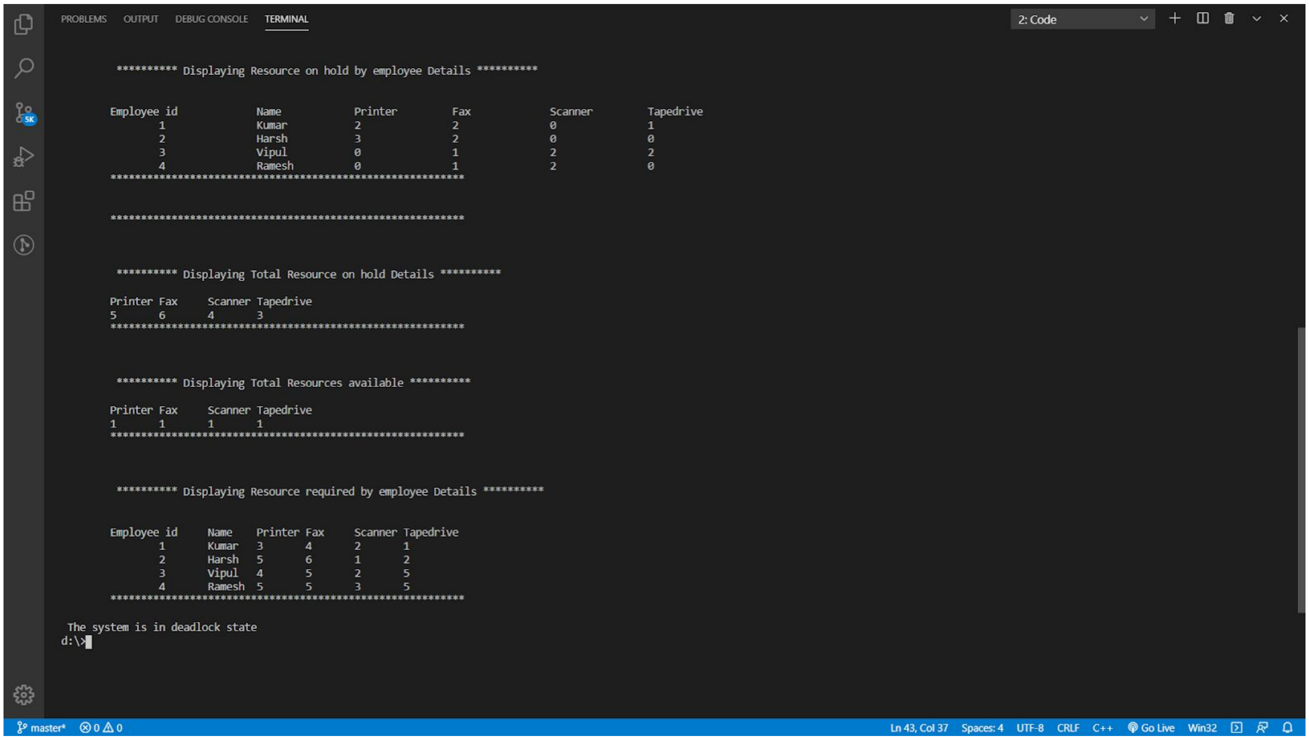
- When the system will be in deadlock state(1)

Input

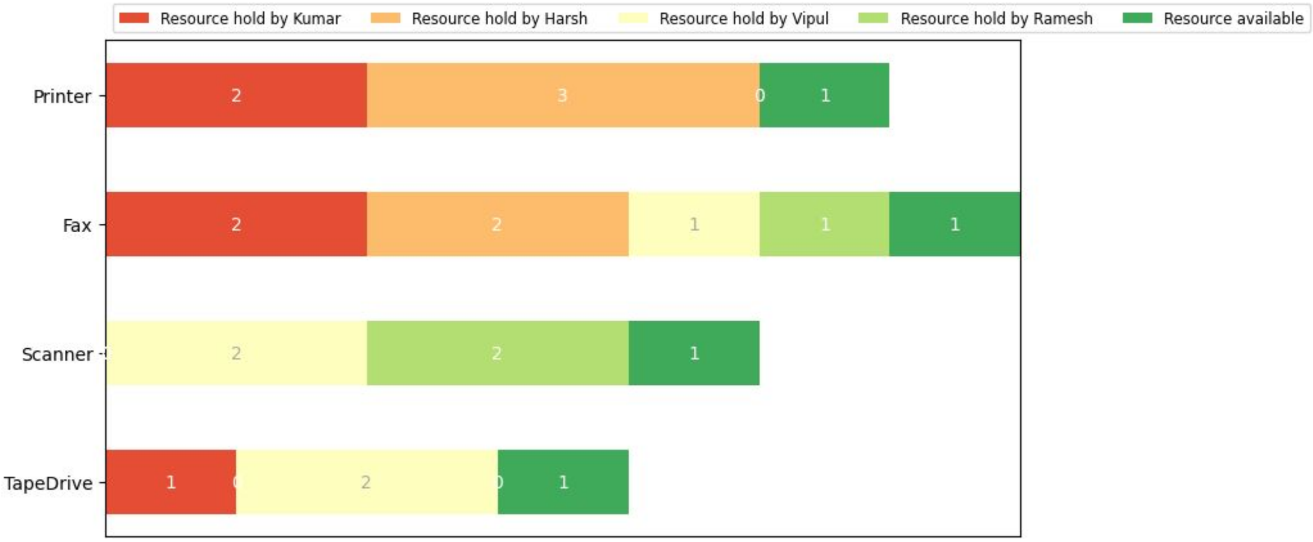


```
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

D:\GIT>cd "d:\" && g++ Deadlock_Simulator.cpp -o Deadlock_Simulator && "d:\"Deadlock_Simulator
*************************Welcome to office resources usage software*************************
************//////////////////////////////\\\\\\\\\\\\\\\****************
************\\\\\\\\\\\\\\/////////////////////////////////////****************
*********                                                                         **********
....................................................................................
....................................................................................
....................................................................................
....................................................................................
Enter the number of printers in your company : 6
Enter the number of fax machines in your company : 7
Enter the number of scanner in your company : 5
Enter the number of tapedrive in your company : 4

Enter the printer,fax,scanner,tapedrive requirements for Kumar :
Enter the number for respective machines: 3
Enter the number for respective machines: 4
Enter the number for respective machines: 2
Enter the number for respective machines: 1

Enter the printer,fax,scanner,tapedrive requirements for Harsh:
Enter the number for respective machines: 5
Enter the number for respective machines: 6
Enter the number for respective machines: 1
Enter the number for respective machines: 2

Enter the printer,fax,scanner,tapedrive requirements for Vipul:
Enter the number for respective machines: 4
Enter the number for respective machines: 5
Enter the number for respective machines: 2
Enter the number for respective machines: 2

Enter the printer,fax,scanner,tapedrive requirements for Ramesh:
Enter the number for respective machines: 5
Enter the number for respective machines: 5
Enter the number for respective machines: 3
Enter the number for respective machines: 5


         ********** Displaying Total Resource Details **********

        Printer         Fax             Scanner         Tapedrive
        6               7               5               4
        ***********************************************************
```

Output

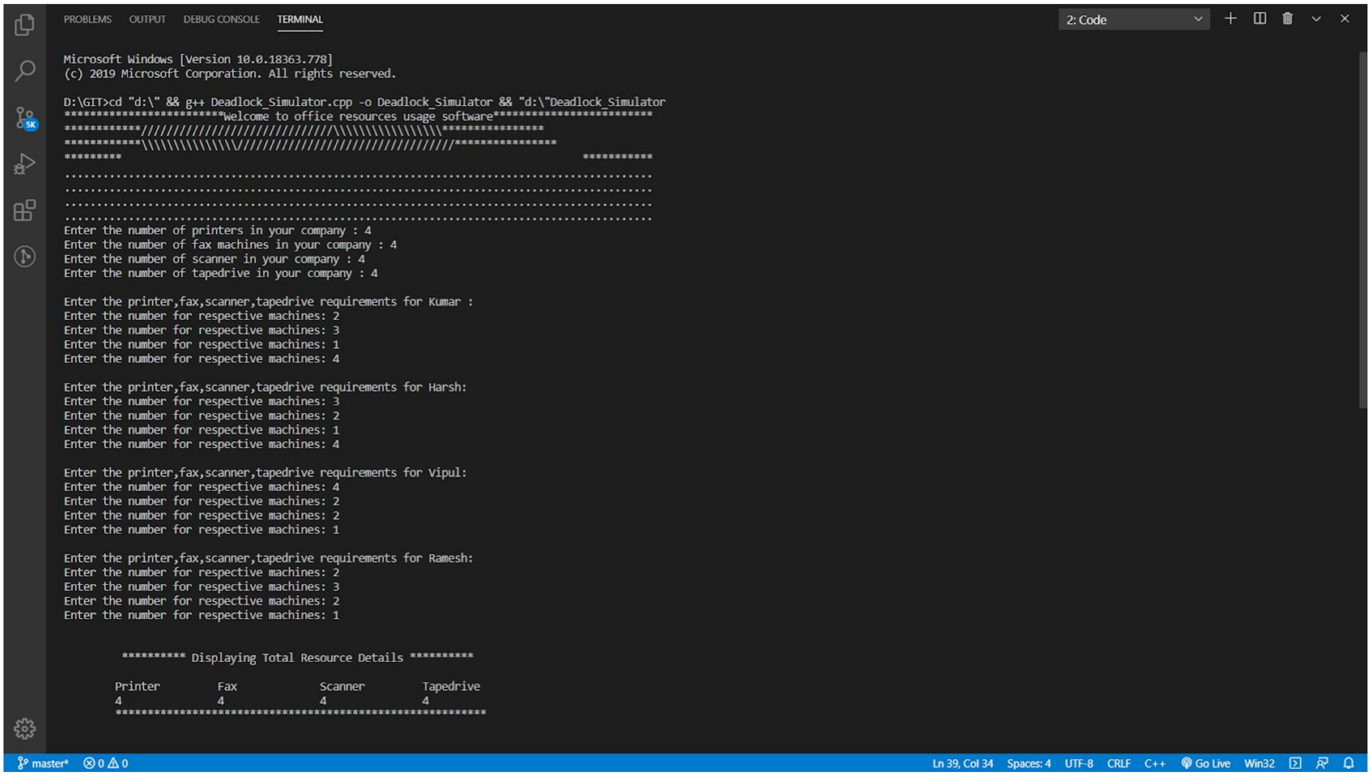


```
         ********** Displaying Resource on hold by employee Details **********


        Employee id             Name            Printer         Fax             Scanner         Tapedrive
                1               Kumar           2               2               0               1
                2               Harsh           3               2               0               0
                3               Vipul           0               1               2               2
                4               Ramesh          0               1               2               0
        ***********************************************************


        ***********************************************************



         ********** Displaying Total Resource on hold Details **********

        Printer Fax     Scanner Tapedrive
        5       6       4       3
        ***********************************************************



         ********** Displaying Total Resources available **********

        Printer Fax     Scanner Tapedrive
        1       1       1       1
        ***********************************************************



         ********** Displaying Resource required by employee Details **********


        Employee id     Name    Printer Fax     Scanner Tapedrive
                1       Kumar   3       4       2       1
                2       Harsh   5       6       1       2
                3       Vipul   4       5       2       5
                4       Ramesh  5       5       3       5
        ***********************************************************

 The system is in deadlock state
d:\>
```



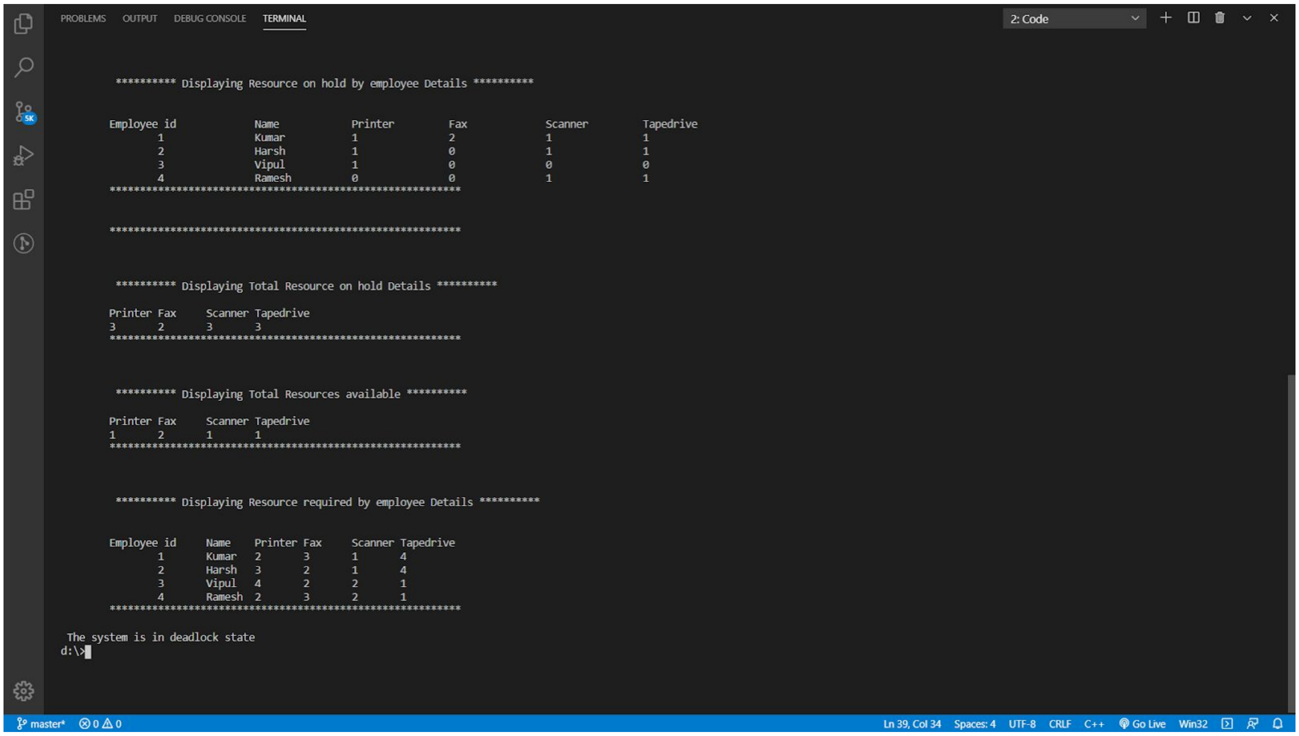
- When the system will be in deadlock state(2)

Input

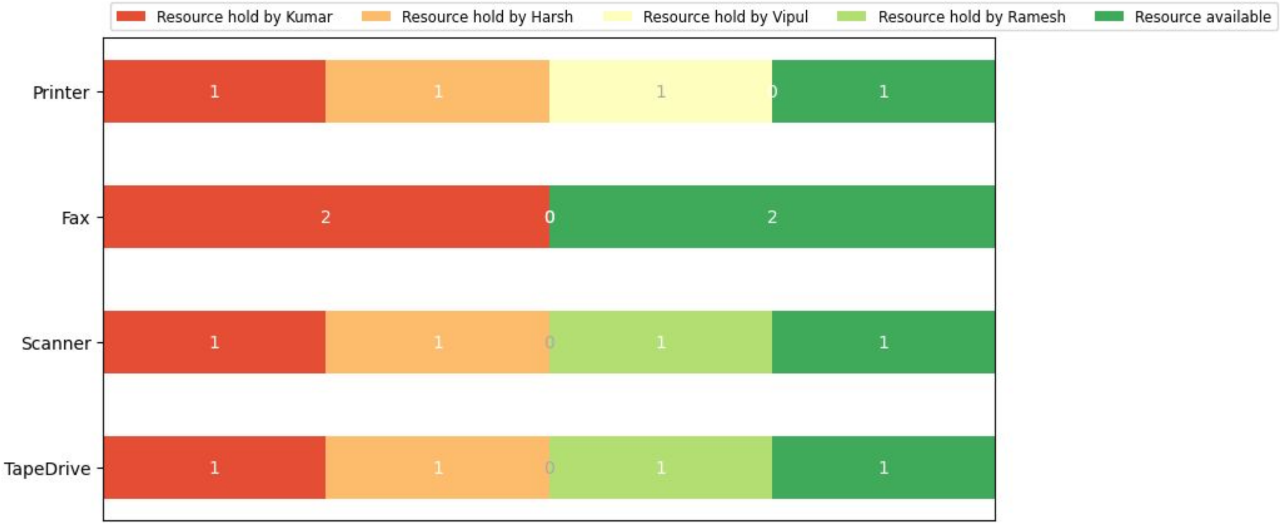


```
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

D:\GIT>cd "d:\" && g++ Deadlock_Simulator.cpp -o Deadlock_Simulator && "d:\"Deadlock_Simulator
************************Welcome to office resources usage software************************
************////////////////////////////\\\\\\\\\\\\\\\\\\****************
************\\\\\\\\\\\\\\\\/////////////////////////////////////****************
*********                                                                ***********
.....................................................................................
.....................................................................................
.....................................................................................
.....................................................................................
Enter the number of printers in your company : 4
Enter the number of fax machines in your company : 4
Enter the number of scanner in your company : 4
Enter the number of tapedrive in your company : 4

Enter the printer,fax,scanner,tapedrive requirements for Kumar :
Enter the number for respective machines: 2
Enter the number for respective machines: 3
Enter the number for respective machines: 1
Enter the number for respective machines: 4

Enter the printer,fax,scanner,tapedrive requirements for Harsh:
Enter the number for respective machines: 3
Enter the number for respective machines: 2
Enter the number for respective machines: 1
Enter the number for respective machines: 4

Enter the printer,fax,scanner,tapedrive requirements for Vipul:
Enter the number for respective machines: 4
Enter the number for respective machines: 2
Enter the number for respective machines: 2
Enter the number for respective machines: 1

Enter the printer,fax,scanner,tapedrive requirements for Ramesh:
Enter the number for respective machines: 2
Enter the number for respective machines: 3
Enter the number for respective machines: 2
Enter the number for respective machines: 1


        ********** Displaying Total Resource Details **********

       Printer         Fax             Scanner         Tapedrive
       4               4               4               4
       **********************************************************
```

Output

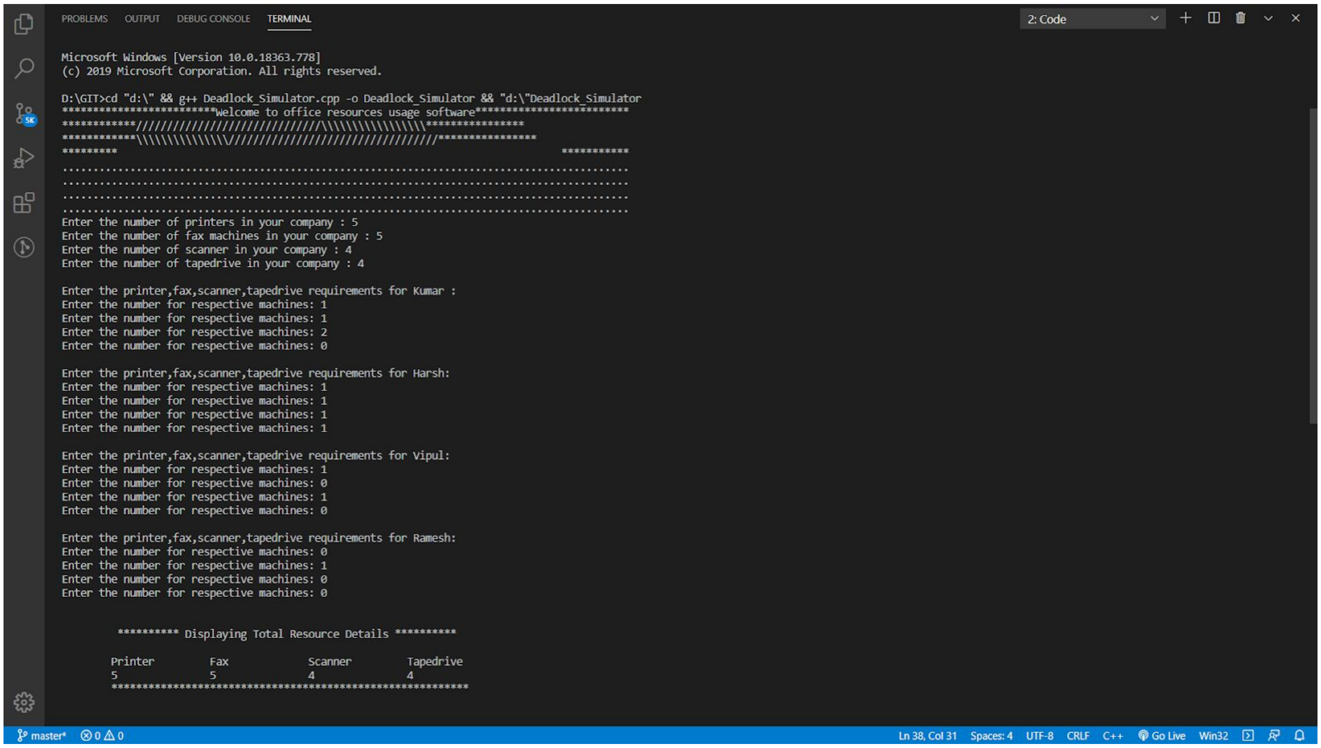


```
 ********** Displaying Resource on hold by employee Details **********

Employee id           Name          Printer       Fax           Scanner       Tapedrive
       1              Kumar         1             2             1             1
       2              Harsh         1             0             1             1
       3              Vipul         1             0             0             0
       4              Ramesh        0             0             1             1
**********************************************************


**********************************************************



 ********** Displaying Total Resource on hold Details **********

Printer Fax     Scanner Tapedrive
3       2       3       3
**********************************************************



 ********** Displaying Total Resources available **********

Printer Fax     Scanner Tapedrive
1       2       1       1
**********************************************************



 ********** Displaying Resource required by employee Details **********


Employee id     Name    Printer Fax     Scanner Tapedrive
       1        Kumar   2       3       1       4
       2        Harsh   3       2       1       4
       3        Vipul   4       2       2       1
       4        Ramesh  2       3       2       1
**********************************************************

 The system is in deadlock state
d:\>
```



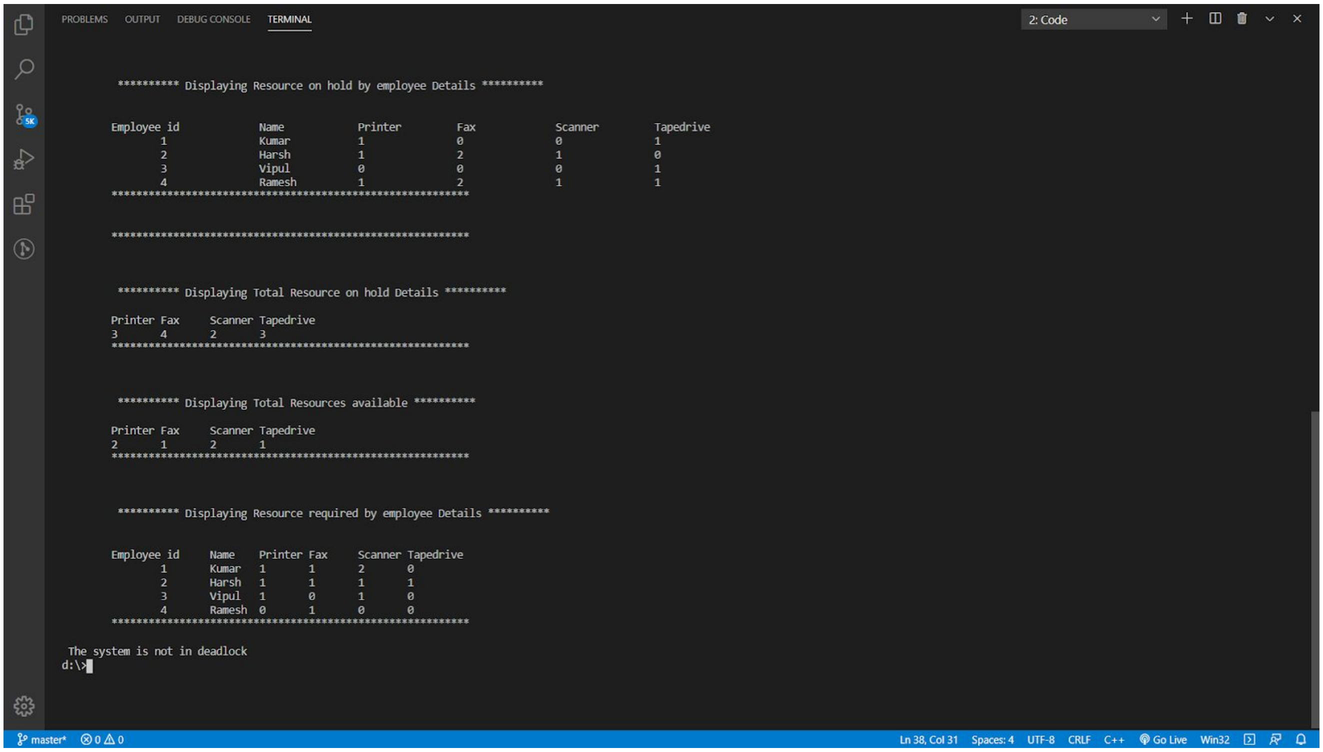
- When the system will not be in deadlock state(1)

Input

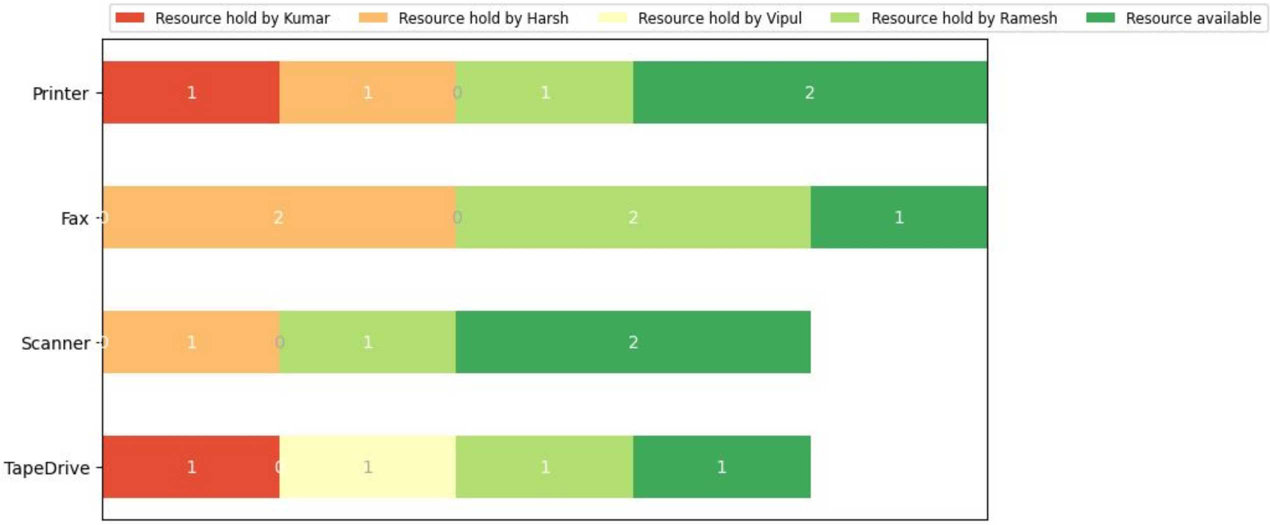


```
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

D:\GIT>cd "d:\" && g++ Deadlock_Simulator.cpp -o Deadlock_Simulator && "d:\"Deadlock_Simulator
*************************Welcome to office resources usage software*************************
************//////////////////////////////\\\\\\\\\\\\\\\****************
************\\\\\\\\\\\\\\\///////////////////////////////////****************
*********                                                                         ***********

 ........................................................................................
 ........................................................................................
 ........................................................................................
 ........................................................................................
Enter the number of printers in your company : 5
Enter the number of fax machines in your company : 5
Enter the number of scanner in your company : 4
Enter the number of tapedrive in your company : 4

Enter the printer,fax,scanner,tapedrive requirements for Kumar :
Enter the number for respective machines: 1
Enter the number for respective machines: 1
Enter the number for respective machines: 2
Enter the number for respective machines: 0

Enter the printer,fax,scanner,tapedrive requirements for Harsh:
Enter the number for respective machines: 1
Enter the number for respective machines: 1
Enter the number for respective machines: 1
Enter the number for respective machines: 1

Enter the printer,fax,scanner,tapedrive requirements for Vipul:
Enter the number for respective machines: 1
Enter the number for respective machines: 0
Enter the number for respective machines: 1
Enter the number for respective machines: 0

Enter the printer,fax,scanner,tapedrive requirements for Ramesh:
Enter the number for respective machines: 0
Enter the number for respective machines: 1
Enter the number for respective machines: 0
Enter the number for respective machines: 0


         ********** Displaying Total Resource Details **********

        Printer         Fax             Scanner         Tapedrive
        5               5               4               4
        **********************************************************
```

Output

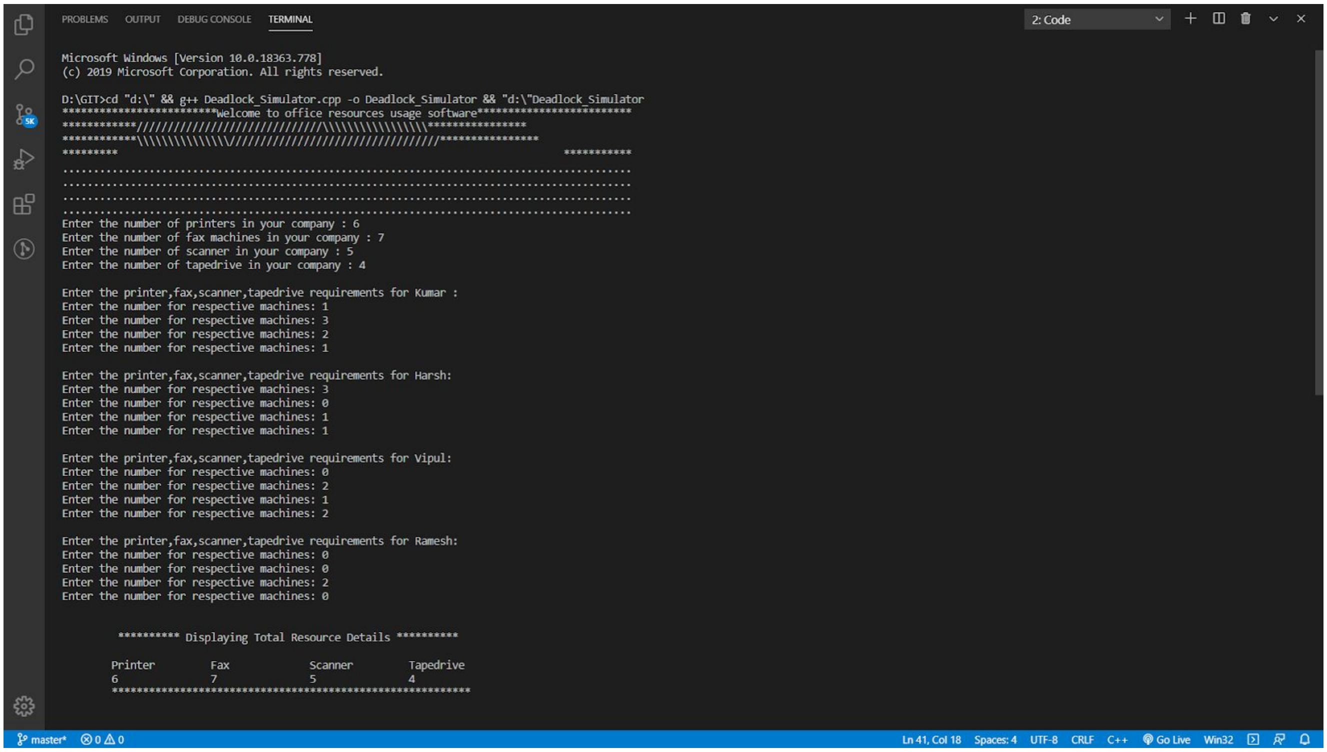


```
         ********** Displaying Resource on hold by employee Details **********


        Employee id             Name            Printer         Fax             Scanner         Tapedrive
                1               Kumar           1               0               0               1
                2               Harsh           1               2               1               0
                3               Vipul           0               0               0               1
                4               Ramesh          1               2               1               1
        **********************************************************


        **********************************************************



         ********** Displaying Total Resource on hold Details **********

        Printer Fax     Scanner Tapedrive
        3       4       2       3
        **********************************************************



         ********** Displaying Total Resources available **********

        Printer Fax     Scanner Tapedrive
        2       1       2       1
        **********************************************************



         ********** Displaying Resource required by employee Details **********


        Employee id     Name    Printer Fax     Scanner Tapedrive
                1       Kumar   1       1       2       0
                2       Harsh   1       1       1       1
                3       Vipul   1       0       1       0
                4       Ramesh  0       1       0       0
        **********************************************************

 The system is not in deadlock
d:\>
```



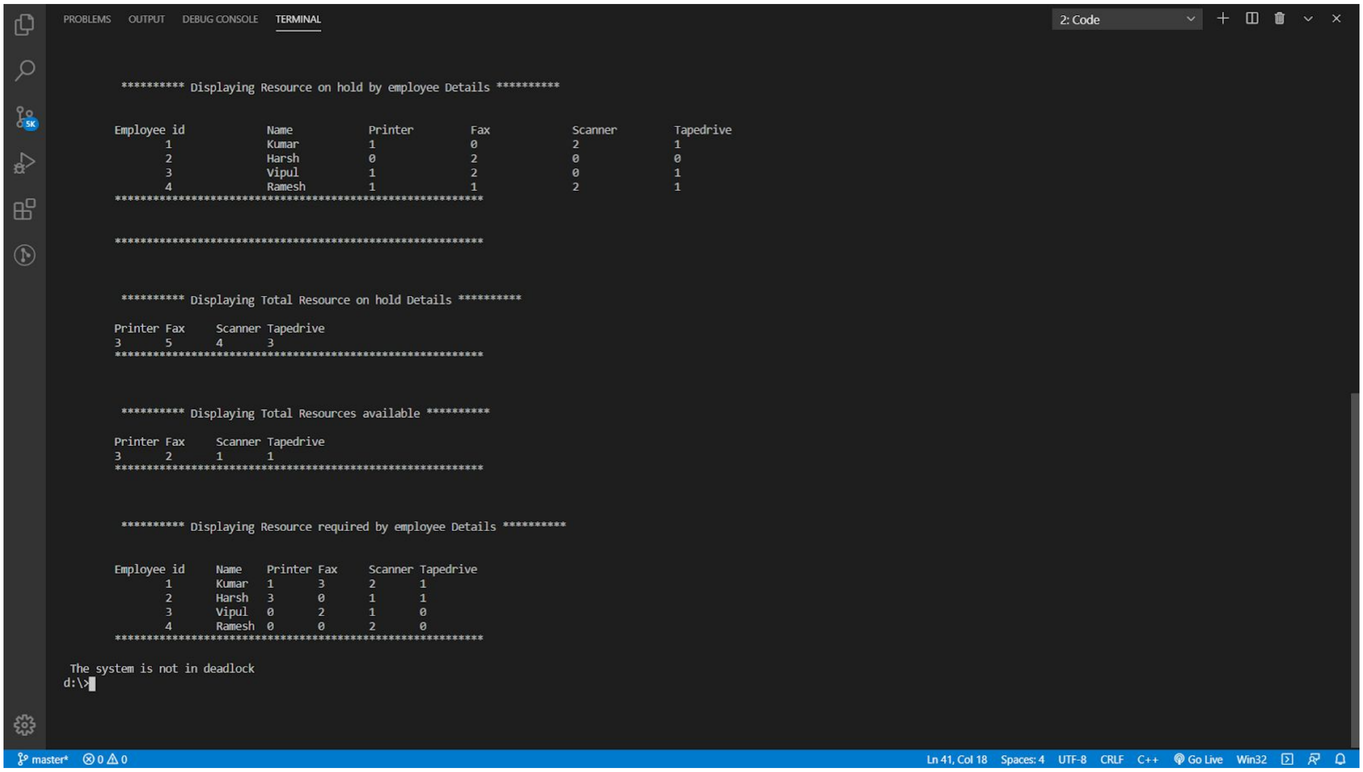
- When the system will not be in deadlock state(2)

Input

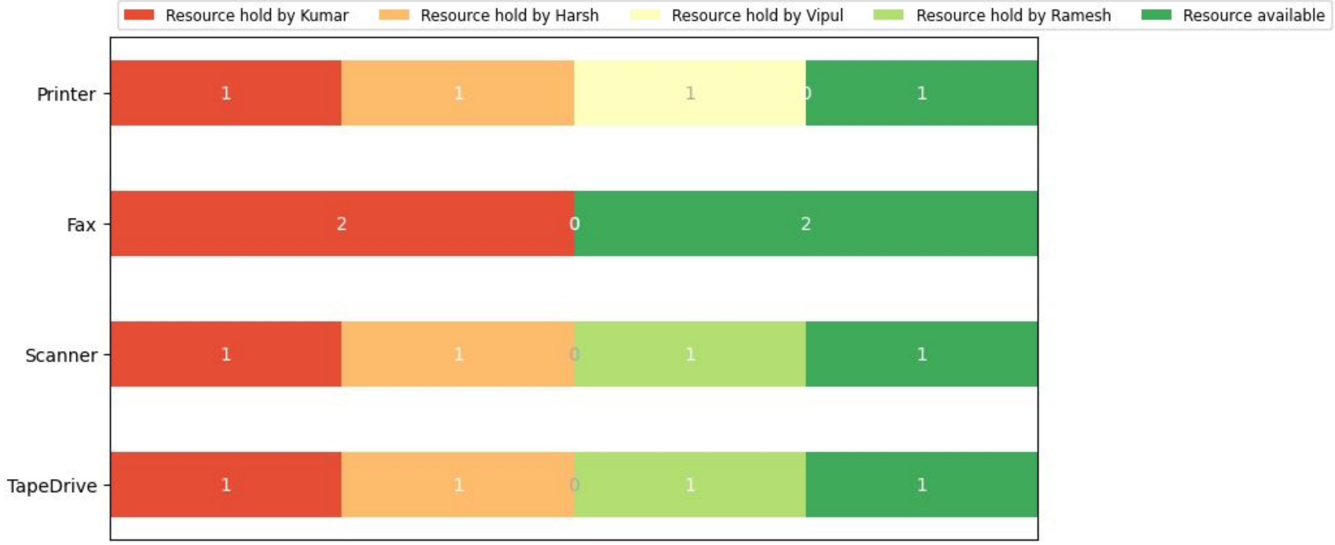


```
Microsoft Windows [Version 10.0.18363.778]
(c) 2019 Microsoft Corporation. All rights reserved.

D:\GIT>cd "d:\" && g++ Deadlock_Simulator.cpp -o Deadlock_Simulator && "d:\"Deadlock_Simulator
*************************Welcome to office resources usage software*************************
************///////////////////////////////\\\\\\\\\\\\\\\\****************
************\\\\\\\\\\\\\\V////////////////////////////////****************
*********                                                                       **********
.......................................................................................
.......................................................................................
.......................................................................................
.......................................................................................
Enter the number of printers in your company : 6
Enter the number of fax machines in your company : 7
Enter the number of scanner in your company : 5
Enter the number of tapedrive in your company : 4

Enter the printer,fax,scanner,tapedrive requirements for Kumar :
Enter the number for respective machines: 1
Enter the number for respective machines: 3
Enter the number for respective machines: 2
Enter the number for respective machines: 1

Enter the printer,fax,scanner,tapedrive requirements for Harsh:
Enter the number for respective machines: 3
Enter the number for respective machines: 0
Enter the number for respective machines: 1
Enter the number for respective machines: 1

Enter the printer,fax,scanner,tapedrive requirements for Vipul:
Enter the number for respective machines: 0
Enter the number for respective machines: 2
Enter the number for respective machines: 1
Enter the number for respective machines: 2

Enter the printer,fax,scanner,tapedrive requirements for Ramesh:
Enter the number for respective machines: 0
Enter the number for respective machines: 0
Enter the number for respective machines: 2
Enter the number for respective machines: 0


        ********** Displaying Total Resource Details **********

        Printer         Fax             Scanner         Tapedrive
        6               7               5               4
        **********************************************************
```

Output



```


         ********** Displaying Resource on hold by employee Details **********


        Employee id             Name            Printer         Fax             Scanner         Tapedrive
                1               Kumar           1               0               2               1
                2               Harsh           0               2               0               0
                3               Vipul           1               2               0               1
                4               Ramesh          1               1               2               1
        **********************************************************


        **********************************************************



         ********** Displaying Total Resource on hold Details **********

        Printer Fax     Scanner Tapedrive
        3       5       4       3
        **********************************************************



         ********** Displaying Total Resources available **********

        Printer Fax     Scanner Tapedrive
        3       2       1       1
        **********************************************************



         ********** Displaying Resource required by employee Details **********


        Employee id     Name    Printer Fax     Scanner Tapedrive
                1       Kumar   1       3       2       1
                2       Harsh   3       0       1       1
                3       Vipul   0       2       1       0
                4       Ramesh  0       0       2       0
        **********************************************************

 The system is not in deadlock
d:\>
```



Limitations

1. The number of employees is hardcoded.We can make it dynamic.

2. The types of resources can be made dynamic in an office scenario(types of resources -hardcoded) based on the new resources brought into the company.

3. There have been a lot of matrices in the code which might lead to confusion for editing purposes.

Future Scope

1. The software is an office scenario based software.However it can be made universal by applying this software in rental stores such as clothing rental stores.

2. A better UI can be build by making it more graphical rather than terminal based

3. We can improve the space complexity by using recursive functions.

4. A better representation like live statistics can be integrated with UI