Department of Computer Science and Engineering (Data Science)

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Experiment 6

(Dynamic Programming)

Aim: Implementation of coin change problem using dynamic programming.

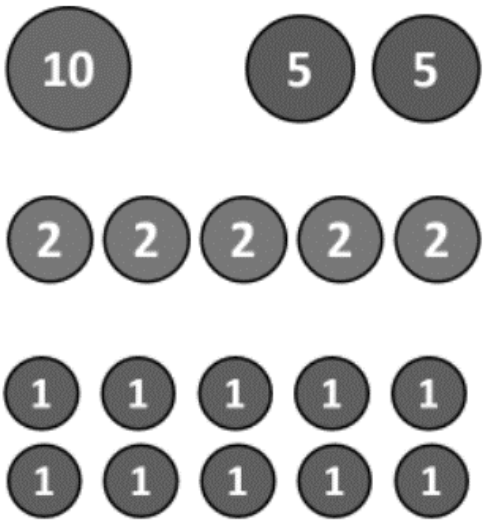
Theory:

Making Change problem is to find change for a given amount using a minimum number of coins from a set of denominations.

Explanation: If we are given a set of denominations D = {d0, d1, d2, …, dn} and if we want to change for some amount N, many combinations are possible. Suppose {d1, d2, d5, d8}, {d0, d2, d4}, {d0, d5, d7} all feasible solutions.

The aim of making a change is to find a solution with a minimum number of coins / denominations. Clearly, this is an optimization problem.

This problem can also be solved by using a greedy algorithm. However, greedy does not ensure the minimum number of denominations.



Various denominations for amount 10

General assumption is that infinite coins are available for each denomination. We can select any denomination any number of times.

Mathematical Formulation:

$$C[i,j] = \begin{cases} 1 + C[1, j - d_i], & \text{, if } i = j \\ C[i-1, j], & \text{if } j < d_i \\ \min(C[i-1, j], 1 + C[i, j - d_i]), & \text{otherwise} \end{cases}$$

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Pseudocode:

```
Algorithm MAKE_A_CHANGE(d,N)
// d[1…n] = [d1,d2,…,dn] is array of n denominations
// C[1…n, 0…N]  is n x N array to hold the solution of sub problems
// N is the problem size, i.e. amount for which change is required

for  i ← 1 to n do
  C[i, 0] ← 0
end

for  i ← 1 to n do
  for  j ← 1 to N do
    if i = = 1 & & j < d [i]  then
          C[i, j]  ←  ∞
    else if i == 1 then
          C[i, j]  ← 1 + C[1, j – d[1])
    else if j < d [i]  then
          C[i, j]  ←  C[I – 1, j]
    else
          C[i, j]  ← min (C[i – 1, j] ,1 + C[i, j – d[i])
    end
  end
end
return C[n, N]

Algorithm TRACE_MAKE_A_CHANGE(C)
// When table C is filled up, i = n and j = N

Solution = { }
while ( j > 0 ) do
  if (C[i, j] == C[i – 1, j] then
    i ← i – 1
  else
    j ← j – di
    Solution = Solution ∪  {d[i] }
  end
end
```

Complexity:

Best Case Time Complexity: O(n)

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Code:

```
// Coin Change Problem
#include <stdio.h>
#define MAX 20

int i, j, coins[MAX], result[MAX][MAX]={0}, num, amount, temp=0, temp1=0,
temp2=0, reqd_coins[MAX];
// Sorting function to sort the coins in ascending order before use
void sort()
{
    for(i=1;i<=num;i++)
    {
        for(j=1;j<=num-i;j++)
        {
            if(coins[j] > coins[j + 1])
            {
                temp = coins[j];
                coins[j] = coins[j + 1];
                coins[j + 1] = temp;
            }
        }
    }
}
// Get the required input
void getInput()
{
    // Enter the number of coins
    printf("Enter the number of denominations: ");
    scanf("%d", &num);
    for (i=1;i<=num;i++)
    {
        printf("Enter coin: ");
        scanf("%d", &coins[i]);
    }
    // Sort the coins in ascending order
    sort();
    printf("Coin Denomination: ");
    for (i=1;i<=num;i++)
        printf("%d ", coins[i]);
    // Ask for change amount
    printf("\nEnter the amount for change: ");
    scanf("%d", &amount);
}
```

```
void coinChange()
{
    // Outer loop for number of coins
    for(i=0;i<=num;i++)
    {
        // Inner loop for the amount
        for(j=0;j<=amount;j++)
        {
            // either i = 0 or j = 0 --> result = 0
            if(i==0 || j==0)
            {
                result[i][j] = 0;
            }
            // Check second formula
            else if(j < coins[i])
            {
                result[i][j] = result[i-1][j];
            }
            // Check first formula
            else if((i==1) || (i==j))
            {
                result[i][j] = 1 + result[i][j-coins[i]];
            }
            // Otherwise
            else
            {
                temp1 = result[i-1][j];
                temp2 = 1 + result[i][j-coins[i]];
                if(temp1 < temp2)
                {
                    result[i][j] = temp1;
                }
                else
                {
                    result[i][j] = temp2;
                }
            }
        }
    }
}

void display()
{
    printf("\n");
    printf("\tj-> ");
```

```
    // printf("\t  ");
    for(j=0;j<=amount;j++)
    {
        printf("%d\t", j);
    }
    printf("\n");
    for(i=0;i<=num;i++)
    {
        printf("di=%d\ti=%d ", coins[i], i);
        for(j=0;j<=amount;j++)
        {
            printf("%d\t", result[i][j]);
        }
        printf("\n");
    }
    printf("Number of coins required is %d", result[num][amount]);
    temp=num;
    for(i=0;i<=temp;i++)
    {
        if(amount!=0)
        {
            if(result[num][amount] != result[num-1][amount])
            {

                reqd_coins[i] = coins[num];
                amount -= coins[num];
            }
            else
                num--;
        }
        else
        {
            printf("\nCoins are { ");
            for(i=0;i<=temp;i++)
            {
                if(reqd_coins[i] != 0)
                    printf("%d ", reqd_coins[i]);
            }
            printf("}");
        }
    }
    // for(i=0;i<result[num][amount];i++)
    //     printf("\nCoins required: %d", reqd_coins[i]);
}
```

```
void main()
{
    getInput();
    coinChange();
    display();
}
```

Output:

```
Enter the number of denominations: 3
Enter coin: 1
Enter coin: 4
Enter coin: 6
Coin Denomination: 1 4 6
Enter the amount for change: 8

        j-> 0   1       2       3       4       5       6       7       8
di=0    i=0 0   0       0       0       0       0       0       0       0
di=1    i=1 0   1       2       3       4       5       6       7       8
di=4    i=2 0   1       2       3       1       2       3       4       2
di=6    i=3 0   1       2       3       1       2       1       2       2
Number of coins required is 2
Coins are { 4 4 }
```