DES2

February 7, 2022

[10]:
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#for plotting graph we need to import library

import matplotlib.pyplot as plt
```

[11]:
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# helper functions
#hexadecimal to Binary

def hexTobin(s):
        mp = {'0' : "0000",
                '1' : "0001",
                '2' : "0010",
                '3' : "0011",
                '4' : "0100",
                '5' : "0101",
                '6' : "0110",
                '7' : "0111",
                '8' : "1000",
                '9' : "1001",
                'A' : "1010",
                'B' : "1011",
                'C' : "1100",
                'D' : "1101",
                'E' : "1110",
                'F' : "1111" }
        bin = ""
        for i in range(len(s)):
                bin = bin + mp[s[i]]
        return bin

#Binary to Hexadecimal
def binTohex(s):
        mp = {"0000" : '0',
                "0001" : '1',
                "0010" : '2',
                "0011" : '3',
                "0100" : '4',
                "0101" : '5',
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                "0110" : '6',
                "0111" : '7',
                "1000" : '8',
        "1001" : '9',
                "1010" : 'A',
                "1011" : 'B',
                "1100" : 'C',
                "1101" : 'D',
                "1110" : 'E',
                "1111" : 'F' }
        hex = ""
        for i in range(0,len(s),4):
                ch = ""
                ch = ch + s[i]
                ch = ch + s[i + 1]
                ch = ch + s[i + 2]
                ch = ch + s[i + 3]
                hex = hex + mp[ch]

        return hex


# Binary to decimal conversion
def binTodec(binary):

        binary1 = binary
        decimal, i, n = 0, 0, 0
        while(binary != 0):
                dec = binary % 10
                decimal = decimal + dec * pow(2, i)
                binary = binary//10
                i += 1
        return decimal

# Decimal to binary conversion
def decTobin(num):
        res = bin(num).replace("0b", "")
        if(len(res)%4 != 0):
                div = len(res) / 4
                div = int(div)
                counter =(4 * (div + 1)) - len(res)
                for i in range(0, counter):
                        res = '0' + res
        return res

# Permute function to rearrange the bits
def permute(k, arr, n):
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        permutation = ""
        for i in range(0, n):
                permutation = permutation + k[arr[i] - 1]
        return permutation

# shifting the bits towards left by nth shifts
def shift_left(k, nth_shifts):
        s = ""
        for i in range(nth_shifts):
                for j in range(1,len(k)):
                        s = s + k[j]
                s = s + k[0]
                k = s
                s = ""
        return k

# calculating xor of two strings of binary number a and b
def xor(a, b):
        ans = ""
        for i in range(len(a)):
                if a[i] == b[i]:
                        ans = ans + "0"
                else:
                        ans = ans + "1"
        return ans

# calculating hamming distance between two strings
def calculate_hamming_distance(str1,str2):
    count=0
    for i in range(len(str1)):
        if(str1[i]!=str2[i]):
            count+=1
    return count

# function to get roundkeys in binary and hexadecimal format for given key
def get_rkb_rk(key):

  # Key generation
  # --hex to binary
    key = hexTobin(key)
# --parity bit drop table
    keyp = [57, 49, 41, 33, 25, 17, 9,
          1, 58, 50, 42, 34, 26, 18,
          10, 2, 59, 51, 43, 35, 27,
          19, 11, 3, 60, 52, 44, 36,
          63, 55, 47, 39, 31, 23, 15,
          7, 62, 54, 46, 38, 30, 22,
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        14, 6, 61, 53, 45, 37, 29,
        21, 13, 5, 28, 20, 12, 4 ]

  # getting 56 bit key from 64 bit using the parity bits
    key = permute(key, keyp, 56)

  # Number of bit shifts
    shift_table = [1, 1, 2, 2,
                   2, 2, 2, 2,
                   1, 2, 2, 2,
                   2, 2, 2, 1 ]

  # Key- Compression Table : Compression of key from 56 bits to 48 bits
    key_comp = [14, 17, 11, 24, 1, 5,
                3, 28, 15, 6, 21, 10,
                23, 19, 12, 4, 26, 8,
                16, 7, 27, 20, 13, 2,
                41, 52, 31, 37, 47, 55,
                30, 40, 51, 45, 33, 48,
                44, 49, 39, 56, 34, 53,
                46, 42, 50, 36, 29, 32 ]

  # Splitting
    left = key[0:28]    # rkb for RoundKeys in binary
    right = key[28:56]  # rk for RoundKeys in hexadecimal
    rkb = []
    rk  = []
    for i in range(0, 16):
        # Shifting the bits by nth shifts by checking from shift table
        left = shift_left(left, shift_table[i])
        right = shift_left(right, shift_table[i])

        # Combination of left and right string
        combine_str = left + right

        # Compression of key from 56 to 48 bits
        round_key = permute(combine_str, key_comp, 48)

        rkb.append(round_key)
        rk.append(binTohex(round_key))
    return rkb,rk
```

[12]:
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# Tables
# Table of Position of 64 bits at initial level: Initial Permutation Table
initial_perm = [58, 50, 42, 34, 26, 18, 10, 2,
```

```
                                60, 52, 44, 36, 28, 20, 12, 4,
                                62, 54, 46, 38, 30, 22, 14, 6,
                                64, 56, 48, 40, 32, 24, 16, 8,
                                57, 49, 41, 33, 25, 17, 9, 1,
                                59, 51, 43, 35, 27, 19, 11, 3,
                                61, 53, 45, 37, 29, 21, 13, 5,
                                63, 55, 47, 39, 31, 23, 15, 7]

# Expansion D-box Table
exp_d = [32, 1 , 2 , 3 , 4 , 5 , 4 , 5,
                6 , 7 , 8 , 9 , 8 , 9 , 10, 11,
                12, 13, 12, 13, 14, 15, 16, 17,
                16, 17, 18, 19, 20, 21, 20, 21,
                22, 23, 24, 25, 24, 25, 26, 27,
                28, 29, 28, 29, 30, 31, 32, 1 ]

# Straight Permutation Table
per = [ 16, 7, 20, 21,
                29, 12, 28, 17,
                1, 15, 23, 26,
                5, 18, 31, 10,
                2, 8, 24, 14,
                32, 27, 3, 9,
                19, 13, 30, 6,
                22, 11, 4, 25 ]

# S-box Table
sbox = [[[14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5, 9, 0, 7],
                [ 0, 15, 7, 4, 14, 2, 13, 1, 10, 6, 12, 11, 9, 5, 3, 8],
                [ 4, 1, 14, 8, 13, 6, 2, 11, 15, 12, 9, 7, 3, 10, 5, 0],
                [15, 12, 8, 2, 4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13 ]],

                [[15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12, 0, 5, 10],
                        [3, 13, 4, 7, 15, 2, 8, 14, 12, 0, 1, 10, 6, 9, 11, 5],
                        [0, 14, 7, 11, 10, 4, 13, 1, 5, 8, 12, 6, 9, 3, 2, 15],
                [13, 8, 10, 1, 3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9 ]],

                [ [10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12, 7, 11, 4, 2, 8],
                [13, 7, 0, 9, 3, 4, 6, 10, 2, 8, 5, 14, 12, 11, 15, 1],
                [13, 6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12, 5, 10, 14, 7],
                        [1, 10, 13, 0, 6, 9, 8, 7, 4, 15, 14, 3, 11, 5, 2, 12␣
 ↪]],

                [ [7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11, 12, 4, 15],
                [13, 8, 11, 5, 6, 15, 0, 3, 4, 7, 2, 12, 1, 10, 14, 9],
                [10, 6, 9, 0, 12, 11, 7, 13, 15, 1, 3, 14, 5, 2, 8, 4],
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                        [3, 15, 0, 6, 10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14]␣
↪],

                [ [2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13, 0, 14, 9],
                [14, 11, 2, 12, 4, 7, 13, 1, 5, 0, 15, 10, 3, 9, 8, 6],
                        [4, 2, 1, 11, 10, 13, 7, 8, 15, 9, 12, 5, 6, 3, 0, 14],
                [11, 8, 12, 7, 1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3 ]],

                [ [12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14, 7, 5, 11],
                [10, 15, 4, 2, 7, 12, 9, 5, 6, 1, 13, 14, 0, 11, 3, 8],
                        [9, 14, 15, 5, 2, 8, 12, 3, 7, 0, 4, 10, 1, 13, 11, 6],
                        [4, 3, 2, 12, 9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13]␣
↪],

                [ [4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5, 10, 6, 1],
                [13, 0, 11, 7, 4, 9, 1, 10, 14, 3, 5, 12, 2, 15, 8, 6],
                        [1, 4, 11, 13, 12, 3, 7, 14, 10, 15, 6, 8, 0, 5, 9, 2],
                        [6, 11, 13, 8, 1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12]␣
↪],

                [ [13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5, 0, 12, 7],
                        [1, 15, 13, 8, 10, 3, 7, 4, 12, 5, 6, 11, 0, 14, 9, 2],
                        [7, 11, 4, 1, 9, 12, 14, 2, 0, 6, 10, 13, 15, 3, 5, 8],
                        [2, 1, 14, 7, 4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11]␣
↪] ]



# Final Permutation Table
final_perm = [ 40, 8, 48, 16, 56, 24, 64, 32,
                        39, 7, 47, 15, 55, 23, 63, 31,
                        38, 6, 46, 14, 54, 22, 62, 30,
                        37, 5, 45, 13, 53, 21, 61, 29,
                        36, 4, 44, 12, 52, 20, 60, 28,
                        35, 3, 43, 11, 51, 19, 59, 27,
                        34, 2, 42, 10, 50, 18, 58, 26,
                        33, 1, 41, 9, 49, 17, 57, 25 ]
```

[13]:

```
# Encryption Function

def encrypt(pt, rkb, rk):
    ciphers=[]
    pt = hexTobin(pt)

    # Initial Permutation
    pt = permute(pt, initial_perm, 64)
    # print("After initial permutation", bin2hex(pt))
```

```
    # Splitting
    left = pt[0:32]
    right = pt[32:64]
    for i in range(0, 16):
        #  Expansion D-box: Expanding the 32 bits data into 48 bits
        right_expanded = permute(right, exp_d, 48)

        # XOR RoundKey[i] and right_expanded
        xor_x = xor(right_expanded, rkb[i])

        # S-boxex: substituting the value from s-box table by calculating row␣
↪and column
        sbox_str = ""
        for j in range(0, 8):
            row = binTodec(int(xor_x[j * 6] + xor_x[j * 6 + 5]))
            col = binTodec(int(xor_x[j * 6 + 1] + xor_x[j * 6 + 2] + xor_x[j *␣
↪6 + 3] + xor_x[j * 6 + 4]))
            val = sbox[j][row][col]
            sbox_str = sbox_str + decTobin(val)

        # Straight D-box: After substituting rearranging the bits
        sbox_str = permute(sbox_str, per, 32)

        # XOR left and sbox_str
        result = xor(left, sbox_str)
        left = result

        # Swapper
        if(i != 15):
            left, right = right, left
        # print("Round ", i + 1, " ", bin2hex(left), " ", bin2hex(right), " ",␣
↪rk[i])
        ciphers.append(left+right)

    # Combination
    combine = left + right

    cipher_text = permute(combine, final_perm, 64)
    return [cipher_text,ciphers]
```

[14]:

```
key = "AABB09182736CCDD"   # 64 bit key
plaintexts =␣
↪['123456ABCD132566','623456ABCD132536','123452ABCD132536','123456ABCF132536','123456ABED132
↪ # list of 5 different plaintexts
parent_plaintext ='123456ABCD132536' # to get parent cipher for calculating␣
↪hamming distance from
```

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rkb, rk = get_rkb_rk(key)

# getting ciphertext from parent plaintext
_, parent_ciphers= encrypt(parent_plaintext, rkb, rk)

# storing cipher texts from list of plaintexts in matrix
matrix=[]
for pt in plaintexts:
  _ , ciphers = encrypt(pt, rkb, rk)
  #print(len(ciphers))
  matrix.append(ciphers)

#print("****************************")
matrix =[[row[i] for row in matrix] for i in range(len(matrix[0]))]
#print(matrix)
#print(len(matrix),len(matrix[0]))


hamming_distances=[]
for i in range(16):
  temp=[]
  for j in range(5):
    hd=calculate_hamming_distance(matrix[i][j] , parent_ciphers[i])
    temp.append(hd)
  hamming_distances.append(temp)
#print(hamming_distances)

mean_hamming_distances=[]
for i in hamming_distances:
  mean_hamming_distances.append(sum(i)/len(i))

plt.plot(mean_hamming_distances)
plt.title('Avalanche Effect on DES Rounds (i) For 5 different plaintexts')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(1,50)
plt.show()
```
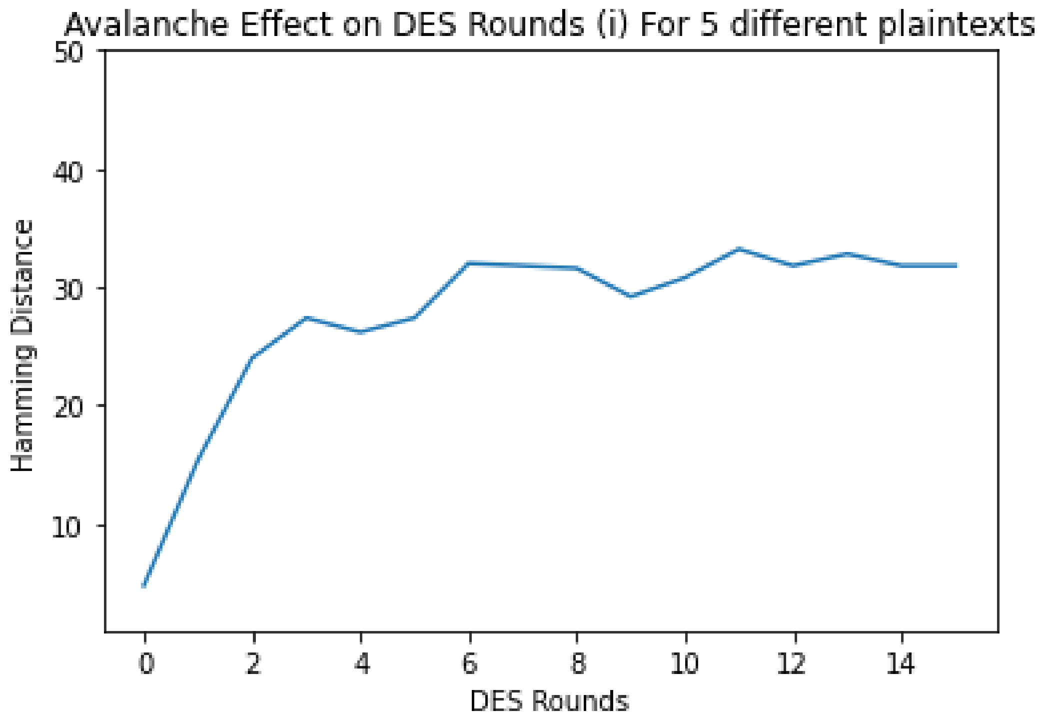
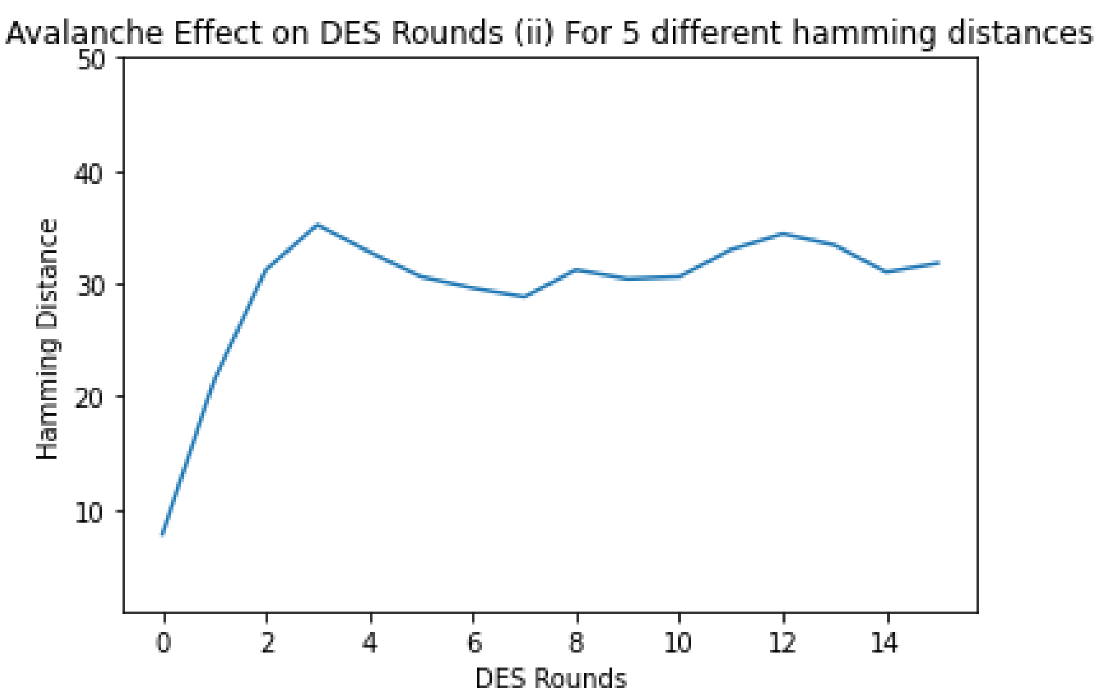
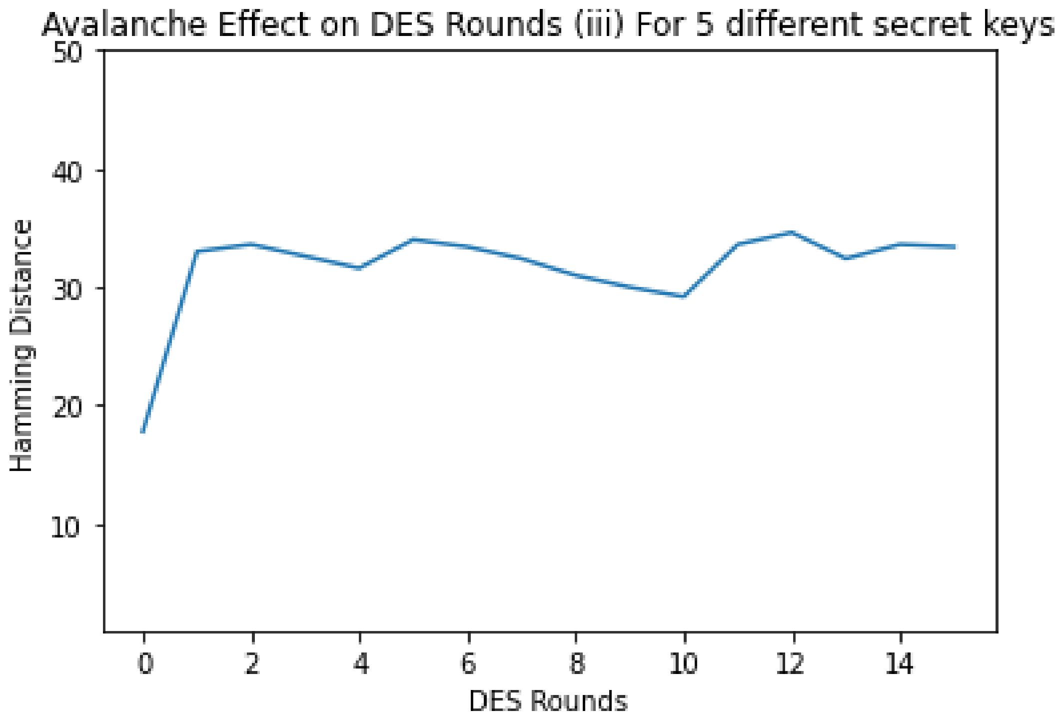



[21]:
```
# the plaintext lists here has different hamming distances from the parent plaintext
key = "AABB09182736CCDD"    # 64 bit key
parent_plaintext ='123456ABCD132536' # to get parent cipher for calculating hamming distance from
plaintexts = ['123456ABCD132566','423456EBCD132536','123452ACDD132536','123156ABCF133636','523456ABEF136
 # list of plaintexts with 5 different hamming distance
# HD            1                    2                   3                  4
                5
rkb, rk = get_rkb_rk(key)

# getting ciphertext from parent plaintext
_, parent_ciphers= encrypt(parent_plaintext, rkb, rk)

# storing cipher texts from list of plaintexts in matrix
matrix=[]
for pt in plaintexts:
  _ , ciphers = encrypt(pt, rkb, rk)
  #print(len(ciphers))
  matrix.append(ciphers)

#print("***************************")
```

```
matrix =[[row[i] for row in matrix] for i in range(len(matrix[0]))]
#print(matrix)
#print(len(matrix),len(matrix[0]))


hamming_distances=[]
for i in range(16):
  temp=[]
  for j in range(5):
    hd=calculate_hamming_distance(matrix[i][j] , parent_ciphers[i])
    temp.append(hd)
  hamming_distances.append(temp)
#print(hamming_distances)

mean_hamming_distances=[]
for i in hamming_distances:
  mean_hamming_distances.append(sum(i)/len(i))

plt.plot(mean_hamming_distances)
plt.title('Avalanche Effect on DES Rounds (ii) For 5 different hamming␣
↪distances')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(1,50)
plt.show()
```



```
[22]: par_key = "AABB09182736CCDD"    # 64 bit key
plaintext ='123456ABCD132536'
keys =␣
 ↪["FCD09288746CCEAE","EEBC09188436CCEE","CEAC19188736CCEE","ABBD19128736DCEE","CDBC19188738C
 ↪# five different secret keys

matrix = []
for k in keys:
  rkb, rk = get_rkb_rk(k)
  _, ciphers = encrypt(plaintext, rkb, rk)
  matrix.append(ciphers)

#print("****************************")
matrix =[[row[i] for row in matrix] for i in range(len(matrix[0]))]
#print(matrix)
#print(len(matrix),len(matrix[0]))

rkb, rk = get_rkb_rk(par_key)
_, parent_ciphers= encrypt(plaintext, rkb, rk)

hamming_distances=[]
for i in range(16):
  temp=[]
  for j in range(5):
    hd=calculate_hamming_distance(matrix[i][j] , parent_ciphers[i])
    temp.append(hd)
  hamming_distances.append(temp)
#print(hamming_distances)

mean_hamming_distances=[]
for i in hamming_distances:
  mean_hamming_distances.append(sum(i)/len(i))

plt.plot(mean_hamming_distances)
plt.title('Avalanche Effect on DES Rounds (iii) For 5 different secret keys')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(1,50)
plt.show()
```


Avalanche Effect on DES Rounds (iii) For 5 different secret keys
Hamming Distance
DES Rounds
50
40
30
20
10
0
2
4
6
8
10
12
14

[ ]: