Assignment 2

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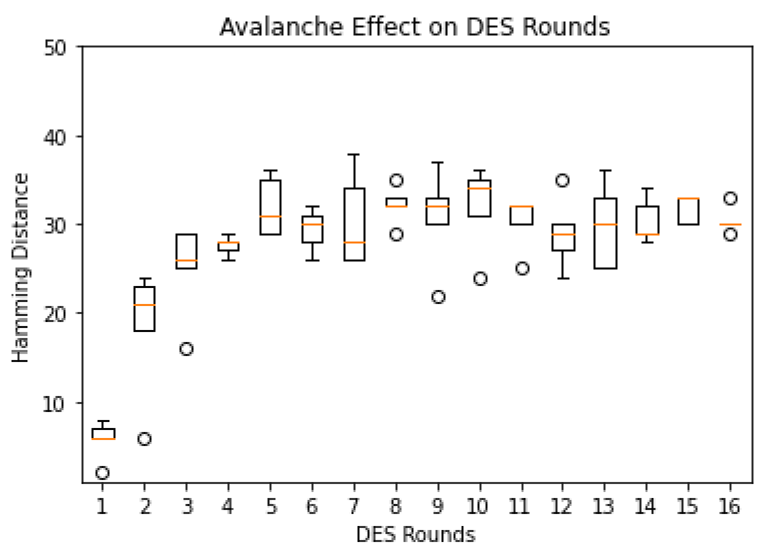
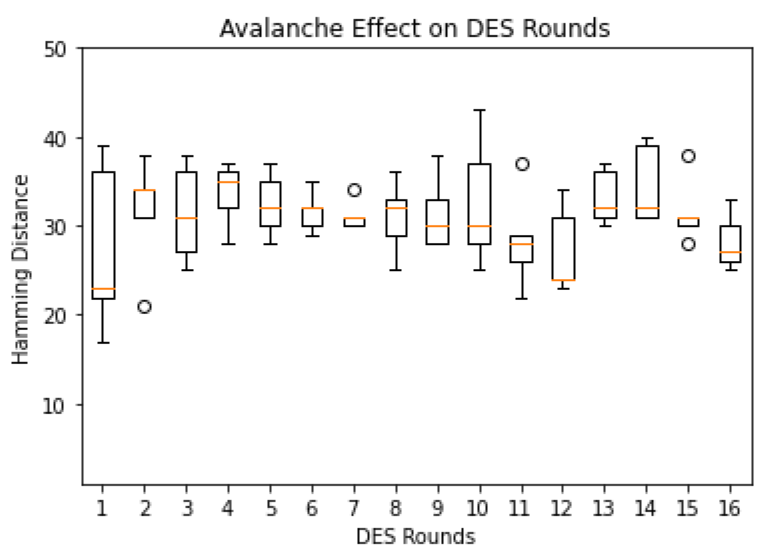
Screenshots

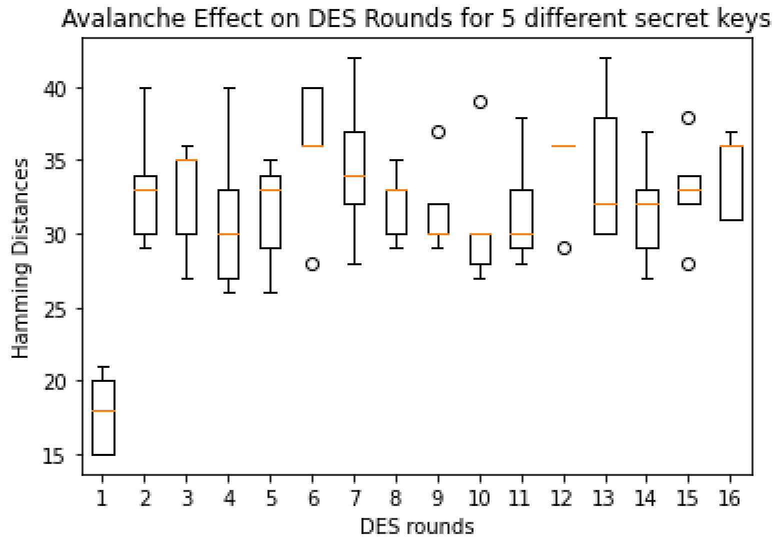
1.



2.



3.


Avalanche Effect on DES Rounds for 5 different secret keys
Hamming Distances
40
35
30
25
20
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
DES rounds

Source Code

```
import matplotlib.pyplot as plt
def hex2bin(hexdecnum):
  binnum = ""
  for i in range(len(hexdecnum)):
    if hexdecnum[i] == '0':
      binnum = binnum + "0000"
    elif hexdecnum[i] == '1':
      binnum = binnum + "0001"
    elif hexdecnum[i] == '2':
      binnum = binnum + "0010"
    elif hexdecnum[i] == '3':
      binnum = binnum + "0011"
    elif hexdecnum[i] == '4':
      binnum = binnum + "0100"
    elif hexdecnum[i] == '5':
      binnum = binnum + "0101"
    elif hexdecnum[i] == '6':
      binnum = binnum + "0110"
    elif hexdecnum[i] == '7':
      binnum = binnum + "0111"
    elif hexdecnum[i] == '8':
      binnum = binnum + "1000"
    elif hexdecnum[i] == '9':
      binnum = binnum + "1001"
    elif hexdecnum[i] == 'a' or hexdecnum[i] == 'A':
      binnum = binnum + "1010"
    elif hexdecnum[i] == 'b' or hexdecnum[i] == 'B':
      binnum = binnum + "1011"
    elif hexdecnum[i] == 'c' or hexdecnum[i] == 'C':
      binnum = binnum + "1100"
    elif hexdecnum[i] == 'd' or hexdecnum[i] == 'D':
      binnum = binnum + "1101"
    elif hexdecnum[i] == 'e' or hexdecnum[i] == 'E':
      binnum = binnum + "1110"
    elif hexdecnum[i] == 'f' or hexdecnum[i] == 'F':
      binnum = binnum + "1111"
  return binnum
```

```python
def bin2hex(s):
  a = int(s,2)
  h = hex(a)

  return h[2:].upper()


# Binary to decimal conversion
def bin2dec(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 dec2bin(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):
  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 xow 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

# 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],
      [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 ]




def encrypt(pt, rkb, rk):
    ciphers=[]
    pt = hex2bin(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 = bin2dec(int(xor_x[j * 6] + xor_x[j * 6 + 5]))
            col = bin2dec(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 + dec2bin(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]

pt0='123456ABCD123436'
pt=['123456ABCD123456','323456ABCD123436','123453ABCD123436','123456ABCA12
3436','123456CBCD123436','123456AECD123436']
key = "AABB09182736CCDD"

key = hex2bin(key)

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,
    14, 6, 61, 53, 45, 37, 29,
    21, 13, 5, 28, 20, 12, 4 ]

key = permute(key, keyp, 56)

shift_table = [1, 1, 2, 2,
        2, 2, 2, 2,
        1, 2, 2, 2,
        2, 2, 2, 1 ]

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 ]


left = key[0:28]
right = key[28:56]

rkb = []
rk = []
for i in range(0, 16):
  left = shift_left(left, shift_table[i])
  right = shift_left(right, shift_table[i])
  combine_str = left + right
  round_key = permute(combine_str, key_comp, 48)

  rkb.append(round_key)
  rk.append(bin2hex(round_key))

_, parent_ciphers= encrypt(pt0, rkb, rk)
matrix=[]
for i in range(5):
  _ , ciphers = encrypt(pt[i], rkb, rk)
  matrix.append(ciphers)
```

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

hamming_distances=[]

def calculate_hamming_distance(str1,str2):
  count=0
  for i in range(len(str1)):
    if(str1[i]!=str2[i]):
      count+=1
  return count


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.boxplot(hamming_distances)
plt.title('Avalanche Effect on DES Rounds')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(1,50)
plt.show()
plt.show()


pt0='123456ABCD123436'
pt=['ABD3C28591234758','ABCD123456789DCB','614453ABCD232536','729456ABCA93
2531','924456CBCD138536','923456AECD132537']
```

```python
key = "AABB09182736CCDD"

key = hex2bin(key)

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,
    14, 6, 61, 53, 45, 37, 29,
    21, 13, 5, 28, 20, 12, 4 ]

key = permute(key, keyp, 56)

shift_table = [1, 1, 2, 2,
        2, 2, 2, 2,
        1, 2, 2, 2,
        2, 2, 2, 1 ]

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 ]


left = key[0:28]
right = key[28:56]

rkb = []
rk = []
for i in range(0, 16):
  left = shift_left(left, shift_table[i])
  right = shift_left(right, shift_table[i])
  combine_str = left + right
  round_key = permute(combine_str, key_comp, 48)
```

```python
  rkb.append(round_key)
  rk.append(bin2hex(round_key))

_, parent_ciphers= encrypt(pt0, rkb, rk)
matrix=[]
for i in range(5):
  _ , ciphers = encrypt(pt[i], rkb, rk)
  matrix.append(ciphers)
matrix =[[row[i] for row in matrix] for i in range(len(matrix[0]))]
print(len(matrix),len(matrix[0]))
print(len(parent_ciphers))

hamming_distances=[]

def calculate_hamming_distance(str1,str2):
  count=0
  for i in range(len(str1)):
    if(str1[i]!=str2[i]):
      count+=1
  return count


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.boxplot(hamming_distances)
plt.title('Avalanche Effect on DES Rounds')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(1,50)
```

```python
plt.show()


def get_keys(key):

  # Key generation
  # --hex to binary
  key = hex2bin(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,
          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(bin2hex(round_key))
  return rkb,rk
par_key = "AABB09182736CCDD"   # 64 bit key
plaintext ='123456ABCD132536'
keys =
["ABCD123456789ABC","EEBC09188436CCEE","CEAC19188736CCEE","ABBD19128736DCE
E","CDBC19188738CCEE"] # five different secret keys

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

matrix =[[row[i] for row in matrix] for i in range(len(matrix[0]))]


rkb, rk = get_keys(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)

plt.boxplot(hamming_distances)
plt.xlabel('DES rounds')
plt.ylabel('Hamming Distances')
plt.title('Avalanche Effect on DES Rounds for 5 different secret keys')
plt.show()
```

Github link:

https://github.com/kavyanshgangwar/netsec_assignment2