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Experiment-7

Convolutional Encoding and Viterbi Decoding

Introduction:

In source coding the input data get compressed whereas in Channel coding the number of bits per symbol increases in order to add redundancy to a digital signal before transmission over a noisy channel, to increase the likelihood of error-free reception.

In this experiment we will be discussing about convolutional encoding and a decoding algorithm known as Viterbi decoding method to decode the channel code.

And we will be looking at 2 different kinds of channels Binary symmetric (BSC) and binary asymmetric channels for the propagation of our channel coded signal.

Key Objectives:

i. To Generate a convolutional code of rate 1/3 for the given input with generator polynomials a. g1= [1 1 0] b. g2= [1 1 1] c. g3= [1 0 1].

ii. To design a Viterbi decoding algorithm, then proceed with the Trellis design followed by the path optimization for Viterbi decoding.

iii. Use a binary symmetric channel with a crossover probability p to perturb the codeword, consider at least 5 different values of p (low to high, between 0 to 1/2) in this experiment and determine the recovered or estimated message.

iv. Plot the bit error rate (fraction of bits is error in the data block) as a function of channel crossover probability p.

v. To do the same using a Binary asymmetric channel.

Brief Theory:.

Main channel coding techniques includes:

a. Repetition method.

b. Hamming codes

c. convolutional codes.

i. Convolutional codes are a type of error-correcting codes used in digital communication systems to detect and correct errors that occur during data transmission. Unlike hamming codes these are not block codes.

ii. Since they can be expressed as a convolution of input data and generator polynomial, they are called as convolutional codes.

iii. The encoder takes in a stream of input bits and produces a corresponding stream of output bits using the linear operation (XOR) defined by the generator polynomial.

iv. In our experiment, rate is given as 1/3 which means for every input bit three output bits get generated.

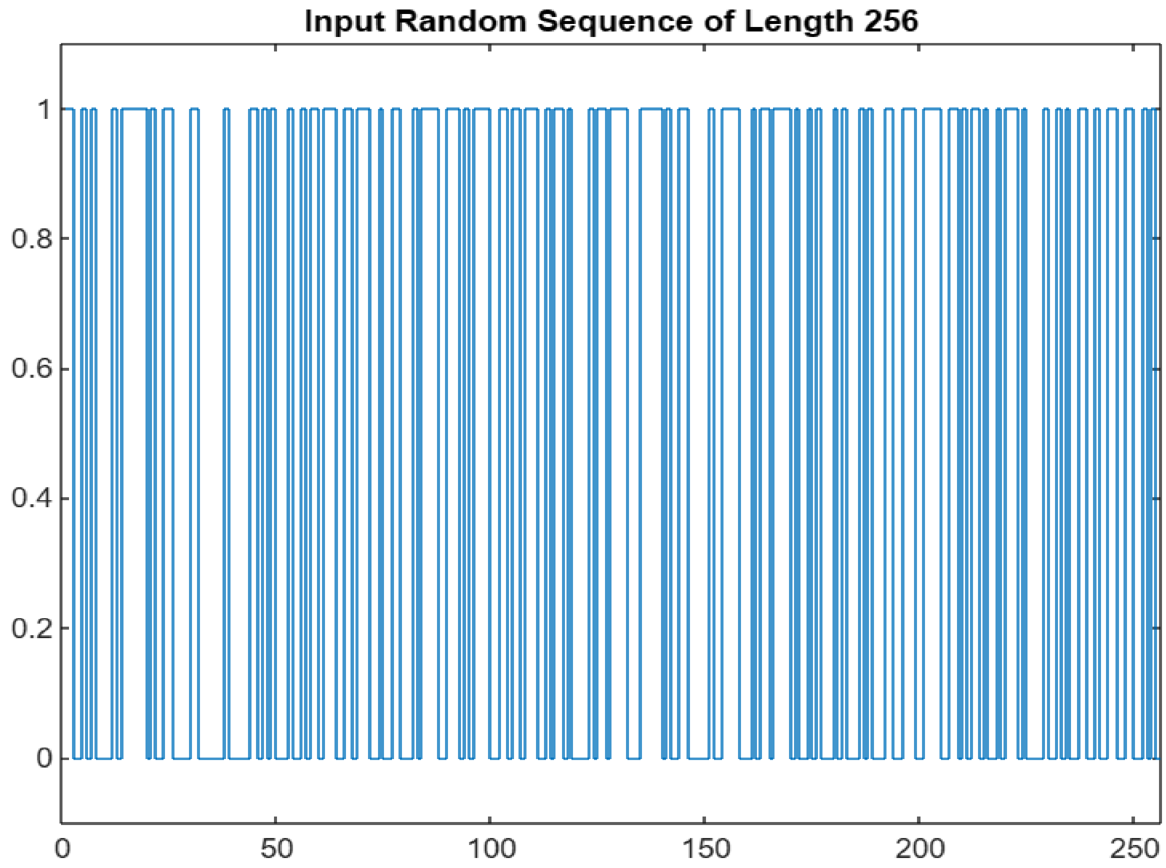
v. For the convolutional code, Viterbi's decoding is an instance of maximum likelihood decoding, if errors are detected, the decoder corrects them by applying the inverse of the convolutional code to the received data.

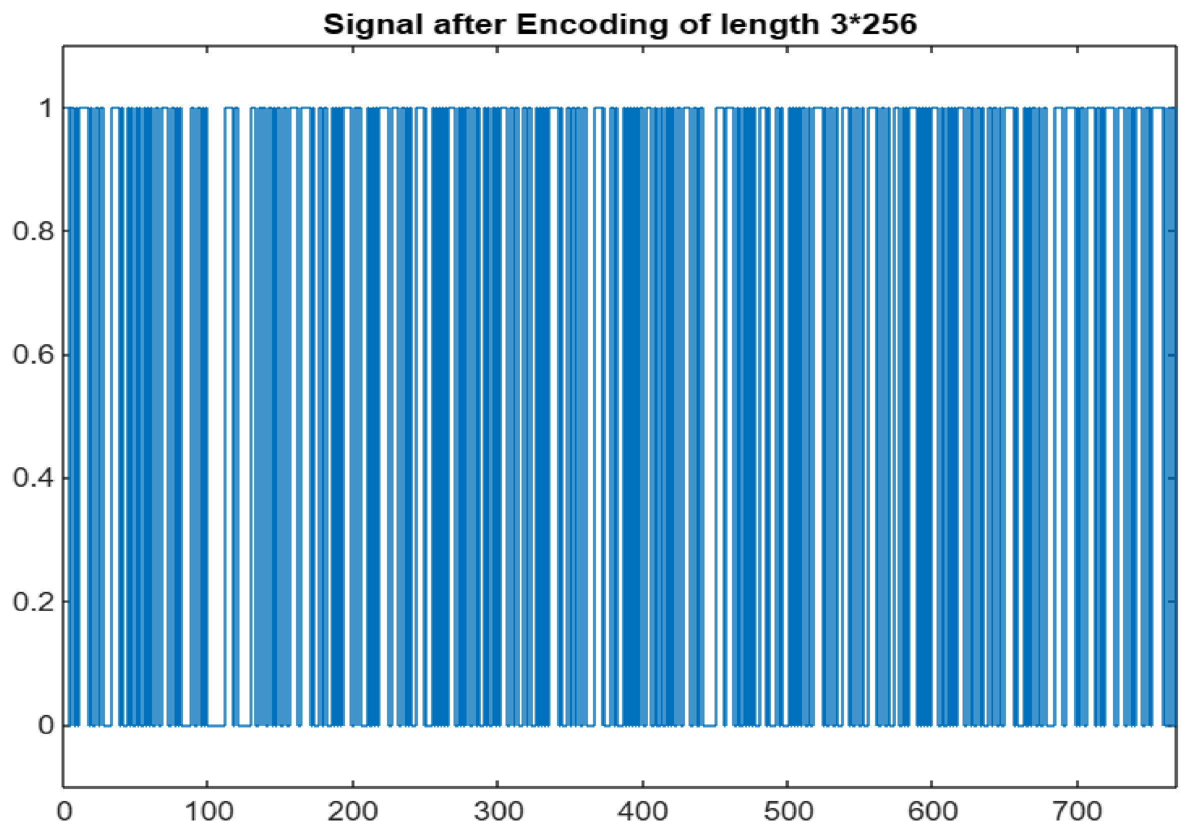
vi. Finally, after decoding the received signal from the channel, we XOR the set of 3 received bits, to get out estimated input signal.

vii. Dynamic programming is the key idea behind Viterbi's algorithm for decoding convolutional codes to efficiently compute the most likely sequence of states in a bottom-up fashion.

viii. And then to perform a traceback operation to determine the most likely sequence of input bits that could have generated the observed output sequence.

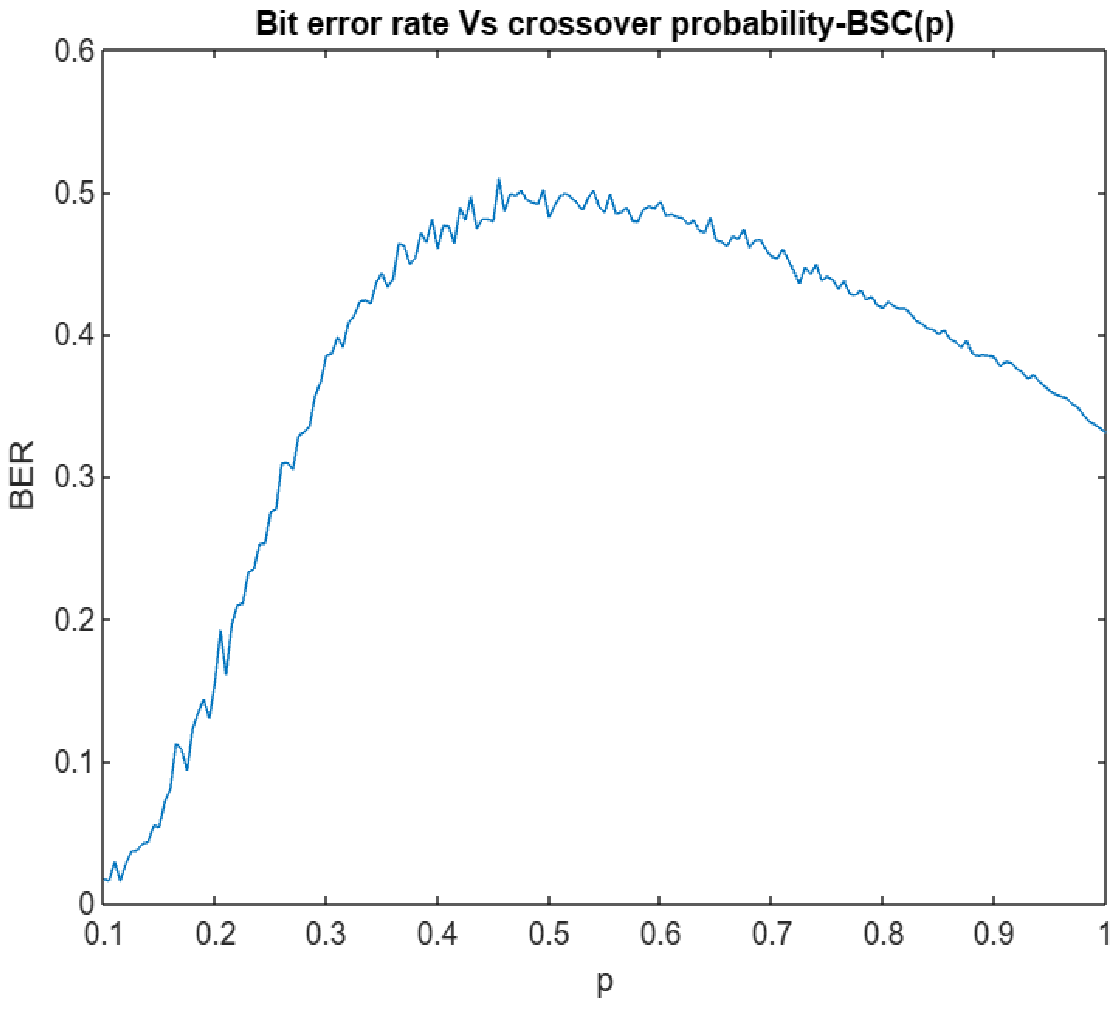
Results:


Input Random Sequence of Length 256
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250


Signal after Encoding of length 3*256
1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
700

• **Binary symmetric channel (BSC):** In a BSC, each transmitted bit may be flipped (or inverted) with a certain probability during transmission. This probability of a bit being flipped is typically denoted by p, and is assumed to be the same for all bits transmitted over the channel.

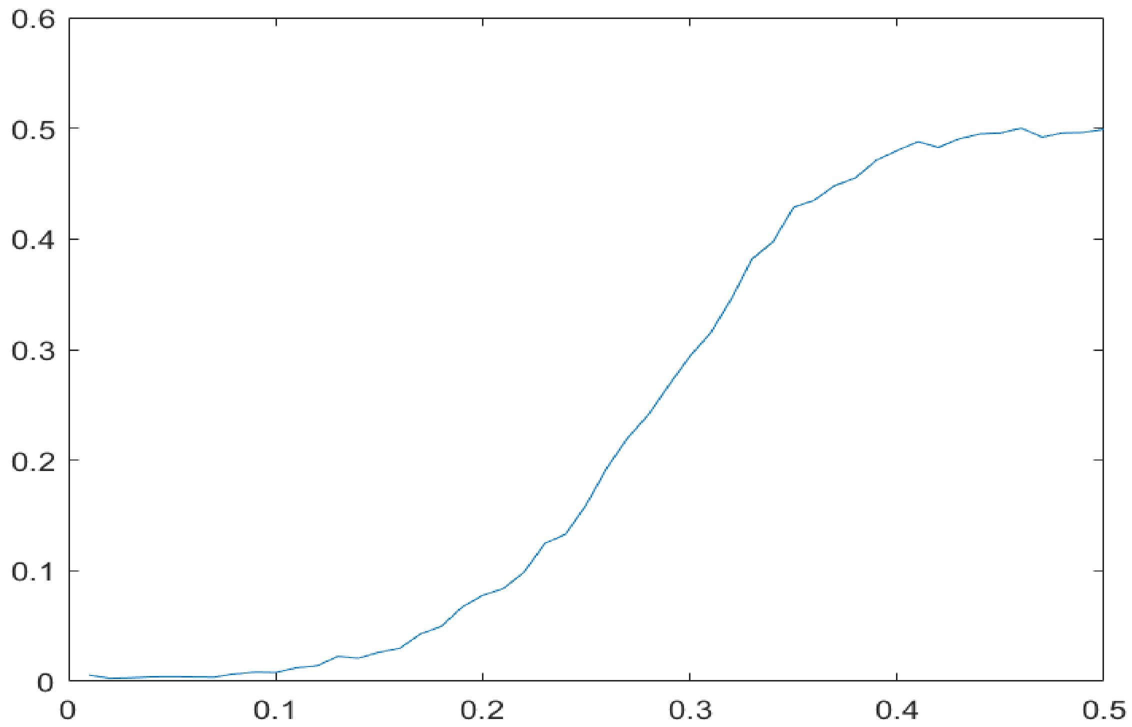
BER vs cross over probability(p) of Binary Symmetric Channel



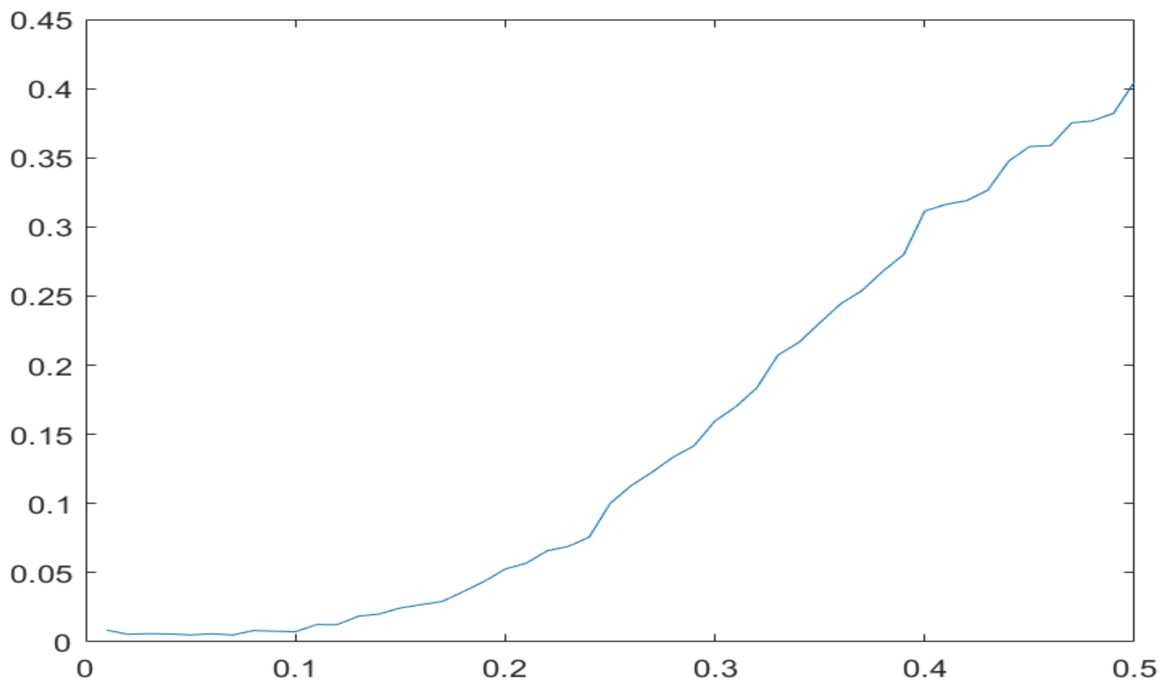
• **Binary Asymmetric channel (BAC):** The probability of a bit being flipped during transmission is not necessarily the same for all bits. In other words, the channel may introduce errors with different probabilities for the two possible bit values (0 and 1).

BER vs cross over probability of Binary Asymmetric Channel:

When 0 to 1 flip probability is fixed at 0.1, and 1 to 0 flip probability varied from 0.01 to 0.5:



When 1 to 0 flip probability is fixed at 0.1, and 0 to 1 flip probability is varied from 0.01 to 0.5:



Discussion:

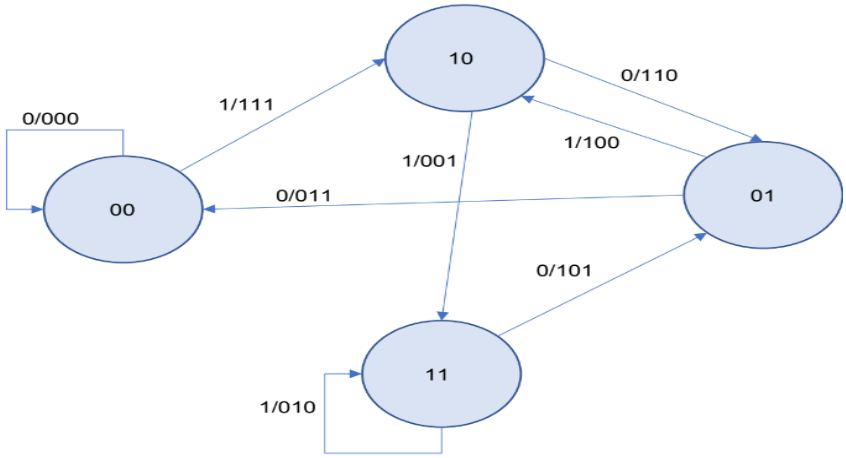
1.They are "convolutional" because the encoding process can be represented as convolution between the input message and a finite impulse response (FIR) filter.

$$c = \sum_{j=0}^{L} g_j . m_{L-j}$$

2. Convolutional codes are characterized by several parameters, such as code rate, constraint length, generator polynomials, and Bit error rate.

3.The fraction of bits in the decoded data not matching with with original data is called Bit Error rate.

4. From the BER vs crossover probability(p) plot, as the p increases to 0.5 the BER increases and then decreases for Binary Symmetric Channel. So the channel is not at all good at peak i.e 0.5



5.From the above state transition diagram, trellis diagram is drawn. And using the Viterbi algorithm we trace back the path to correct the error

6. This algorithm follows the most likelihood decoding giving optimal algorithm to have a uniquely decoded bits sequence

7. For BSC ; the metric is to maximise

$$\max_{X} P_{Y|X}(\overline{y}|\overline{x})$$

Where x' input vector, y'-received vector

8. So, to maximize this expression we need to minimize d when $p \leq 0.5$. and when $p > 0.5$, we simply interchange 0 and 1 in the received signal (y). Here d is nothing but Hamming distance .

So, for a BSC channel Hamming distance is our metric.

9. For a BAC channel, in which the cross over probability are different for 0 to 1 (P01) and 1 to 0 (P10).

Here the objective remains the same as before, i.e.,

$$\max_{X} P_{Y|X}(\overline{y}|\overline{x})$$