Chapter 2

Trellis Diagram and the Viterbi Algorithm

Introduction

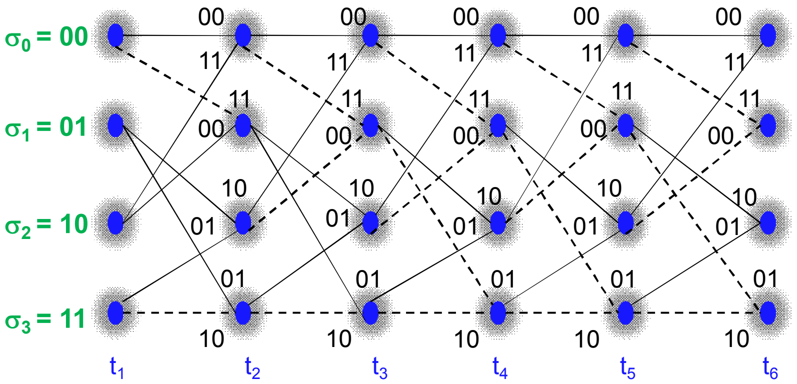
In principle the best way of decoding against random errors is to compare the received sequence with every possible code sequence.

This process is best envisaged using a code trellis which contains the information of the state diagram, but also uses time as a horizontal axis to show the possible paths through the states.

The corresponding output is written over the solid/dashed line

The transitions leaving a state are labelled with the corresponding output. While a solid line denotes an input bit, zero, and a dashed line denotes an input bit, one.

Trellis Diagram for our example

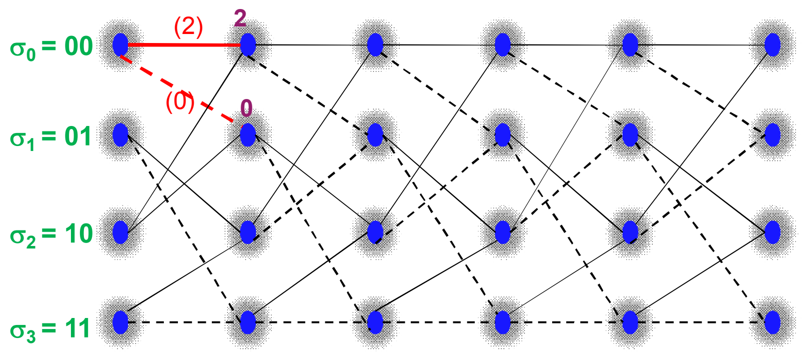


Viterbi Algorithm

- In this section we only consider terminated convolutional codes.
- We consider all the possible distances between the starting node to the final node
- When we consider these distance metrics we will probably find that one of the paths is better than all the others.
- The best way to discuss the algorithm is through an example
- Let us assume that we receive the sequence 11 10 10 01 11
- In the first stage we consider only starting from state 00

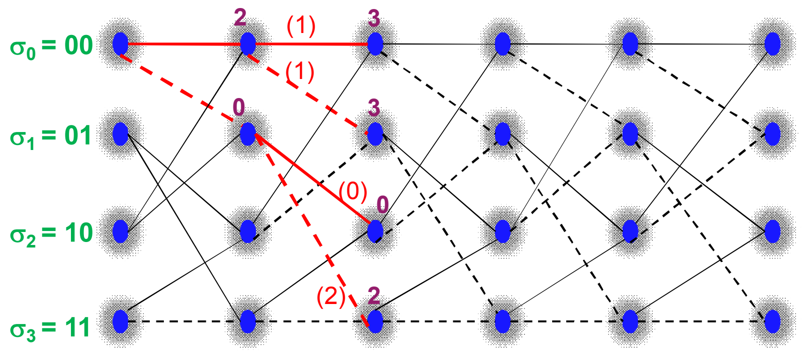
Viterbi Algorithm

The received code is 11 10 10 01 11. calculate the distances for the first time slot



Viterbi Algorithm

The received code is 11 10 10 01 11. calculate the distances for the second time slot



Viterbi Algorithm

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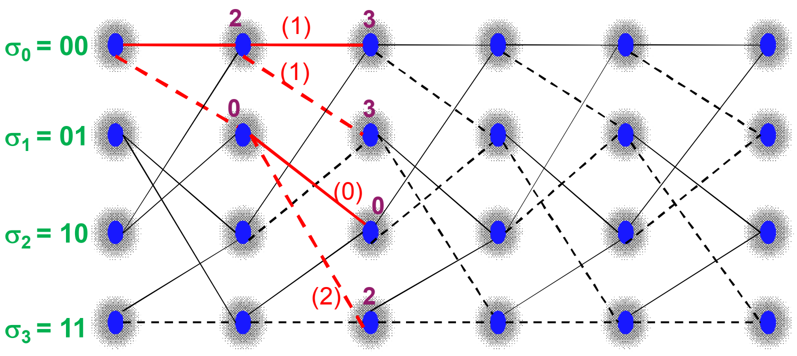

Viterbi Algorithm

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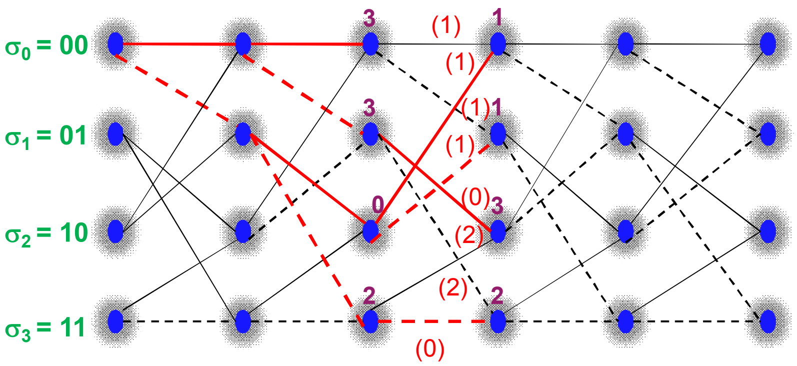

Viterbi Algorithm

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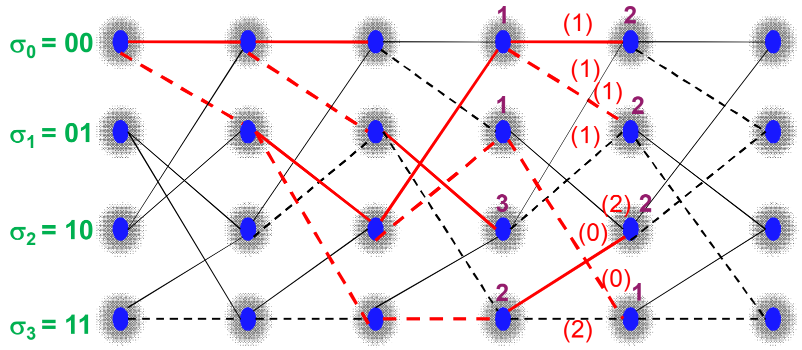

Viterbi Algorithm

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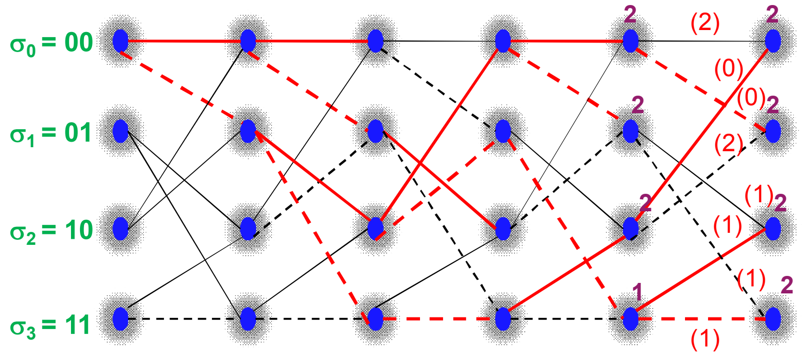

Soft Decoding using Viterbi

When we have continuous flow of information we use two set of registers

A set A associated with the start states at the beginning of the frame

A set B associated with the end states after the path extensions.

The extension of the path in A00 will be written in B00 and B01
The extension of the path in A01 will be written in B10 and B11
The extension of the path in A10 will be written in A00 and A01
The extension of the path in A11 will be written in A10 and A11

Both A and B register are compared to choose the better metric and the good path is written in register A.

Soft Decoding using Viterbi

If we use the soft metric -3.5, -2.5, -1.5. -0.5 , 0.5, 1.5, 2.5, 3.5

The received sequence is
+3.5 +1.5 +2.5 -3.5 +2.5 -3.5 -3.5 +3.5 +2.5 +3.5

We initialize the *A* register with the following

Location	Path	Metric
A00		0
A01		-64
A10		-64
A11		-64
B00		
B01		
B10		
B11		

Soft Decoding using Viterbi

In the first frame the received sequence is +3.5 +1.5

Location	Path	Metric
A00	0	-69
A01	1	-59
A10	0	-66
A11	1	-62
B00	0	-5
B01	1	+5
B10	0	-62
B11	1	-66

Soft Decoding using Viterbi

Now compare the pairs and write the highest into register A gives

Location	Path	Metric
A00	0	-5
A01	1	+5
A10	0	-62
A11	1	-62
B00		
B01		
B10		
B11		

Soft Decoding using Viterbi

In the 2ndframe the received sequence is +2.5 -3.5

Location	Path	Metric
A00	00	-63
A01	01	-61
A10	10	-68
A11	11	-56
B00	00	-4
B01	01	-6
B10	10	+11
B11	11	-1

Soft Decoding using Viterbi

Now compare the pairs and write the highest into register A gives

Location	Path	Metric
A00	00	-4
A01	01	-6
A10	10	+11
A11	11	-1
B00		
B01		
B10		
B11		

Soft Decoding using Viterbi

In the 3rd frame the received sequence is +2.5 -3.5

Location	Path	Metric
A00	100	+10
A01	101	+12
A10	110	-7
A11	111	+5
B00	000	-3
B01	001	-5
B10	010	0
B11	011	-12

Soft Decoding using Viterbi

Now compare the pairs and write the highest into register A gives

Location	Path	Metric
A00	100	+10
A01	101	+12
A10	010	0
A11	111	+5
B00		
B01		
B10		
B11		

Soft Decoding using Viterbi

In the 4th frame the received sequence is -3.5 +3.5

Location	Path	Metric
A00	0100	0
A01	0101	0
A10	1110	+12
A11	1111	-2
B00	1000	+10
B01	1001	+10
B10	1010	+5
B11	1011	+19

Soft Decoding using Viterbi

Now compare the pairs and write the highest into register A gives

Location	Path	Metric
A00	1000	+10
A01	1001	+10
A10	1110	+12
A11	1011	+19
B00		
B01		
B10		
B11		

Soft Decoding using Viterbi

In the 5th frame the received sequence is +2.5 +3.5

Location	Path	Metric
A00	11100	+18
A01	11101	+6
A10	10110	+20
A11	10111	+18
B00	10000	+4
B01	10001	+16
B10	10010	+9
B11	10011	+11

Soft Decoding using Viterbi

Now compare the pairs and write the highest into register A gives

Location	Path	Metric
A00	11100	+18
A01	10001	+16
A10	10110	+20
A11	10111	+18
B00		
B01		
B10		
B11		

Applications of Convolutional Codes

A Convolutional code has been used in satellite communiction. The main application is digital speech with convolutional code of rate ½ and k =7. the achieved BER is 10-5.

In GSM system the accepted error rate is 10^{-3}. convolutional code with rate k = ½ and K = 5. the generators are

$$g^{(1)}(D) = D^4 + D^3 + 1$$
$$g^{(0)}(D) = D^4 + D^3 + D + 1$$

In UMTS, IS-95, CDMA-2000 standards for mobile communication use a K = 9 convolutional codes. For rate = ½ generator polynomials are

$$g^{(0)}(D) = D^8 + D^4 + D^3 + D^2 + 1$$
$$g^{(1)}(D) = D^8 + D^7 + D^5 + D^3 + D^2 + D + 1$$