Channel Coding and Various Codes Used In Information Theory and Coding

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Abstract – Channel Coding is encoding information to be transmitted in the most efficient way. It is an important aspect in communication system. It also has to do with methods of detecting and correcting errors due to noise in the environment, so that the original message can be received faithfully and also in the most efficient way. To overcome the effect of noise, redundancy is added in the message resulting in code words.

Key Words: Channel Coding, Cyclic Codes, BOSE Choudhari Hocquenghem Codes

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SHANNON'S CHANNEL CODING THEORM

Shannon's Channel Coding theorm establishes the limit on the average code word length of a source of symbols in terms of entropy of the source. It states that the average code word length of a source of symbol can be greater than or equal to its entropy. It cannot be less than its entropy. i.e.

$$L(z) \geq H(z)$$

Here L(z) is the average code word length of the source

H(z) is the source entropy.

$$L(z) = \sum_{i=1}^{n} L(a_i)\, p(a_i)$$

$$H(z) = \sum_{i=1}^{n} p(a_i)\, Log(a_i)$$

$L(a_i)$ is the length of symbol a_i and $p(a_i)$ is probability of symbol a_i

CODING EFFICIENCY

Coding efficiency in channel encoding is the ratio of source entropy and average code word length.

$$\text{Coding efficiency} = \frac{H(z)}{L(z)}$$

$$= \frac{\sum_{i=1}^{n} p(a_i) Log(a_i)}{\sum_{i=1}^{n} L(a_i)\, p(a_i)}$$

Since according to shannon channel coding theorm, the average code word length of a source of symbol can be greater than or equal to its entropy The value of coding efficiency is between 0 and 1.

VARIOUS CODES USED IN INFORMATION THEORY AND CODING

Depending on the methods of adding redundancy we have various error detection and error correction codes used in information theory and coding as following.

1. Cyclic codes

2. BCH Codes

3. Gold Codes

4. Reid Solomon Codes

CYCLIC CODES

Cyclic codes are efficient error correcting and error detecting codes. They belong to the category of linear block codes with an extra property. If the code word of a cyclic code is cyclically shifted, the result is another code word. e.g. 1100111 is a valid code word. If we circularly shift the code word right by one bit such that LSB becomes MSB, the resultant word 1110011 will be another code word. Cyclic codes satisfy the following two properties.

a)   Linearity property

b)   Cyclic Shifting.

Cyclic codes are represented using Polynomials.

There are two types of cyclic codes

a)   Non Systematic

b)   Systematic

Non Systematic

A non-systematic code word is represented by $Y(x)=m(x)g(x)$ where m(x) is message polynomial and g(x) is generator Polynomial.

A systematic code word is represented by

$$Y(x) = x^{n-k} \cdot m(x) + P(x)$$

Where M(x) is message polynomial, n is block length, k is no. of message bits.

$$P(x) = Rem \ \frac{x^{n-k} \cdot m(x)}{g(x)}$$

BCH CODES

BCH stands for BOSE Choudhari Hocquenghem codes. These are cyclic error correcting codes capable of correcting multiple bit errors. These are very useful in computer science. They are powerful random error correcting codes with a low amount of redundancy. One advantage of these codes is that there is precise control over the no. of symbol errors correctable. The properties of BCH codes are:

In a t-error correcting BCH code,

Block Length $n = 2^m - 1$ where m is a positive integer greater than or equal to 3.

No. of Check bits= n-k , k is no. of message bits.

Hamming distance = 2t+13

They are constructed using polynomials. The generator polynomial of BCH code is given by

$$g(x) = LCM[m_1(x), m_2(x) \ldots \ldots m_{2t}(x)]$$

One advantage of BCH code is that block size is smallest for given message block of length k bits.

Also the block length and code rate are variable in case of BCH codes. That's why they are widely used.

GOLD CODES

Gold codes were invented by Dr. Robert Gold in 1967. Gold Codes are binary sequence widely used in communication system for regeneration of correct sequence. They are most commonly used in GPS and mobile phones. They can be easily generated with hardware and software. In GPs systems when multiple satellites transmit simultaneously, receiver can select the signals from individual satellite because each has a unique gold code,

They are based on either X-OR gate or Shift Registers.

REID – SOLOMON CODES

These are non-binary BCH codes. They are block based error correcting codes. They operate on symbols rather than bits.

A t-error correcting Reid Solomon code has following properties.

Block Length $= n = 2^m - 1$ symbols where m is no. of bits in symbol.

Message Length = k symbols.

Parity size = n-k

Minimum Hamming distance= 2t+1.

Reid Solomon codes are used in storage in CDs, DVDs, Hard disk drives. They are also used in wireless links and digital communication.

One of the main advantage of these codes is that they make the highest efficient use of redundancy. Also they offer flexibility in block length and symbol length. Wide range of code rates are possible. Efficient decoding techniques are there for decoding of Reid Soloman codes.

To generate the Reid Soloman code, the message signal is multiplied with the generator polynomial.

RS codes are decoded by syndrome decoding. It consists of following steps.

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1.   Syndrome Calculation - It detects if an error has occurred in the transmission of data.

2.   It determines the location of error.

3.   It calculates the magnitude of error.

4.   It evaluates and applies the error correction.

RS code are capable of detecting multiple errors.

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