Claude Shannon, American

$x$ is the undesirable disturbances

Circle: Reed

Communication sporadic and,

if 0 and 1

...Introduced the term “bits” to reference

A

Channel coding major solution to deep

...By adding specific types of

$x

m$

Can detect and correct multiple

Encoder usually a simple circuit with

The

LDPC decoded on parity check matrix

~10 years later Cyclic codes

Since n transmitted symbols from an

Long delay, weak received signal,

Traditionally used concatenation of

Codewords consist of all function

A code C of distance d is an

Turbo

Adds a parity digits to every three

$x$

codes discovered

Not related to what you say but what

$x$

$x$

Low

log

Constacyclic

Infinite but fundamentally don’t

$x$

$x$

$x$

Circle: relatively weak Reed

Very high efficiency

...

A binary channel is

g

Deep

as you leave Earth

Can correct a burst error of up to

$x$

Noise
codes

only

and Applications

added to

1

A physical frame contains information

,A

Focused on the best way to encode

rate

A

Length

$x

=\log()$ with LDPC under Solar Scintillation, Qi Li, 2012 ; A Survey of Deep Space

by John

College of Art and Sciences

History


Not related to what you say but what you could say.

Focused on the best way to encode information that a sender wants to transmit.

Introduced the term “bits” to reference a binary digit.

$H = \sum p(x) \log p(x)$

= Shannon Entropy, measure of information in a message in bits; p(x)Probability of a certain symbol, x; turning up; log[p(x)]=Number of bits needed to represent x

Used probability theory to prove

- 10 years later Cyclic codes discovered

- 10 years later Negacyclic codes discovered

- Constacyclic codes discovered

Abstract

Definitions

Coding Theory is the study of methods for efficient and accurate transfer of information from one place to another; finding noise and error correcting errors; Code is a set of codewords. A block code is a set of codewords of the same length; Codewords are the words belonging to a given code; made up of digits; A channel is a physical medium through which the information is transmitted. A binary channel only sends digits 0 or 1; Noise is the undesirable disturbances which may cause information received to differ from that which was sent; Length is the number of digits in a codeword; A binary channel is symmetric if 0 and 1 are transmitted in equal accuracy; The information rate is a number designed to measure the proportion of each codeword that is carrying the message; $\frac{1}{n}$ is an (n,k) code of length n; The Hamming weight is the number of times the digit 1 occurs in a codeword $\vdottedash\vdottedash\vdottedash\vdottedash\vdottedash\vdottedash\vdottedash\vdottedash$; The Hamming distance is the number of positions in which w and v disagree, denoted d(w,v);

Parity Digit is an added digit that follows a certain algorithm to reduce errors; A code C of distance d is an error correcting code if it detects all error patterns of weight less than or equal to (d-1) and there is at least one error pattern of weight d which C will not detect; A cyclic code is a block code where the circular shifts of each codeword gives another word that belongs to the code, error-correcting

$E_{c}(x_{1}, x_{2}, x_{3}) = (x_{1} \cdot x_{2} \cdot x_{3})$

...A constacyclic code is a cyclic code where the circular shifts of each codeword gives another word that belongs to the code with the first symbol being a $\times v$-tuple

$E_{c}(x_{1}, x_{2}, x_{3}) = (x_{3} \cdot x_{1} \cdot x_{2})$

...A negacyclic code is a cyclic code where the circular shifts of each codeword gives another word that belongs to the code with the first symbol changing sign

$E_{c}(x_{1}, x_{2}, x_{3}) = (x_{1} \cdot x_{3} \cdot x_{2})$

Deep Space Communication

Deep space communication is communication between earth stations and remote spacecraft, other planets, or space beyond Earth’s gravitational field.

- Most missions never return to earth, failed reception and a consequent retransmission not an option
- Communication sporadic and ultra long distances
- Long delay, weak received signal, and variable distances according to orbits
- Asymmetrical uplink and downlink capacities
- Limited mass, power source, and volume
- Intensity of electromagnetic radiation decreases according to $\alpha$ as you leave Earth

- Channel coding major solution to deep space issues
- Traditionally used concatenation of convolutional code and Reed-Solomon code.
- Convolutional code have greater simplicity of implementation over a block code of equal power
- Infinite but fundamentally don’t offer more protection against noise than the equivalent block code
- Encoder usually a simple circuit with memory and logic while decoder in software or firmware

$c^{*}(x) = (c_{n}, c_{n-1}, c_{n-2}, \ldots, c_{k}, c_{k-1}, c_{k-2}, \ldots, c_{1}, c_{0})$

- By adding specific types of redundancy, can recover data perfectly with high probability, even under huge amounts of noise
- Low-Density Parity-Check (LDPC) are on a matrix containing only a few ones in each row and column
- LDPC decoded on parity check matrix which grows larger as the code rate decreases, low rate LDPC more critical
- Turbo codes are constructed by applying 2 or more simple to decode encoding rules to different permutations of the same information sequence, achieve data rates more near Shannon limit (theoretical max)
- Turbo codes decoded on trellises with one trellis per information bit corresponding to several code symbols
- LDPC now international standard while Turbo codes are used for extremely long transmissions(outter planets or outside solar system)

Compact Disc (CD)

- Reed-Solomon Codes with binary digits represented on the disc as pits and lands, first introduced in 1982
- Code is so strong any playback error comes from tracking error using the laser to jump tracks
- Reed-Solomon codes discovered in 1960 by Irving Reed and Gustave Solomon.
- Can detect and correct multiple errors, including burst errors.
- Can correct a burst error of up to 4000 bad bits, or a physical defect of 2.47 mm long through parity digits and interleaving.
- Interpolation can conceal errors up to 1,200 bits of 8.5 mm long.
- Two layers of Reed-Solomon code separated by a 28-way convolutional interleaver. Cross-Interleaved Reed Solomon Code (CIRC)
- High random error correctability
- Long burst error correctability
- In case exceed, interpolation provide concealment approximation
- Very high efficiency
- Simple decoder strategy with reasonable sized memory
- Codewords consist of all function tables of polynomials of degree less than k over the finite field with n elements (is prime). $\alpha^i\gamma^k$
- Interpolat k given symbols as the first segment of the function table.
- Remaining n-k symbols generated by evaluating polynomial at points
- Since n transmitted symbols from an over-determined system that specifies polynomial of degree less than k, interpolation can recover original message.
- Adds a parity digits to every three
- 1st Circle: relatively weak Reed-Solomon (32,28), can correct up to 2 bit errors in 32 bit block and flags errors with more than 2 bit
- 2nd Circle: Reed-Solomon (28,24), can correct up to 4 erasures per block
- CIRC interleave audio frames through disc over several consecutive frame
- A physical frame contains information from many audio frames. This adds 44 bits of error correction data to each frame. 8 bit of subcode added to each frame.