ERROR-CORRECTING CODES

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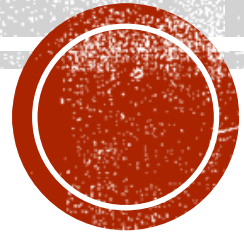


AGENDA

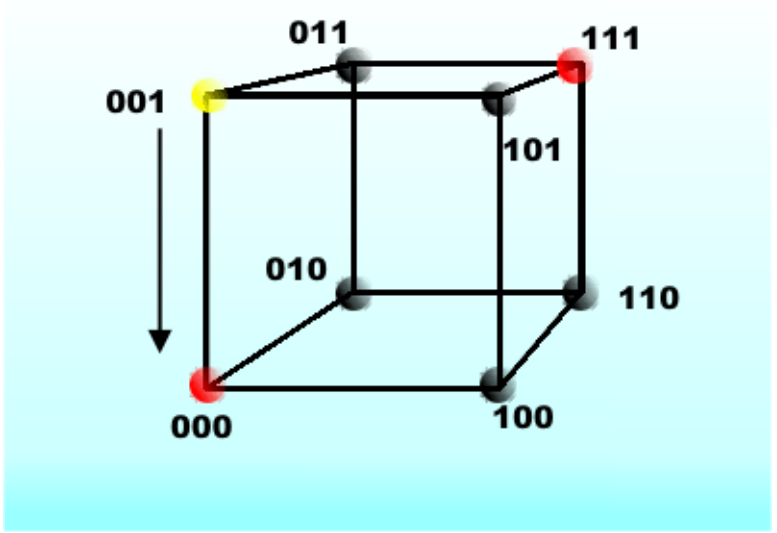
- What are Error-Correcting Codes?
- How do they works?
- Example: Hamming Codes (7,4)
- Types of Error-Correcting Codes
- Applications

WHAT ARE ERROR-CORRECTING CODES?

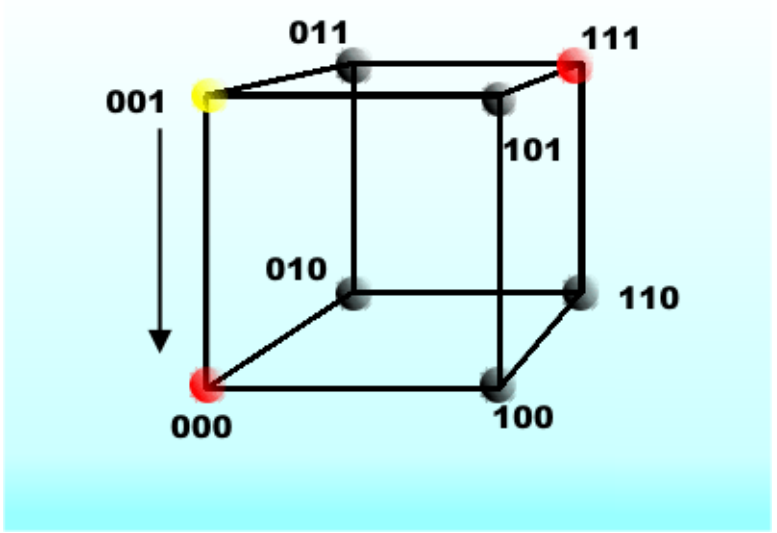
- Basic idea: add redundant bits
- Code Rate: Proportion of data-stream that is useful
  - Denoted as Code(n, k), n > k, generates n bits for every k bits
  - Code Rate = k / n
- Error Detection Vs Error Correction
- How much errors can be corrected?
  - Shannon Limit 1948:
    - The theoretical maximum information transfer rate of the channel
    - ***Shannon theorem:*** "Given a noisy channel with channel capacity C and information transmitted at a rate R, then if R < C there exist codes that allow the probability of error at the receiver to be made arbitrarily small"

HOW IT WORKS?

Triplet received	Interpreted as
000	0 (error free)
001	0
010	0
100	0
111	1 (error free)
110	1
101	1
011	1

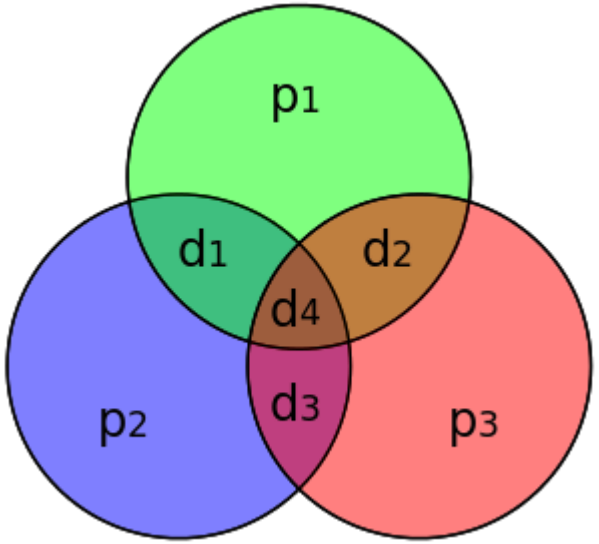


- In general, to correct m bits, each valid symbol has to be surrounded by a sphere of radius m+1 of invalid codes.



EXAMPLE: HAMMING CODE (7,4)

- Introduced by Richard Hamming in 1950, then was frustrated with the error-prone punched card reader
- For every 4 bits of data: d1, d2, d3, d4
- Add 3 parity bits: p1, p2, p3
- Transmit: p1 p2 d1 p3 d2 d3 d4



TYPES OF ERROR-CORRECTING CODES

- Convolutional Codes:
  - Sliding window on bit streams of arbitrary length
  - Most often decoded with the Viterbi algorithm
- Block Codes:
  - Work on fixed-size blocks of bits
  - Generally decoded in polynomial time to their block length
  - E.g. Reed-Solomon Code, Golay, BCH, Multidimensional parity, and Hamming codes.
- Turbo Codes:
  - Combines two or more relatively simple convolutional codes and an interleaver to produce a block code

APPLICATIONS

- Convolutional codes used in:
  - both CDMA and GSM digital cellular
  - dial-up modems
  - Satellite and deep-space communications
  - 802.11wireless LANs
- Reed-Solomon coding has widespread use on the Compact disc, the DVD, and in hard disk drives
- Hamming ECC is commonly used to correct single level cell NAND flash memory errors

APPLICATIONS (2)

- LDPC codes are now used in many recent high-speed communication standards:
  - DVB-S2 (Digital video broadcasting)
  - WiMAX (IEEE 802.16e standard for microwave communications)
  - High-Speed Wireless LAN (IEEE 802.11n)
  - 10GBase-T Ethernet (802.3an)
  - G.hn/G.9960 (ITU-T Standard for networking over power lines, phone lines and coaxial cable).
- Turbo coding CDMA2000 1x and EV-DO
  - Digital cellular technology developed by Qualcomm and sold by Verizon Wireless, Sprint, and other carriers.

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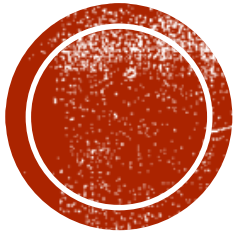

THANK YOU

Questions?