**Lab 6：LDPC Code**

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| **Introduction**  **Experimental Objective:**  Understand channel coding algorithms in digital communications and be able to experimentally verify them using LabVIEW  **Generate Matrix:**  The generation matrix for LDPC coding is a sparse matrix used to code the input data into an error correcting code. Each row of the generation matrix corresponds to a parity bit and each column corresponds to a data bit. The structure of the generating matrix determines the performance of the error correcting code. The generating matrix can be constructed using different methods such as random construction, Gaussian elimination, etc. The construction process of generating matrix: Suppose there is an LDPC code with generating matrix H of size m × n, where m denotes the number of parity bits and n denotes the number of data bits. Initialize H as an all-zero matrix. Randomly select some positions (called concatenations) in H set to 1 to ensure that each parity bit is concatenated with at least k data bits, where k is a preset parameter. Using Gaussian elimination or some other method, convert H to standard form so that the submatrix in the upper left corner of H is a unit matrix. Randomize each column of H to increase the randomness of the encoding. Optionally, the structure of H is optimized using certain methods, such as minimizing the degree of parity bits, minimizing the correlation between parity bits, and the like.    **Check matrix:**  The checksum matrix is a relatively generic representation tool, and linear grouping codes can all be determined from the checksum matrix. Genericity often means that it is often difficult to represent some properties, e.g., low density. A good representation is often the key to solving the problem. There is a matrix representation of graphs in graph theory, and the checksum matrix is sparse; a good representation is to point out the positions of 1 in it, and it is these positions that we care about. This purpose is served if the sparse matrices are described using graphs, a class of graphs known as Tanner graphs    **Syndrome:**  In LDPC, a syndrome is an error indication vector obtained at the receiving end by decoding the received codeword. The syndrome can be used to detect and localize the error bits in the codeword. The concatenation is usually obtained by multiplying the received code word with the transpose of the checksum matrix. The transpose of the checksum matrix is a sparse matrix where each row corresponds to a checksum equation and each column corresponds to a codeword bit. The result obtained by multiplying the received codeword with the transpose of the checksum matrix is the concomitant equation. Each bit of the concomitant equation indicates whether the corresponding code word bit satisfies the checksum equation. If a bit in the concomitant equation is 0, the corresponding code word bit is correct; if a bit in the concomitant equation is 1, the corresponding code word bit has an error. By analyzing the concomitant equation, the location of the error bit can be determined and corrected. The decoding algorithm in LDPC coding usually uses iterative decoding to reduce the number of error bits gradually by calculating the concomitant equation several times, and finally achieves the correct decoding result.    **Tanner graph:**  What the Tanner graph expresses is actually the checksum matrix of a code. the Tanner graph contains two types of vertices: n code word bit vertices (called bit nodes or variable nodes) corresponding to the columns of the checksum matrix, and m checksum equation vertices (called checksum nodes) corresponding to the rows of the checksum matrix. If a checksum matrix contains a certain code element, a line connects the variable nodes to the checksum nodes. If the ith variable node and the jth checksum node are connected by an edge, then H(j,i)=1, otherwise H(j,i)=0.    **Rings in LDPC:**  The term "ring" in LDPC codes refers to the ring structure formed by the nonzero elements of the LDPC check matrix. If there is a closed path of non-zero elements in the check matrix of an LDPC code, then this path is called a ring.  **Introduction to two channel coding algorithms, Hamming code and LDPC code:**  Hamming code, a common channel coding algorithm, is an error-detecting and correcting code that detects and corrects errors that occur in the data as it is sent from the sender to the receiver by adding check bits to the data. Hamming code is known for its simplicity and practicality, and is usually used for smaller data transmissions, where an error in transmission does not require the sender to retransmit the data. It can detect how many bits have errors in them and can perform error repair in some cases. The disadvantage is that the addition of redundant information increases the transmission overhead and wastes part of the channel bandwidth.  LDPC code, known as Low-Density Parity Check Code, is also a commonly used channel coding algorithm.The design goal of LDPC code is to pursue the smallest possible number of redundant bits while guaranteeing error correction performance.The advantage of LDPC code is that it is derived from distributed matrix computation, and therefore in practice it tends to provide performance very close to the channel capacity limit, which can be close to the limit of the channel's capacity - Shannon's limit - at a certain coding rate.1 There are two main decoding algorithms for LDPC codes, iterative decoding and exact decoding. Iterative decoding is currently the most commonly used method for decoding LDPC codes, which updates the decoding matrix iteratively to obtain the correct solution. Exact decoding, on the other hand, solves all the solutions at once, but the computational complexity of this method is high, and it is usually only used for theoretical research.  **Lab results & Analysis**：  1. LDPC code-4QAM (block diagram, programming process, simulation results):        And the figures below are 16QAM. | |
| **Experience**  Question we met:      Experience  By this experiment, I have more understanding with LDPC code. The use of channel encoding algorithms has several key benefits. Firstly, it enhances the reliability and accuracy of data transmission, leading to a reduced error rate and improved overall system performance. Furthermore, it enables the implementation of error detection and correction techniques, such as parity checks and cyclic redundancy checks, which are essential for ensuring data integrity in noisy environments. In addition, channel encoding algorithms play a crucial role in facilitating reliable communication over non-ideal channels, such as wireless or noisy communication environments. By introducing redundancy and error correction capabilities, these algorithms help to mitigate the impact of channel impairments and improve the quality of the received data.  Overall, the use of channel encoding algorithms is fundamental to achieving robust and reliable digital communication, particularly in scenarios where signal quality may be compromised. By incorporating redundancy and error correction capabilities, these algorithms are instrumental in ensuring the integrity of transmitted data and enhancing the overall performance of digital communication systems. | |
| **Score** | 100 |