ITC Homework Assignment
Block code and Cyclic codes
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1. Implementation of cyclic code encoding and decoding

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#include <iostream>
#include <vector>
#include <string>
#include <algorithm>

// Cyclic Codes Implementation
// A polynomial division based approach for detecting
transmission errors

class CyclicCodeProcessor {
private:
    std::vector<int> generator_poly;
    int data_length;
    int checksum_size;

public:
    CyclicCodeProcessor(const std::vector<int>& gen_polynomial)
:
        generator_poly(gen_polynomial),
        checksum_size(gen_polynomial.size() - 1) {
        // Validate generator polynomial (must start with 1)
        if (gen_polynomial.empty() || gen_polynomial[0] != 1) {
            throw std::runtime_error("Invalid generator
polynomial");
```

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        }
    }

    // Performs polynomial division in GF(2)
    // Returns the remainder of dividend / divisor
    std::vector<int> calculateRemainder(const std::vector<int>&
dividend) const {
        // Create a working copy of the dividend
        std::vector<int> work_buffer = dividend;
        int dividend_size = work_buffer.size();
        int divisor_size = generator_poly.size();

        // Perform polynomial long division in GF(2)
        for (int i = 0; i <= dividend_size - divisor_size; i++)
{
            // If current bit is 1, perform XOR with generator
            if (work_buffer[i]) {
                for (int j = 0; j < divisor_size; j++) {
                    // XOR operation (addition in GF(2))
                    work_buffer[i + j] = work_buffer[i + j] ^
generator_poly[j];
                }
            }
        }

        // Extract remainder (last checksum_size bits)
        std::vector<int> remainder;
        remainder.reserve(checksum_size);
        for (int i = dividend_size - checksum_size; i <
dividend_size; i++) {
            remainder.push_back(work_buffer[i]);
        }

        return remainder;
```

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    }

    // Creates a codeword from message by appending checksum
    std::vector<int> createCodeword(const std::vector<int>& msg)
{
        data_length = msg.size();

        // Step 1: Create dividend by appending zeros
        std::vector<int> padded_msg = msg;
        for (int i = 0; i < checksum_size; i++) {
            padded_msg.push_back(0);
        }

        // Step 2: Calculate remainder
        std::vector<int> checksum =
calculateRemainder(padded_msg);

        // Step 3: Create codeword = message + checksum
        std::vector<int> result = msg;
        result.insert(result.end(), checksum.begin(),
checksum.end());

        return result;
    }

    // Validates a received codeword and extracts original
message if valid
    bool validateAndExtract(const std::vector<int>&
received_word, std::vector<int>& extracted_msg) {
        // Calculate syndrome (remainder after division)
        std::vector<int> syndrome =
calculateRemainder(received_word);

        // Check if syndrome is all zeros (indicating no errors)
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        bool is_valid = true;
        for (int bit : syndrome) {
            if (bit != 0) {
                is_valid = false;
                break;
            }
        }

        // Extract original message if valid
        if (is_valid && data_length > 0) {
            extracted_msg.clear();
            for (int i = 0; i < data_length; i++) {
                extracted_msg.push_back(received_word[i]);
            }
        }

        return is_valid;
    }

    // Debug helper to print bit arrays
    static void printBits(const std::string& label, const
std::vector<int>& bits) {
        std::cout << label;
        for (int bit : bits) {
            std::cout << bit;
        }
        std::cout << std::endl;
    }
};

// Demo function showing cyclic code error detection
void demonstrateCyclicCode() {
    // Define a generator polynomial (x³ + x + 1)
    std::vector<int> generator = {1, 0, 1, 1};
```

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    // Sample message to encode
    std::vector<int> message = {1, 0, 1, 1};

    // Create processor with our generator polynomial
    CyclicCodeProcessor processor(generator);

    std::cout << "=== CYCLIC CODE ERROR DETECTION DEMO ===" <<
std::endl;
    processor.printBits("Generator polynomial: ", generator);
    processor.printBits("Original message:     ", message);

    // Encode the message
    std::vector<int> encoded =
processor.createCodeword(message);
    processor.printBits("Encoded codeword:     ", encoded);

    // Testing error-free transmission
    std::vector<int> clean_received = encoded;
    std::vector<int> extracted_msg;

    std::cout << "\n--- TEST 1: ERROR-FREE TRANSMISSION ---" <<
std::endl;
    processor.printBits("Received codeword:    ",
clean_received);

    bool is_valid = processor.validateAndExtract(clean_received,
extracted_msg);
    if (is_valid) {
        std::cout << "Status: VALID - No errors detected" <<
std::endl;
        processor.printBits("Extracted message:    ",
extracted_msg);
    } else {
```

```
        std::cout << "Status: INVALID - Errors detected" <<
std::endl;
    }

    // Testing with an error
    std::cout << "\n--- TEST 2: TRANSMISSION WITH ERROR ---" <<
std::endl;
    std::vector<int> corrupted = encoded;

    // Introduce an error at position 5
    int error_pos = 5;
    corrupted[error_pos] = corrupted[error_pos] ^ 1;

    processor.printBits("Corrupted codeword:   ", corrupted);

    is_valid = processor.validateAndExtract(corrupted,
extracted_msg);
    if (is_valid) {
        std::cout << "Status: VALID - No errors detected" <<
std::endl;
        processor.printBits("Extracted message:    ",
extracted_msg);
    } else {
        std::cout << "Status: INVALID - Errors detected" <<
std::endl;
        std::cout << "Message cannot be reliably decoded" <<
std::endl;
    }
}

int main() {
    try {
        demonstrateCyclicCode();
    }
```

```
    catch (const std::exception& e) {
        std::cerr << "ERROR: " << e.what() << std::endl;
        return 1;
    }

    return 0;
}
```

```

OUTPUT:

Output

```
=== CYCLIC CODE ERROR DETECTION DEMO ===
Generator polynomial: 1011
Original message: 1011
Encoded codeword: 1011000

--- TEST 1: ERROR-FREE TRANSMISSION ---
Received codeword: 1011000
Status: VALID - No errors detected
Extracted message: 1011

--- TEST 2: TRANSMISSION WITH ERROR ---
Corrupted codeword: 1011010
Status: INVALID - Errors detected
Message cannot be reliably decoded

=== Code Execution Successful ===
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