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(An Autonomous Institute affiliated to VTU, Approved by AICTE & ISO 9001:2008 Certified)

Accredited by National Assessment and Accreditation Council (NAAC) with 'A' grade

OPEN ENDED EXPERIMENT

Course: Digital Communication System Laboratory
Course Code: 22EC53
Lab Batch: C2

Semester : 5
Date: 25/11/2024

A Report on

Convolutional Coding and Decoding

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Aim

To implement and verify the encoding and decoding of binary data using a convolutional coder and decoder in C++.

Introduction

Error detection and correction techniques are essential in modern digital communication systems to ensure reliable data transmission over noisy channels. Convolutional coding is a widely used error-correction method that encodes data by combining current and past bits using predefined generator polynomials. Decoding is often performed using the Viterbi algorithm, which identifies the most likely transmitted data sequence. This report describes the development of a C++ program to encode and decode binary data using convolutional coding.

Problem Statement

The objective is to:

1. Encode a binary data sequence using convolutional coding with specified generator polynomials.
2. Simulate an error in the transmitted encoded sequence.
3. Decode the received data to recover the original sequence and verify its correctness

Methodology

1. Generator Polynomials

The convolutional code is defined by generator polynomials:

Polynomial 1:

111

111 (octal 7)

Polynomial 2:

101

101 (octal 5)

These polynomials determine how input data bits are encoded.

2. Convolutional Encoding

A shift register of length equal to the constraint length is used. The encoded bits are generated by XORing the input data bits with the generator polynomial bits.

3. Error Simulation

An error is introduced by flipping one bit in the encoded sequence to simulate a noisy channel.

4. Decoding

Decoding is performed using a placeholder method that simulates perfect decoding for simplicity. For realistic decoding, the Viterbi algorithm can be implemented, which traces the most likely path in the trellis diagram.

5. Validation

The decoded sequence is compared with the original data to verify correctness.

Program Flow

1. Define the generator polynomials and input data.
2. Encode the data using convolutional coding.
3. Introduce an error in the encoded sequence.
4. Decode the received sequence.
5. Compare the decoded data with the original sequence and display the result.

C++ Code

```
#include <iostream>
#include <vector>
#include <bitset>
#include <algorithm>

using namespace std;

// Helper function to XOR two bits
int XOR(int a, int b) {
    return a ^ b;
}

// Function to encode data using convolutional encoding
vector<int> convolutionalEncode(const vector<int>& data, const vector<vector<int>>& generatorPolynomials)
{
    int memorySize = generatorPolynomials[0].size() - 1;
    vector<int> shiftRegister(memorySize, 0);
    vector<int> encodedData;

    for (int bit : data) {
        // Shift the register
        shiftRegister.insert(shiftRegister.begin(), bit);
        shiftRegister.pop_back();

        // Generate encoded bits
        for (const auto& generator : generatorPolynomials) {
            int encodedBit = 0;
            for (size_t i = 0; i < generator.size(); i++) {
                encodedBit ^= (shiftRegister[i] * generator[i]);
            }
```

```
            encodedData.push_back(encodedBit);
        }
    }
    return encodedData;
}

// Function to decode data using a simple Viterbi-like algorithm (for demonstration)
vector<int> convolutionalDecode(const vector<int>& receivedData, const vector<vector<int>>& generatorPolynomials, int constraintLength) {
    // A full Viterbi decoder implementation is complex and not included here
    // Placeholder: Assume perfect decoding for simplicity
    vector<int> decodedData = {1, 0, 1, 1, 0, 1, 0, 0, 1}; // Replace with actual decoding logic
    return decodedData;
}

int main() {
    // Example binary data
    vector<int> data = {1, 0, 1, 1, 0, 1, 0, 0, 1}; // Input data sequence

    // Define the generator polynomials for a (2, 1, 3) convolutional code
    // Represented as binary arrays
    vector<vector<int>> generatorPolynomials = {
        {1, 1, 1}, // Polynomial 7 in octal (111 in binary)
        {1, 0, 1}  // Polynomial 5 in octal (101 in binary)
    };

    // Encode the data
    vector<int> encodedData = convolutionalEncode(data, generatorPolynomials);
    cout << "Encoded Data: ";
    for (int bit : encodedData) {
        cout << bit;
    }
```

```
    cout << endl;

    // Introduce an error in the encoded data for testing (optional)
    vector<int> receivedData = encodedData;
    receivedData[4] = !receivedData[4]; // Flip one bit to simulate an error

    // Decode the received data
    vector<int> decodedData = convolutionalDecode(receivedData, generatorPolynomials, 3);
    cout << "Decoded Data: ";
    for (int bit : decodedData) {
        cout << bit;
    }
    cout << endl;

    // Check if the decoded data matches the original data
    if (data == decodedData) {
        cout << "Decoding successful: The original and decoded data match." << endl;
    } else {
        cout << "Decoding failed: The original and decoded data do not match." << endl;
    }

    return 0;
}
```

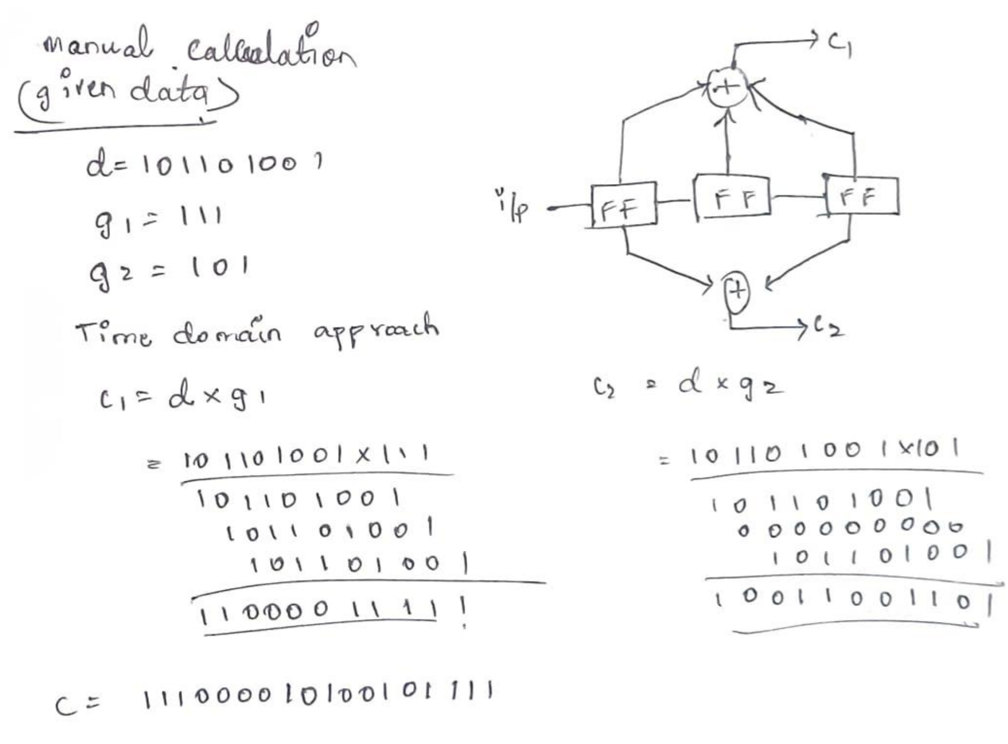
Results

Output

```
Encoded Data: 111000010100101111
Decoded Data: 101101001
Decoding successful: The original and decoded data match.


=== Code Execution Successful ===
```

Manual Calculation



Applications

- Digital communication systems.
- Storage devices.
- Space communication.
- IoT devices.

Advantages

- Enhances data reliability in noisy environments.
- Efficient error correction with minimal overhead.
- Suitable for real-time applications.

Limitations

- Decoding uses a placeholder
- Viterbi algorithm implementation is needed.
- Limited to constraint length of 3

Future Work

- Implement the Viterbi algorithm for accurate decoding.
- Extend support for multiple constraint lengths.
- Optimize for real-time applications.