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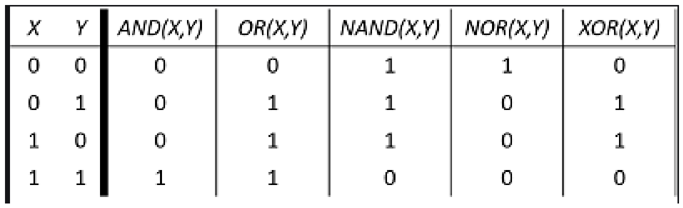
ASGN5 Design

notes:

m = message 4 bits	XOR for addition
c = hamming code 8 bits	OR for multiplication
G = vector-matrix multiplication	
e = error syndrome	



X	Y	AND(X,Y)	OR(X,Y)	NAND(X,Y)	NOR(X,Y)	XOR(X,Y)
0	0	0	0	1	1	0
0	1	0	1	1	0	1
1	0	0	1	1	0	1
1	1	1	1	0	0	0

Hamming(8,4)
8 = Hamming Code
4 = message

PRELAB IS LATER IN DOCUMENT

Quicknotes*

Encode and Decode will both be in hamming.c
File is just a sequence of bytes,
Binary is read from right to left, and matrix is read from left to right.

In a 1x8 Matrix Code, the first 4 bits is the message.

Writeup: show error rate and stuff and entropy
Lookup tables, You don't need to search through them, should be indexed
If the value of error syndrome is 15, then just look at index 15 of the table. The error syn value corresponds to exact index

BitVector

Struct:

- Uint32_t length // Length in bits
- Uint8_t *vector // Array of bytes. It's uint8_t because we extended the last bit to be p3

16 bit vector

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
														🟩		
Byte 0								Byte 1								

Setbit(n)

- Byte =n/8
  - Now we have to locate the specific bit inside of that byte.
- Offset n % 8
  - byte= Byte (OR) 1 << (offset)
- One line: v-> vector[n/8] |= (1 << (n%8)

Ex.

Set bit (14)

Byte = 14/8 = 1 // Byte 1

Offset = 14 %8 = 6//   Bit 14 is in byte 1 and bit 6 offset

To set the 6th bit

MSB	1	0	1	1		0	1	1	0	LSB
	0	0	0	0		0	0	0	1	Shift it 6 times
OR	0	0	0	1		0	0	0	0	
=	1	1	1	1		0	1	1	0	

To set a bit in a byte, shift a "1" to the index then bitwise OR operation = byte w/ bit set

Bv_clr_bit(n):

- Get 1's in every position BUT the bit
- MSB 0111 0110 LSB, Shift to the position, Invert it = 1101 1111   AND it, to become 0101 0110.
- v->vector[n/8] &= ~(1<< (n%8))

Bv_get_bit(n):

- v->vector[n/8] >> (n %8) & 0x1

MSB 0011 0010 LSB LS AND 0001 0000 0001 0000 Now shift right 4 back to position	MSB 0011 0010 LSB Right shift 4, 0000 0011 AND 0000 0001 = 0000 0001

XOR_BIT:

- MSB 0011 1100 LSB

MSB 0011 0010 LSB LS to position XOR 0010 0000 0001 1100	

4x8 Matrix = 32 bits.
4x4 Matrix = 16 bits.
Bc we know num of rows and columns, we always know the amount of bits.

Bit Matrix:

Bit Matrix serves as a wrapper over Bit Vector so most of these could be done with one line.

Using Bit Vector in Bit Matrix requires we follow the formula : R*N + C. Row being the row we're on, N being the number of columns, and C being the column we're on.

Struct: Stores u32 rows Store u32 Cols Bitvector *vector	Bitmatrix = m rows, n columns Rth row, Cth column R*N + C

Bit matrix Create:

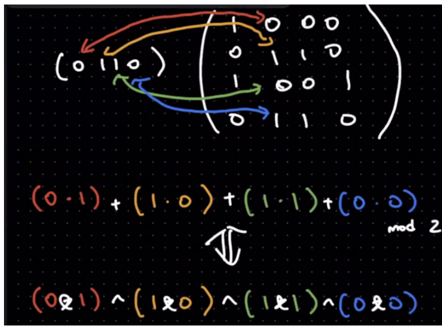
As the struct has a Bitvector *vector, we need to create a vector in regards to that. The number of bits in the bit matrix is calculated as row * cols

Two functions to return the number of rows and columns.

Bm set bit (rows, cols). We need to be able to set a bit, and as said before we follow the command R*N + C. Then pass that to the Bitvector get vector function. Bm clr bit is similar but we're just turning it into a 0

Next up we have to convert a matrix into binary and convert a binary into matrix:
Bm from data - bm to data
Needed bc we need to multiply bit vectors/matrices
We need a way to convert bytes to specific matrix
Msg = MSB 0000 1101 LSB // We need to convert this into a bit matrix
We can loop through bits, clear bit, set bit.
Bitmatrix *M = bm_from_data(msg, 4//(haming 4/8scheme))
To convert into bit matrix:
Code = MSB 1110 0000 LSB
Bit Matrix 8C = bm_from_data(code, 8)

Finally, multiply two matrices. Multiplying matrices looks like the example:
The thought process I have of multiplying matrices, is having three for loops. One iterating over the cols in first matrix, second the bigger, and third the smaller one again.



Hamming Encode

As arguments we receive the Bitmatrix G and a uint8_t msg.
The Bitmatrix G is a matrix that looks like this

$$G = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \end{pmatrix}.$$

The left side shows

C = m.g

What Hamming Encode is doing is receiving a msg (Which is one byte, also one character)
To encode a message we need to multiply M*g

We need to follow the formula: C = m.g to get the encoded message.
First: Convert the msg into a matrix
Second: Multiply the new matrix and G.
Third: Profit, convert that matrix back into binary and return it.

A general Idea of what the more built pseudo code will look like:

```
   BINARY VERSION   = (Convert binary (msg) into a matrix) * (G)
If e == 0
         No error return Ham ok
Else
         lookup(e)
```

Hamming Decode:

Hamm decode is similar to encode but doing the exact opposite. To decode a message we need to multiply the code by the transposed matrix of G, which looks like :

$$\begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

This is the transposed version of the matrix used in encode, and we use the transposed matrix because the code is 8 bits.
When multiplying matrices together, (A*B). We need the A's columns to equal the B's rows. As the code is 8 bits, 8 columns, we can multiply that to the 8 rows of the transposed matrix.

Once we multiply it, we convert it into binary. (We get a 1x4 matrix) or 4 bit long binary. This is called the error rate

If the error rate is 0000, then there are no errors and we could return HAM_OK.

PRELAB:

1.

Index	Error Syndrome	row in H^t
0	0000	HAM_OK
1	0001	4
2	0010	5
3	0011	HAM_ERR
4	0100	6
5	0101	HAM_ERR
6	0110	HAM_ERR
7	0111	3
8	1000	7
9	1001	HAM_ERR
10	1010	HAM_ERR
11	1011	2
12	1100	HAM_ERR
13	1101	1
14	1110	0
15	1111	HAM_ERR

2.

a. Decode 1110 0011.
We do this by converting the binary into a matrix.

$$(1\ 1\ 0\ 0\ \ 0\ 1\ 1\ 1\ ) * \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

That brings us to the decoded matrix: (1 0 1 1)

If we look at the lookup graph, we see that that this points to the second row. Now we require to flip the second element of the code to become (1 0 0 0 0 1 1 1). Now we can POSITIVELY say that the message is the first 4 bits of the code: 1100.

b. Decode 1101 1000.
Matrix = (0001 1011)
Multiplied = (0101) | Binary = 1010.
This brings us to HAM_ERR. So we CAN NOT decode it

Encoder Main()

```
getopt() loop
Take in two possible arguments. Infile and outfile.

Create generator Matrix G // This is going to be a bit matrix
Create the generator matrix by using a series of for loops to create the 4x8 matrix.

while fgetc != EOF
    byte = MSB 1100 0110 LSB
    msg1 = low nibble of byte
    msg2 = high nibble of byte
code 1 = ham_encode (G, message to encode); // 8 bits  = 1 byte
code 2 = ham_encode (G, msg2); // 8 bits = 1 byte

We can use fputc  // Writing a character OUT to a file stream
and free memory later
```

Decoder Main()

```
getopt loop()
create H transpose (H^t)
while fgetc != EOF
    When we're decoding, every byte is a code.

    How much code do we need to convert back to a single byte of data? 2.
    get code 1
    get code 2
    msg1= decode (H^t, code 1) // nibble
    msg2 = decode(H^t, code 2) //Nibble
    Now we have to combine them and pact them together using pack_byte.
    Pact the nibbles into a byte.
    fputc( packed nibbles)
```

Now we have the gist of the assignment, but in addition to the core of this we were supplied with error.c, and entropy.c.

ERROR

Error produces noise into the program so we'll start having issues attempting to decode things.
The usage of error.c is as follows.

```
OPTIONS
  -h               Program usage and help.
  -s seed          Specifies the random seed.
  -e error_rate    Specifies the error rate.
```

The error rate basically means that whatever percent we choose, we'll have that /1000 of bits flipped. (INCORRECT)

Because of Error we need to know how many bits we processed, how many bits are corrected, not corrected, and the error rate. We find this out by printing that information out in decode.c main function.

ENTROPY

Entropy calculates the amount of randomness in our encode/decode. If we have a file that has no patterns and is RANDOM we're going to have very high entropy.
The usage for entropy is as follows:

```
./entropy < [input (reads from stdin)]
```