University at Buffalo

Image Compression and Transmissison over wireless channel Simulation while applying Reed Solomon coding.

Final Project Report

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1. Literature Review :

RS coding is one of FEC (Forward Error Correction) techniques.In telecommunication, information theory, and coding theory, forward error correction (FEC) or channel coding is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. The central idea is the sender encodes their message in a redundant way by using an error-correcting code (ECC).They described a systematic way of building codes that could detect and correct multiple random symbol errors. By adding '*t*' check symbols to the data, an RS code can detect any combination of up to *t* erroneous symbols, or correct up to $\lfloor t/2 \rfloor$ symbols

The basic idea used is to add few redundant bits with original code word/bits so that if some error occurs we can use those redundant bits to get original code word/bits. The two main categories of FEC codes are block codes and convolutional codes.Block codes work on fixed-size blocks (packets) of bits or symbols of predetermined size. Practical block codes can generally be decoded in polynomial time to their block length.There are many types of block codes, but among the classical ones the most notable is **Reed-Solomon coding** because of its widespread use on the Compact disc, the DVD, and in hard disk drives. From now on we will discuss more on Reed-Solomon coding in which I have implememted in this project.

Reed Solomon coding are used where we can expect burst error in our transmiting data even the first time use of Reed Solomon coding was in 'Voyager 2' spacecraft which send image of Uranus from a distance of 600,000 miles.

Figure 1.1. Uranus from 600,000 miles away.

The main purpose of this research project is to understand the duel properties of data transmission in every day usage which includes compression and error correction. Not in all but there are applications which have limitation of storage and their transmission or bandwidth limitation which may include lot of noise and this project is inspired by such application one of the application is stated as above as Space craft image retreivel and multimedia transfer on wireless network like Image Transmission or video streaming. My main motive would be to extract as same data as I can on receivers end which is transmitted from senders end.

This coding is also famous in application of storage devices (including tape, Compact Disk, DVD, barcodes, etc), wireless or mobile communications (including cellular telephones, microwave links, etc), satellite communications, Digital television / DVB,High-speed modems such as ADSL, xDSL, etc.

3.a Introduction:

(i) Advances in general multimedia communication research

Their are many field in which have to operate under restriction of network bandwidth and have to deal with noise one of the field is related is Wireless Sensor multimedia transfer. The specific network used for such application is WSN(wireless sensor network). A wireless sensor network (WSN) of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern WSN networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

Limited power resources and low computing capability have been the two most concern in recent research related to Wireless Sensor Network (WSN). Nowadays, instead of using WSN for communicating scalar sensor data, many researches have begun to improve the WSN system so that the WSN transceiver device sometimes referred as sensor that can send data wirelesslly can carry multimedia data mainly images and video. Specifically, the research is how to make the such network capable of transmitting images captured by instruments which are highly prone to noise.

(ii) Literature reviews

All the papers discussed below have proposed their implementation of Reed Solomon coding in different areas like medical, Sensor technology etc. We tried to understand the best way possible to grasp the implementaion of the algorithm and how the image compression and is followed by RS and then transmission.

a. Image transmission quality analysis over adaptive Reed-Solomon coding

In this paper Author discuss about the various channel coding method as trade off between Image quality and Error correction capability. This paper investigates the effects of noise on the performance of Reed-Solomon coding methods for different errors correction capability.

Paper focused on first analysing the relation between BER , SNR and code length and then the transmission performance of RS codes association with different modem schemes are analysed.This paper focused more on the performance of different RS coding then any other thing as we will see in coming papers.

b. Bandwidth Aggregation with Path Interleaving Forward Error Correction Mechanism for

Delay-Sensitive Video Streaming in Wireless Multipath Environments

In this Author has tried to implemnet RS coding in multipath environment.Author describes Multipath transmission as in which multiple paths for data transfer has been used in wireless networks to improve the performance of end-to-end transmission. However, wireless networks suffer from high packet loss rate, variations in end-to-end delay and available bandwidth. Hence, the Forward Error Correction (FEC) mechanism has been proposed to recover lost packets by adapting to the changing conditions in the network. Legacy multipath transmission with the FEC mechanism is used not only to improve the transmission performance by relying on bandwidth aggregation but also to reduce packet losses by relying on path selection. However, paper talks about bandwidth aggregation of legacy multipath transmission with the FEC mechanism cannot select the appropriate transmission rate on each path as this needs more FEC redundancy to protect lost packets.

Moreover, because the larger end-to-end delay leads to the video frame not being playable on-time at the receiver end, legacy multipath transmission with the FEC mechanism cannot be used in delay-sensitive video streaming when the FEC block length is so long that may exceed the end-to-end delay. This paper proposes the Bandwidth Aggregation with Path Interleaving FEC (BAPI-FEC) mechanism for delay-sensitive video streaming in a wireless multipath environment.

Result for this research concludes that the approach proposed has mechanism relies on path interleaving technology to disperse the burst packet losses to different FEC blocks which helps to overcome abve mention issue.

c. Implementation of Source and Channel Coding for Power Reduction in Medical Application Wireless Sensor Network

Paper talk about limitation that WSN (Wireless Sensor Network) posses as discussed above WSN has limited power resources and low computing capability have been the two most concern in recent research related to Wireless Sensor Network (WSN). In papers it is cited that the data is first compressed using Huffman coding and then FEC technique RS coding is applied and then on receiver end the data is again fetched successfully but there are other things they have to worry about here like hardware and software compatibility the current RS coding is not so optimized with sensors hardware which forces the system to output long computational time that made the coding seem less practical. As discussed the main reason is due to the limitations of using the 8-bit microprocessor.

The result for this shows that also computational time of purely software oriented implementations are not optimal in such areas we also have to consider hardware compatibility.

d. Forward Error Correction for Image Transmission System using IEEE 802.15.4

This paper also talk about the image transmission in WSN but the application is different. The discussion in this paper is about image transmission study from multimedia community and suggestion regarding the possibility of realizing the system in WSN is drawn. Auther discussed the use of efficient Reed Solomon channel code in WSN system and the performance of Reed Solomon code in AWGN and fading channel. It also discussed a proposed system to evaluate ECC and also to realize image transmission in WSN. It is also shown that the performance of coded WSN is way better than uncoded WSN. Although in conventional way, the SNR is interpreted more into the how far the transmission can be established,coupling the issue with image transmission, one important thing that author concluded is that the good SNR does not necessarily improved the image quality.

(iii) Motivation and Reason

My interest in Image coding came from second assignment where we have to implement different algorithms like Huffman Encoding/Decoding, Zigzag Scan etc. This assignment was very mathematicaly challenging and So I found an interesting oppourtunity to extend this assignmnet to my final project where I can apply very robust algorithm like Reed solomon. Images are integral part of multimedia and are very where. Their are so many applications which are based on image like Remote sensing, medical , day to day image transmission on various web applications all these application has need to compress images and deal with noise which has been imtroduced while transmission.

I came across related papers which talk about the use of different application of RS coding in different areas in different channel setting of RS coding and I wonder up to what extend we can decode a noise image so I my basic try in this project is to correctly implement the algorithm and get as noise free image I can.

(iv) Overview of Project

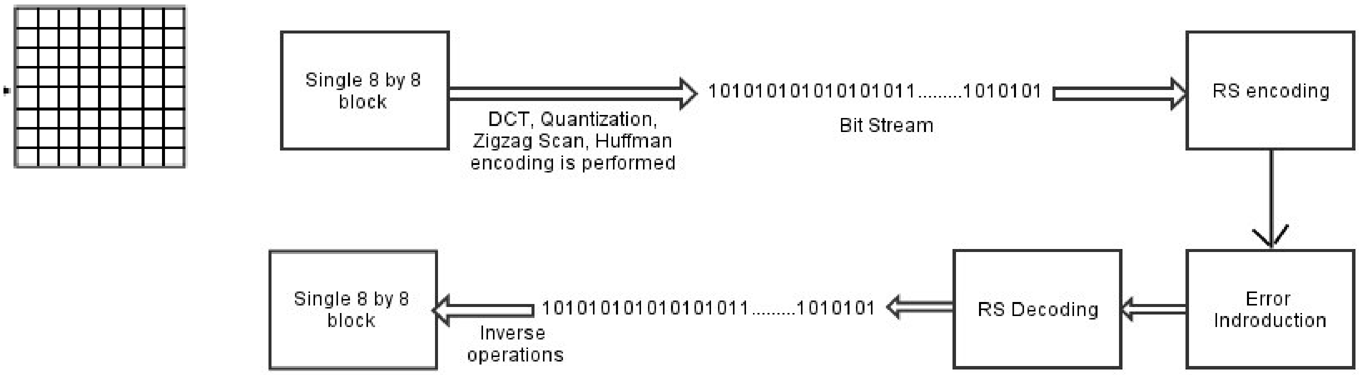
Project starts with basic algorithmic implementation of Quantization, DCT, Zigzag scan,Run Length coding followed by Huffman encoding, Reed-Solomon encoding and then introduce error in that bit stream which we are supposed to send over network. On the receivers end the original bitstream is corrected by RS decoding and then Huffman decoding and other operations are performed to get original image. Galois Field which is used in this project is GF(2^6) = GF(64) based on polynomial P(x) = x6 + x5 + x4 + x + 1. We will further discuss this in detail in coming section.

3. Proposed Approach

(i) The overall system and how the proposed component fits

As shown In fig below a image is first converted to 8 by 8 block and then DCT, Quantization, Zigzag, Runlength and Huffman coding is performed and then RS coding is implemented with GF(64) and standard polynomial P(x) = x6 + x5 x4+x+ 1 and parity is added in this process and then the error polynomial is created which is added to polynomial. This is way error is been added to the signal and then the RS decoding is done by lookup table which will be describe in a while and the original signal is then decoded with Huffman and other inverse operations of IDCT, Quantization, Reverse Zigzag scan and Reverse run length coding. All of this applied on all 8 by 8 block and original image is decoded in this way.

Image



<u>Example for RS coding and decoding including Error generation part:</u>

let Input message F(x) = **10x4+ 9x3 + 25x+48x +50** and **G(x) =1x2+6 x + 8 (Generator polynomail) where GF = 2^6 and** systematic (63,61) codeword with **t=1.** Consider an input message F(x) having sixty one 6-bit symbols which are all zero except the five final symbols. Only the five non-zero symbols are shown here; this does not affect the codeword computation. It is necessary to append two parity symbols to make the complete RS codeword having sixty three symbols.

Multiply F(x) by x2 to append two zeros, then divide by G(x) . $\mathbf{F(x)\,x^2 = 10\,x^6 + 9\,x^5 + 25\,x^4 + 48x^3 + 50\,x^2 + 0x + 0}$

$$\mathbf{(F(x)\,x^2) / G(x) = (10\ 53\ 17\ 50\ 22), \text{ remainder } (40\ 37)}$$

The remainder (40 37) is substituted for the two zeros to give the Reed Solomon codeword:

$$\mathbf{C(x) = 10x^6+9x^5+25x^4+48x^3+50x^2+40x+37}$$

This systematic codeword is an exact multiple of G(x)

<u>Adding the single-symbol error E(x):</u>

$$\mathbf{E(x) = 4x^5}$$

And the valid codeword C(x) from above:

$$\mathbf{C(x) = 10x^6+9x^5+25x^4+48x^3+50x^2+40x+37}$$

Adding the error to the codeword gives M(x) = C(x) + E(x):

$$\mathbf{M(x) = 10x^6+13x^5+25x^4+48x^3+50x^2+40x+37}$$

The errored symbol is shown highlighted.

<u>Correcting the Error</u>

Dividing the errored codeword M(x) by G(x) gives a non-zero remainder, signalling the presence of an error.

M(x) / G(x) = (10 13 25 48 50 40 37) / G(x), giving remainder (22 57)

Observe that dividing the error pattern E(x) by G(x) gives the same non-zero remainder.

E(x) / G(x) = (0 4 0 0 0 0 0) / G(x), giving remainder (22 57)

<u>This Error (4) is looked up in RS Standard table for RS(63,61) (In code file RSEncoDeco.m)</u>

Error Introduction Explanation:

For adding error to **$C(x) = 10x^6 + 9x^5 + 25x^4 + 48x^3 + 50x^2 + 40x + 37$** first we have to create another polynomial for degree to which we want to add error (degree is picked randomly from minimum to maximun range which is here 0 to 6) like here we took error as **$E(x) = 4x^5$** Both cofficeint 4 and degree 5 are randomly generated and are added to **C(x)**. in every 42 bits we can always expect some error in any place.

(ii) The Software implementation plan

Their are following modules written/ optimized during this project :

1. Optimization for code of Huffman encoding and zigzag coding is done. (1 day)
2. Changes in Huffman decoding is done to handle any unextected error is which is not handled by RS decoding.(1 half day)
3. RS Encoding this is new module which is introduced which basically adddes redundancy in original signal. Galios field used is GF(64) and polynomail used is P(x) = x6 + x5 x4+x+ 1 and systematic RS(63,61) codeword with **t=1** using G(x) = 1 x2 + 6 x + 8 is used. (4 days)
4. Error introduction is done by adding error polynomial to whatever polynomail is generated by RS encoding(2 day)
5. RS decoding is also major module being introduced which removes errors from noisy signal.(5 days)

Time which is applied is also includes all the understanding which is being build during project.

(iii) Resource used for implementation

Coding environment : Matlab

To understand the RS coding few of papers and a text book is followed **"Digital Communications by Bernard Sklar"**

4. Outcome and Deviations

(I) Presentation of the project outcome

Following are images which are get after running RS coding on self image.

Fig: 1

Fig: 2

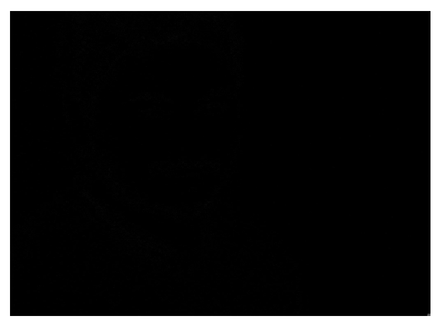


Fig: 3

Figure 1 Is image which is to send (before sending).

Figure 2 is image on which RS coding is applied and is decoded with errors.

Figure 3 is image which is difference between 2 images.

Table 1 : Compression Ratio Table without any RS coding:

No of bits in original image : 1024*1024*8

	Self Image	Outside
Quantization 1 (standard Jpeg table)	Ratio = 0.044 (Compressed bits : 375723)	Ratio = 0.0367(Compressed bits : 308096)
Quantization 2 (4 *Quantization 1)	Ratio = 0.01789 (Compressed bits : 150136)	Ratio = 0.01607(Compressed bits : 134808)
Quantization 3 (8 *Quantization 1)	Ratio = 0.01410 (Compressed bits : 118305)	Ratio = 0.01356(Compressed bits : 113825)

Table 2 : Compression Ratio Table with RS coding:

	Self Image	Outside
Quantization 1 (standard Jpeg table)	Ratio = 0.062 (Compressed bits : 525833)	Ratio = 0.0514(Compressed bits : 431334)
Quantization 2 (4 *Quantization 1)	Ratio = 0.02505 (Compressed bits : 210190)	Ratio = 0.02249(Compressed bits : 188731)
Quantization 3 (8 *Quantization 1)	Ratio = 0.01974 (Compressed bits : 165627)	Ratio = 0.01899(Compressed bits : 159355)

Table 3 : PSNR Table without RS coding and without Error:

	Self Image	Outside
Quantization 1	19.1713	18.0090
Quantization 2	19.1058	17.9483
Quantization 3	18.9659	17.9031

Table 4 : PSNR Table with RS coding with Error:

	Self Image	Outside
Quantization 1	37.3003	35.8971
Quantization 2	34.6803	32.1762
Quantization 3	30.8895	29.0123

(ii)Results Discussion and deviation observed

It is quite interesting RS coding can generate almost similar image which is send and its difference image Is also not showing any difference visible to naked eye. Over here I did not put image which is output with errors when I decode it does shows only pixels when I tried to debug why this is happening I get following understanding.

Let suppose we have bitstream as

100010101010101111100000110111100111010**1010**101010101**1010**1111101010101111**1010**

where in **blue bold** colour is EOB of Huffman coding.

And now we try to introduce error and is shown in **Red bold** colour and error has occurred in first EOB and it has changed like following.

10001010101010111111000001101111 0**011101010**101010101**1010**1111101010101111**1010**

so when we try to deocde this from Huffman lookup table and try to find EOB it will pick any random number and there is possibility that even second EOB is also noisy and it would also not recognized so this way whole image can consist of random pixels.

I try to include Quantization tables for understanding the effect of Huffman compression and RS coding on image. Like if we comsider table 1 it is without any RS coding and observation is like If the compression ratio is high then we can't expect much Quality in Image this is because increase in magnitude of numbers in table the values will be smaller and when we divide this table with original image we will have small numbers to encode and hence with this we can get highly compressed images, but the quality of these images will not be good. In case of table 2 where the compression ratio is reletively small is because of extra bits which are been add for error correction for every 30 bits we have added 12 bits. Like original message **F(x) = 10x4+ 9x3 + 25x+48x +50** whith each cofficient with 6 bits and encoded polynomial is

C(x) =$10x^6+9x^5+25x^4+48x^3+50x^2+40x+37$ with added 12 bits on end.

Now let us have look at Table 3 and 4 : Table 3 has PSNR value which are calculated on images without RS coding and without error and table 4 has PSNR values which are calculated on images having RS coding and with error. Ofcourse the PSNR value calculated is should be much higher in table 4 which is obsered case here with increase in magnitute of Quantization table the PSNR value decreases becasuse of less no of bits to encode and less error which is introduced. So the value is decreasing for Quantization 2 and 3.

(iii) Lessons learned from the experiments

It was very fun to learn another Image algorithm which I can apply in any transmission protocol. RS coding is very robust coding if applied correctly can deviler whatever it promises.But the computaions involve in this is very heavy and time taken to dencode and decode is very high.Setting chosen I thing are very effective like for every 30 bit 12 bits are used as parity bits and main difference that I observed is this is block(like can correct 6 bits at a time)correcting algorithm different from Linear block coding which only correct 1 bit at a time. I tried to keep implementaion as simple as possible so results are as accurate as I can get.

5. Summary and Discussion

(i) Project Summary

In this project compression and transmission techniques of huffman coding and RS coding is imployed.Systematic RS(63,61) codeword is used in this project in which an input message F(x) having sixty one 6-bit symbols which are all zero except the five final symbols. As discussed above in detail only the five non-zero symbols are used for polynomial creation, this does not affect the codeword computation. It is necessary to append two parity symbols to make the complete RS codeword having sixty three symbols. I also tried to run this code on different quantization setting which shows different results in manner of their compression ratios and quality of image.

(ii) Lessons Learnt from this course

All homeworks were extremely important and were extremenly challenging not even algorithmic prespective as well as mathematically. Now I know when I talk on phone how the my speech is processed by LPC or any other speech technology or when I send my image what processes it is going through or when I watch movies what sort of codec processing the videoo is going on.

Mainly I was very impressed by how the images are been processed and how the compression works which is also imployed in this project my main focus in this project was RS coding.

Overall Final exam , all Homeworks and assignments were very knowledgeful and related to our day to day media dealing.

And this project Final project is like milestone in whatever I have gain in multimedia course.

6. Acknowledgement

I would like to thank Prof for introducing us to this course and guideing us all on this project and through out semester.

7. Reference List

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