IMPROVED DISTRIBUTED WYNER-ZIV VIDEO CODING BASED ON REED SOLOMON ERROR CORRECTION SCHEME AND FRAME ESTIMATION FOR WIRELESS TRANSMISSION

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by

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LIST OF ABBREVIATIONS

AWGN	Addition White Gaussian Noise
BER	Bit Error Rate
CRC	Cyclic Redundancy Check
DCT	Discrete Cosine Transform
DVC	Distributed Video Coding
FEC	Forward Error Correction
GF	Galois Field
GOP	Group of Pictures
LDPC	Low Density Parity Check Codes
MSE	Mean Square Error
PSNR	Peak Signal to Noise Ratio
RD	Rate Distortion
RS	Reed Solomon
SER	Symbol Error Rate
SI	Side Information
SNR	Signal to Noise Ratio
WZ	Wyner-Ziv

LIST OF SYMBOLS

R_X	Rate of compression of source data, X
$H(X)$	Entropy of compression of source data, X
$\widehat{D}$	Distortion between source data and reconstructed frame
Δ	Difference between source data and reconstructed frame
$D\ (i,j)$	DCT equation to calculate (i,j)-th element in DCT matrix
d_{ij}	(i,j)-th element in DCT matrix
N	Total number of pixels of a block of frame
$p\ (x,y)$	Grayvalue of the (x,y)-th pixel of a frame
Q_τ	Quantization matrix of predefined number of level, τ
q_{ij}	(i,j)-th element in quantization matrix
b_{ij}	(i,j)-th element in resultant block of frame after quantization
E	Number of errors in received RS codeword
A	Number of erasures in received RS codeword
T	Number of redundant symbols (RS codes) or bits (LDPC codes)
N	Number of codeword symbols (RS codes) or bits (LDPC codes)
K	Number of source symbols (RS codes) or bits (LDPC codes)
m	Number of bits per source or codeword symbols for RS codes
$r(z)$	Received codeword in polynomial form for RS codes
$c(z)$	Encoded codeword in polynomial form for RS codes
$e(z)$	Errors in received codeword in polynomial form
$g(z)$	Generator polynomial for RS codes
$s(z)$	Syndrome expressions

β	Primitive element in Galois field
$\sigma(z)$	Error locator polynomial for RS codes
Y	Degree of error locator polynomial for RS codes
Z	Locations of error vectors for RS codes
C	Encoded codeword vector for LDPC codes
U	Source data vector for LDPC codes
G	Generator matrix for LDPC codes
I_τ	Identity matrix of degree, τ
P	Coefficient matrix for LDPC codes
S	Parity check matrix for LDPC codes
s_{ij}	(i,j)-th element in S
w_i	Total number of 1 in every row of S
w_j	Total number of 1 in every column of S
F	Linear interpolation function
r_e	Total number of erroneous bits received
B	Total number of bits transmitted
ϕ	Index number of a frame in GOP
F_ϕ	ϕ-th frame in GOP
M	total number of frames in a video sequence
Ψ	Remainder
T	Time

PENGEKODAN VIDEO WYNER-ZIV TERAGIH DIPERBAIKI BERASASKAN SKIMA PEMBETULAN RALAT REED SOLOMON DAN PENGANGGARAN RANGKA UNTUK PENGHANTARAN TANPA WAYAR

ABSTRAK

Semenjak beberapa tahun yang lalu, terdapat peningkatan terhadap permintaan untuk aplikasi komunikasi multimedia yang laju, cekap, dan berkualiti tinggi melalui kabel dan sistem tanpa wayar. Ini telah membuka jalan kepada penyelidikan dalam bidang pengekodan video teragih (DVC) untuk berkembang. Objektif tesis ini adalah menganalisis kecekapan pelbagai skim pembetulan ralat kehadapan dalam DVC untuk melindungi sumber data dan mengurangkan jumlah bingkai yang dihantar oleh pengekod. Terkini, kod pemeriksaan keseimbangan padatan rendah (LDPC) dipilih sebagai teknik pengekodan saluran untuk mengekod bingkai Wyner-Ziv dalam DVC kerana kod LDPC mempunyai prestasi pembetulan ralat yang lebih baik berbanding dengan kod turbo. Walau bagaimanapun, kod LDPC menggunakan algoritma pengekodan dan penyahkodan yang kompleks. Dalam tesis ini, kod LDPC digantikan dengan kod Reed Solomon (RS) untuk mengekod bingkai Wyner-Ziv. Prestasi kod RS dalam melindungi sumber maklumat akan dibandingkan dengan kod LDPC. Oleh sebab kod RS menggunakan algoritma pengekodan dan penyahkodan yang kurang kompleks, keseluruhan jumlah masa sistem dapat dikurangkan dan hasil dapat diperolehi dalam masa yang lebih singkat. Keputusan kajian menunjukkan model yang dicadangkan mencapai pengurangan masa pemprosesan sebanyak antara 9.3% hingga 9.4%, bergantung kepada jujukan video kemasukan dan kualiti jujukan video keluaran yang dapat diterima. Kod RS adalah terkenal dengan kebolehan untuk membetulkan ralat ledakan, yang kebiasaannya wujud dalam saluran yang pudar. Bahagian kedua tesis ini adalah pengurangan jumlah bingkai yang dihantar oleh pengekod. Hanya sebahagian bingkai dari kumpulan gambar yang dihantar oleh pengekod untuk mengurangkan jumlah keseluruhan masa sistem penghantaran. Bingkai-bingkai yang tidak dihantar haruslah dianggar di penyahkod supaya terdapat kumpulan gambar yang lengkap untuk pembentukan semula video keluaran. Keputusan kajian menunjukkan model yang dicadangkan adalah lebih cekap kerana jujukan video keluaran dapat dibentuk dalam masa yang lebih singkat. Model yang dicadangkan mencapai pengurangan masa pemprosesan sebanyak antara 4.0% hingga 4.7%, bergantung kepada jujukan video kemasukan. Tambahan lagi, kualiti bingkai-bingkai yang dianggar oleh model yang dicadangkan mempunyai kualiti yang dapat diterima berbanding dengan bingkai-bingkai kemasukan yang asal.

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ABSTRACT

Recent years have witnessed the increase in demand for fast, efficient, and high quality communication of multimedia applications through the wireless and wired transmission. This has opened up the research area in distributed video coding (DVC) to flourish. The objectives of this thesis are to evaluate efficiency of implementation of different channel encoding schemes in DVC in protecting the source data in channel impairment environment and also reduce the number of frames transmission from the encoder. Most recently, the low density parity check codes (LDPC) are chosen to be the forward error correction technique to encode the Wyner-Ziv frames in DVC as the LDPC has more superior error correction performance than the turbo codes. However, the LDPC involves complicated encoding and decoding algorithm. In this thesis, the LDPC is replaced with the Reed Solomon (RS) codes to encode the Wyner-Ziv frames. Performance of RS codes in protecting source message is compared with the LDPC codes. As the RS codes involve less complicated encoding and decoding algorithm, the overall system time is reduced and the output is obtained in a shorter time. Based on the experiment results, the proposed model achieves a reduction of about 9.3% to 9.4 % in processing time, depending on the input video sequence, with acceptable quality of output video sequence. The RS codes are known for their capabilities to correct burst errors, which are common in fading channel. The second part of this thesis is the reduction of the number of frames transmission from the encoder. Only certain frames in the group of picture are transmitted from the encoder to reduce the overall transmission time of the system. The frames that are not transmitted shall be estimated at the decoder so that there will be a complete set of the group of picture at the decoder for the output video reconstruction. Based on the experiment results, the proposed model seems more effective and efficient as output video sequence could be obtained in a shorter time. The proposed model achieves a reduction of about 4.0% to 4.7 % in processing time, depending on the input video sequence. Moreover, the estimated output frames of the proposed model are also with acceptable quality as compared to the original input frames.

CHAPTER 1

INTRODUCTION

1.1 Preface

The change in the video coding paradigm is motivated by the demand to reduce the computational power for video compression and transmission [1], [2]. In the traditional coding paradigm of digital video, the architecture of the encoder is very complicated and complex. This is mainly due to the task of motion estimation, as all the encoder needs to make all the coding decisions, whereas the decoder only acts as a pure executer based on the orders from the encoder [2], [3]. However, this approach is unsuitable for applications where the users have the interest to produce and transmit video and multimedia, using the lightweight devices, such as their cell phones or mobile devices. Moreover, these devices usually operate with batteries, and hence, the power consumption is a constraint if they need high computational power [4], [5].

As this scenario is rapidly evolving, it calls for a new multimedia coding paradigm, to shift the high computational power to the decoder, in order to keep the encoder as simple as possible for video compression and radio transmission [6]. Distributed video coding (DVC) offers an alternative predictive video coding paradigm, to fulfill this purpose. DVC encodes video frames separately but decodes them jointly as there is no complexity constraint at the decoder [6], [7], [8]. Based on the Slepian-Wolf and Wyner-Ziv theories, the degradation in performance of DVC for separately encoding the video frames is small [9]. In another words, it is indeed achievable to encode two correlated sources independently while obtaining the same efficiency as if the encoder is exploiting the knowledge of both sources [10].

This research of DVC with promising result has eventually led to growing interest in various applications, especially in the wireless transmission [11]. An example of application of DVC is in the monitoring or surveillance systems. There is a network of video sensors or video cameras [12], [13]. Each sensor does not communicate to each other and will independently send the video frames to a common receiving station. There is a central decoder to jointly decode these frames, which are correlated to each other [12], [13], [14]. Therefore, the every potential complex computation is shifted from the sensor sources with limited battery power to a central decoder which is connected to a main power supply [11]. As a result, the constraint of critical power that directly determines the lifespan of a wireless sensor node is solved. Other similar applications of DVC are in the compression of secure biometric data, which requires robust wireless video transmission but the information exchange between the source nodes is neither impossible nor unpractical [11].

As this is a relative new field of study, there is no standard model yet for the DVC [6]. Each researcher is adopting his or her own models or methods, with their own advantages and disadvantages. One model is proposed after another to boost the performance of the previous model or to solve the limitations of the previous model. The state of the art of detailed architecture and operation of every DVC model are discussed in the next chapter in section 2.4.