FRAME ALIGNMENT AND INSERTION ALGORITHM FOR VIDEO STREAM OVER MOBILE NETWORK

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Dedicated to my beloved parents, Alimsyahbana and Yunita.

Thank you for the gene.

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ABSTRACT

Video stream over mobile network has become popular service influencing trend and lifestyle in society. The condition is highly correlated with customer satisfaction that needs to be managed by service stakeholders. One of the efforts is to evaluate their service quality that can be represented by measuring quality of video that they stream to the customer. Peak Signal to Noise (PSNR) is a dominant method to measure video quality that has been widely used. However, PSNR concept cannot be used for video that streamed over wireless and mobile network. It is due to occurrence of packet loss that is inherent in the network and results to frame loss. To overcome this shortcoming, this research proposes an algorithm called frame alignment algorithm to locate frame loss position and do measurement on pair of corresponding frames between frame in reference video and frame in streamed video. This research also enhances the first algorithm accuracy by inserting adjacent frame to the frame loss position, frame insertion algorithm. Simulation of video stream has been conducted to generate video test material, and the proposed algorithms are used to measure quality of the video test material. Performance of the the proposed algorithms are evaluated by benchmarking the experiment result towards the conventional PSNR and the equivalent method, Modified-PSNR (MPSNR) based on Pearson product-Moment Correlation Coefficient (PMCC) value. Based on the result, frame alignment algorithm achieves 0.85 in terms of PMCC value that overcomes inaccuracy of the conventional PSNR that only results 0.77. Frame alignment algorithm also has better performance than MPSNR method that only reaches 0.84. Besides, the investigation on frame insertion algorithm can also enhance accuracy with PMCC value of 0.86. From this result, the proposed algorithms are potential to be used as an alternative method in measuring streamed video quality that still keeps simplicity of PSNR concept but with better accuracy.

ABSTRAK

Aliran video melalui rangkaian mudah alih telah menjadi perkhidmatan popular yang mempengaruhi trend dan gaya hidup dalam masyarakat maju. Keadaan ini berkait rapat dengan kepuasan pelanggan yang perlu diatur oleh pihak berkepentingan. Salah satu usaha adalah untuk menilai kualiti perkhidmatan mereka yang boleh diwakili dengan mengukur kualiti video yang mereka alirkan kepada pelanggan. Kadar isyarat puncak terhadap gangguan (PSNR) adalah satu kaedah utama untuk mengukur kualiti video yang telah digunakan secara meluas. Namun, konsep PSNR tidak boleh diguna untuk video yang dialirkan melalui rangkaian mudah alih. Ia adalah disebabkan berlakunya kehilangan paket yang sedia ada dalam rangkaian dan menyebabkan kehilangan bingkai. Untuk mengatasi kelemahan ini, kajian ini mencadangkan satu algoritma yang dipanggil algoritma penjajaran bingkai untuk mencari posisi bingkai yang hilang dan melakukan pengukuran pada sepasang bingkai yang sama antara bingkai dalam video rujukan dan bingkai dalam video yang telah dialirkan. Kajian ini juga meningkatkan ketepatan algoritma yang pertama dengan memasukkan bingkai bersebelahan bingkai yang telah hilang, algoritma sisipan bingkai. Simulasi aliran video telah dijalankan untuk menghasilkan bahan video dan algoritma yang dicadangkan diguna bagi mengukur kualiti bahan video tersebut. Prestasi algoritma yang dicadangkan dinilai terhadap PSNR konvensional dan PSNR yang dimodifikasi (MPSNR) berdasarkan nilai koefisien korelasi *Pearson product-Moment* (PMCC). Berdasarkan hasil, algoritma penjajaran bingkai mencapai 0.85 dari segi nilai PMCC yang mengatasi ketidaktepatan PSNR konvensional yang hanya menghasilkan 0.77. Algoritma penjajaran bingkai juga mempunyai prestasi yang lebih baik daripada kaedah MPSNR yang hanya mencapai 0.84. Disamping itu, siasatan pada algoritma sisipan bingkai juga boleh meningkatkan ketepatan dengan nilai PMCC daripada 0.86. Daripada keputusan ini, algoritma yang dicadangkan memiliki potensi untuk digunakan sebagai kaedah alternatif dalam mengukur kualiti video yang dialirkan dengan masih mengekalkan konsep kesederhanaan PSNR tetapi dengan ketepatan yang lebih baik.

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LIST OF ABREVIATIONS

4CIF	-	4 Common Intermediate Format
AAC	-	Advanced Audio Coding
ACR	-	Absolute Category Rating
ANSI	-	American National Standard Institute
APSNR	-	Aligned Peak Signal to Noise Ratio
AVI	-	Audio Video Interleave
CIF	-	Common Intermediate Format
CQI	-	Channel Quality Indicator
DCR	-	Degradation Category Rating
DNA	-	Deoxyribonucleic Acid
EURANE	-	Enhanced UMTS Radio Access Network Extension
FR	-	Full Reference
FRUC	-	Frame Rate Up Conversion
HSDPA	-	High-Speed Downlink Packet Access
HVS	-	Human Visual System
IPTV	-	Internet Protocol Television
ITS	-	Institute for Telecommunication Sciences
ITU	-	International Telecommunication Union
MOS	-	Mean Opinion Score
MPEG	-	Moving Picture Expert Group
MPSNR	-	Modified Peak Signal to Noise Ratio
MSE	-	Mean Square Error
NR	-	No Reference
NR-B	-	No Reference Bit
NR-P	-	No Reference Pixel

NTIA	-	National Telecommunication and Information Administration
PC	-	Pair Comparison
PMCC	-	Pearson Product Moment Correlation Coefficient
PSNR	-	Peak Signal to Noise Ratio
QCIF	-	Quadrature Common Intermediate Format
RGB	-	Red Green Blue
RNA	-	Ribonucleic Acid
RR	-	Reduced Reference
TCP	-	Transmission Control Protocol
TDuCSMA	-	Time-Division Unbalanced Carrier Sense Multiple Access
UDP	-	User Datagram Protocol
VoD	-	Video on Demand
VQEG	-	Video Quality Expert Group
VQM	-	Video Quality Metric

CHAPTER 1

INTRODUCTION

1.1 Overview

Video stream service over mobile network has become trend and lifestyle in advanced society. The service has become part of daily activities, either to serve an entertainment or to support communication. Service customers are delighted with variety of video based service such as Video on Demand (VoD), IP television (IPTV), video call, and video teleconference. This promising demand of the service engenders competitive atmosphere among the service providers to attract new customers and to maintain their existing customers. As almost in many services, the condition is highly correlated with customer satisfaction that needs to be managed

In video stream service, service quality that determines the customer satisfaction is mostly influenced by quality of video that received in customer's mobile device (Winkler and Mohandas, 2008). It is known as quality of streamed video. High quality of streamed video ensures satisfaction of the customer. On the other hand, low quality of streamed video degrades customer satisfaction and may cause the customer to switch to other service provider. Based on this proposition, knowing how well quality of the streamed video is essential. In line with this, the role of video quality measurement is also important.

1.2 Background of the Problem

Objective approach is one of popular approach to measure the video quality. For measurement purpose, objective approach uses objective parameter and evolves into wide variety of methods. Winkler and Mohandas (2008) have classified these methods into three categories based on objective parameter that is used to measure the quality. The first category is data-based metric that uses video data such as video signal, video pixel, and bit error to measure the video quality. The second category, picture-based metric, uses inherent visual information such as color perception, contrast sensitivity, and pattern masking to determine the quality. The last category uses header information and encoded bit stream of video packet to define the quality.

The popularity of objective approach is also supported by its advantage over the alternative approach, the subjective approach. Unlike SVQA that conducted in form of quality survey, objective approach uses simple approach with minimum involvement of human resource. It also saves measurement time. Result of objective approach also can be obtained faster than the SVQA that requires additional statistical calculations to process the survey result. Some objective approach also enable in-service and real time measurement that cannot be done by SVQA. These advantages make the objective approach a promising method that can be further developed for wide variety of video service.

Video Quality Expert Group (VQEG) also classifies the objective approach method into other three categories based on requirement of reference video for the measurement process. The three categories are Full Reference (FR), Reduced Reference (RR), and No Reference (NR). FR method needs existence of reference video for quality benchmark of the distorted video. The second category, RR method is similar with FR method but it only requires partial information of the reference video. The last category, NR method, does not use any reference video to measure quality of the distorted video.

Focused on FR category that has highest accuracy among other two categories, Peak Signal to Noise Ratio (PSNR) is one of widely used method (Chih-Heng *et al.*, 2006; Wolf and Pinson, 2009). For example, PSNR is used to measure quality of image that has been processed by digital image watermarking (Divecha and Jani, 2013). For image quality measurement, PSNR also has been improved by considering human visual system as proposed by Jinjian *et al.* (2013).

In video, early application of PSNR measures quality of analog video that is seen as blur in the video (Ojansivu *et al.*, 2003). In digital video, PSNR uses video frame and pixel condition as the objective parameter. It compares every frame in distorted video against every frame in reference video and measures the quality degradation between the two.

PSNR method has been applied in many areas. Supported by its simplicity, PSNR method works well for evaluating video quality in encoding/decoding process such as work by Yong and Kai-Kuang (2003) and Siyuan and Lin (2010). PSNR is also used for benchmarking purpose that evaluates performance of newly proposed objective approach such as used by Fei *et al.* (2007) and Hosik *et al.* (2010). Different research by Korhonen and Reiter (2009) also uses PSNR to analyze impact of bit error on video quality.

Inaccuracy of conventional PSNR is arisen when conventional PSNR is used to evaluate quality of video that streamed over the mobile network. The PSNR does not consider packet loss issue that inherence in mobile network. Packet loss makes quality degradation on video frame and many occurrences of packet loss may lead to frame loss in the streamed video. In case of frame loss, the conventional PSNR blindly compares noncorresponding frames between frame in original video and frame in streamed video. In consequence, the measurement result from the conventional PSNR does not represent the quality of the streamed video.

Regarding the frame loss issue, previous work such as NTIA VQM (Pinson and Wolf, 2004) and work by Engelke *et al.* (2010) also have not explicitly handled the issue. These researches more focus on predicting how the viewer perceives the video quality as an effect of frame losses occurrence.

One of previous research that has tried to consider the frame loss issue is proposed by Chan *et al.* (2010), namely Modified-PSNR (MPSNR). Chan *et al.* (2010) has designed alignment process before PSNR measurement. The idea is to search corresponding frame by comparing PSNR value from every pair of original and streamed video frame. However, the searching process is only limited to five window pairs. The proposed MPSNR cannot search the corresponding frame if there are more than five sequential frame losses.

1.3 Statement of the Problem

Video stream in mobile network has unique characteristic. Firstly, the video is streamed over limited network capacity. Besides that, it uses UDP protocol to satisfy delay constraint in the streaming (ITU-T Recommendation J.144, 2004). UDP, unlike TCP, has unreliable transmission (Chan *et al.*, 2010). The video packet tends to experience variation of delay (jitter). As consequence, the video packet is susceptible to data bit error and even worse, the video packet can be lost during the streaming process. For the data bit error, it introduces quality degradation on video frame or mentioned as frame in the following discussion. On the other hand, the packet loss can lead to frame loss in the streamed video.

The conventional PSNR may encounter accuracy degradation while applied to measure quality of video that streamed over mobile network. While the conventional PSNR is applied to measure this streamed video, conventional PSNR blindly compares frame in streamed video with frame in original video. Therefore, this research addresses the need of pre-measurement step to align every frame in streamed video with its corresponding frame in original video. Based on the need, the research questions that are essential to be answered are:

i. How to find corresponding frame pair between frame in streamed video and frame in original video?

ii. How to consider unpaired original frame that still need to be considered in measurement process?

1.4 Aim of the Research

The aim of this research is to develop frame alignment algorithm to improve conventional PSNR accuracy. Besides that, it is also aimed to develop frame insertion algorithm to consider unpaired frame in the original video. Both of the algorithms are applied on the proposed Aligned-PSNR (APSNR) method.

1.5 Objectives

The specific objectives of this research are:

i. To develop frame alignment algorithm in order to find corresponding frame between every frame in streamed video to frame in original video.

ii. To develop frame insertion algorithm to enhance accuracy of the proposed APSNR.

iii. To test and validate frame alignment algorithm and frame insertion algorithm based on Pearson product-Moment Correlation Coefficient (PMCC) value.

1.6 Scope and Key Assumptions

This research is limited to the following:

i. The frame alignment algorithm and insertion algorithm do not consider audio part in streamed video.

ii. Both proposed algorithms will be implemented in out-of service condition. Therefore, the experiment can access both original and streamed video.

iii. As the proposed APSNR method is categorized into data-based metric, influence of packet error rate does not considered in the measurement. In addition, consideration of packet error rate increases complexity of the algorithm that contrasts with simplicity of the PSNR method.

1.7 Research Contributions

Figure 1.1 highlights the research contributions as hierarchy of contributions. At the top is the main contribution of this research. The philosophy is to improve the conventional PSNR accuracy while applied to measure quality of streamed video. The concept of this philosophy is by finding corresponding frame between original video frame and streamed video frame. In addition, it also inserts adjacent frame to the frame loss position to enhance the accuracy. There will be two proposed algorithm namely frame alignment algorithm and frame insertion algorithm.

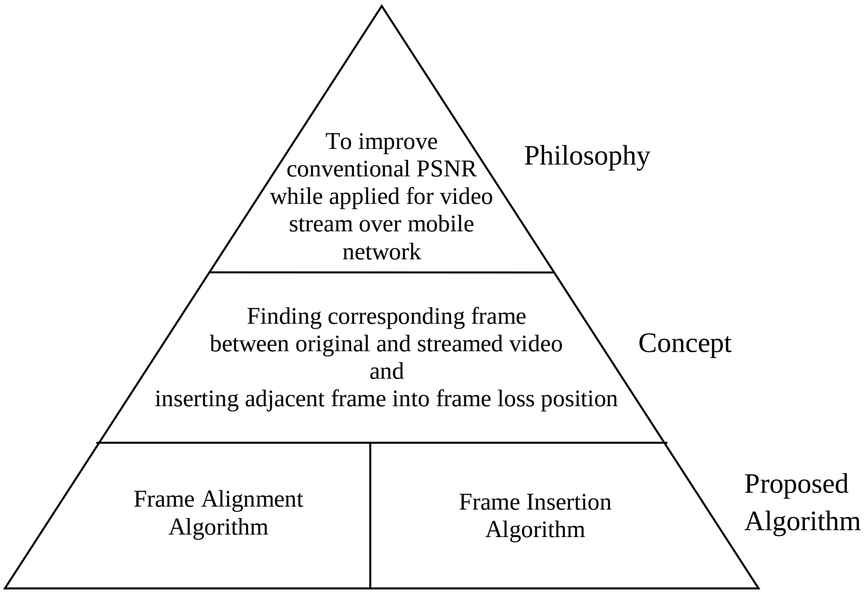

Figure 1.1 Summary of research contributions

1.8 Organization of the Thesis

This thesis is organized into six chapters. Chapter 1 provides introduction of the research. Chapter 2 reviews some literatures that become background information and reference to formulate this research. It involves review of literature on quality composition in video, some perspectives in determining the video quality, approaches to measure the quality, and PSNR method as foundation of the proposed algorithm. Chapter 3 outlines research methodology that used in this research. Chapter 4 focuses on experiment process and result for frame alignment algorithm. Following this, Chapter 5 deals with frame insertion algorithm. It focuses on the conducted experiment and evaluation of the result. Chapter 6 discusses performance of the proposed APSNR. Finally, Chapter 7 concludes the thesis with achievements and future works.

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