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1. Introduction

The rapid increasing amount of mobile devices and video information creates opportunities for mobile video to become the next significant application. However, the viability of mobile video to a great extent depends on the overall user experience (UX), which includes user's requirements and perceptions, system of supporting the service, and context in which mobile videos are used. There is a big challenge to achieve an optimal UX because of the limitations of mobile video itself (such as, heterogeneous mobile devices, limited network bandwidth, and poor-quality videos that are not designed for mobile applications) and the complexity of influence factors of UX.

This study aims to optimise UX on mobile video using a user-centred adaptation strategy and automatic content repurposing. The adaptation strategy can actively adjust the video encoding quality to maximise UX under the current network environment and the specific device capabilities. In order to implement the adaptation, Quality of Experience (QoE) [1] models will be constructed to compute the quality level of user's experience. The automatic content repurposing will be implemented upon the detection and encoding of Regions-of-Interest (ROIs) using the correlation between content features and user's perception.

There are three main contributions of this study. Firstly, the QoE model will be built with multi-dimensional influence factors and upon the results of field user studies to achieve a high consistency in UX of mobile video. Secondly, the adaptation strategy will be flexible and effective to adapt the video bit stream for different scenarios. Finally, the automatic content repurposing will provide video contents designed for mobile applications to meet mobile users' expectations.

2. Related Work

In order to comprehend UX on mobile video (mobile TV), many user studies have been conducted in different countries[2-4]. These studies focused on how UX on mobile video was influenced by social-psychological effects, such as consumption model, service, context, user profile, and their motivations. However, a number of subjective video quality assessments demonstrated that technical factors (e.g., spatial and temporal resolution, bitrate, and content features) significantly influenced user's perceptual quality [5-7]. However, the shortcomings of these studies are that they were conducted in lab environments ignoring the effects of context and type of devices. Although some researchers raised the question – "can content quality criteria be found for Mobile TV as a function of usage situations, watching routines and socio-economic background factors", they could not give a clear answer [8]. Therefore, the important missing in the research field of UX on mobile video is that combination impact of all factors on UX has not been considered thoroughly.

For measuring UX, a commonly used index is QoE (Quality of Experience), recommended by ITU-T [1]. Several studies addressed the QoE modeling based on only transmission parameters [9, 10]. Perkis' QoE model for multimedia services modeled UX as a tree with two branches, differentiating measurable and non-measurable parameters of quality [11]. However, it was theoretical. Nokia suggested two approaches to measure QoE of mobile services: service level approach and network management system approach [12]. Yet, how to implement the QoE measurement was an extremely challenging task.

Another emergent field is video adaptation that is essential for adapting to the limited bandwidth of mobile network, the restricted display ability of mobile devices and the heterogeneous users' needs. Among a lot of adaptive mechanisms, content-aware/based adaptations may be most effective in gaining better user perceived quality under restricted network resources, which adjusted network transmission using the correlation between video content and its perceptual quality [13-16]. Region-of-Interest (ROI)-based video coding may be counted as an adaptive method that generally allocates more encoding bits to ROI than other regions for taking into account both bitrate limitation and user's perceptual quality. However, there is still a great gap in understanding and utilizing the correlation due to the extreme complexity of user's perception. Moreover, the user perceived video quality cannot represent the user experience on video that is influenced by system effects, user expectations and context. Hitherto the effective UX-oriented adaptation scheme has not been exploited to control or provide good UX in various scenarios.

In addition, some researchers argued that media adaptation can not be achieved merely by adjusting encoding or transmission parameters, content must be edited specially for the type of terminals [7, 17]. A few studies have attempted in this aspect [18, 19]. Unfortunately, they did not offer insights into the area of how to edit contents for mobile devices to guarantee an optimal user perception. So far "made-for-mobile content" is still an unsolved problem [17].

3. Research Problem

Regarding to the existing challenges in understanding and modelling of user experience (UX), effective adaptation and content re-edition, the research problems confronted in this study are illustrated in Figure 1.

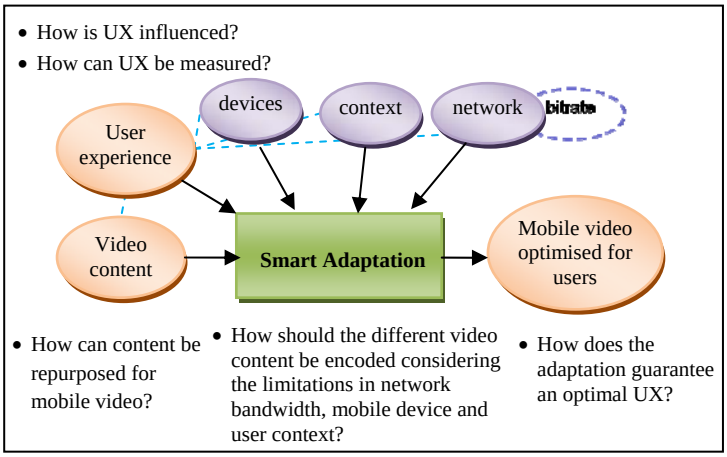

Figure 1. Overall of research problems

This figure also shows the process of mobile video coding and the relationships of all kinds of components. First of all, users' viewing experiences are related to mobile devices, network bandwidth (or bitrate), context, users themselves, video contents, and the technical parameters for coding the video content. But how do these factors influence UX? And how can UX be measured? Second, since an optimal UX is the target to be achieved, a smart adaptation should consider all limitations and influences on UX. The problem here is how to implement this adaptation. Furthermore, for the user-accepted mobile video, how can we know whether the adaptation can guarantee an optimal UX? Finally, in the input end, the issue is how to automatically repurpose the regular video content with high resolution into mobile videos based on user's perception and content features.

Concluding the above discussion, the research questions can be boiled down to:

- How is UX on mobile video influenced by technical and non-technical factors?
- Is it possible that UX on mobile video can be modeled? How?
- How to implement an adaptive coding to maximise user's viewing experience on mobile video?
- How can the existing video contents be automatically repurposed for mobile video applications?

4. Methodology

In order to resolve the above problems, field user studies are necessary to gather more reliable user data than that gained in a lab, and then to deeply understand how user experience on mobile video is impacted. Based on the understanding, an adaptation strategy of mobile video is proposed in this study, aiming to achieve an optimal user experience in various scenarios. The implementation framework consists of three steps: 1) data collection; 2) data analysis and QoE modelling, and 3) adaptation design and application.

4.1 Data Collection

For collecting proper and confidential data, some critical issues need to be carefully determined.

1) What indicators should be involved? The indicators represent the possible influence factors of quality of user experience. In this study, they are defined as technical indicators (whereby it refers to the factors that can be adjusted with the video coding technique): bitrate, frame rate, spatial resolution, and quantization scale, and non-technical indicators: content type, context, screen size of mobile device, memory capacity of mobile device, user profile. The selection is based on the results of literature review and the pilot study on subjective video quality assessment.

2) Where, when and from whom to collect data? The typical time and place that mobile video viewing happens will be chosen. Around 50-60 recruited participants are required. While, as supplementary, 10-20 participants might be randomly selected volunteers in testing contexts when data are inadequate for analysis.

3) What materials and tools are being used? Considering type, duration, encoding parameters of video content, several rationales will be used for choosing video content. Firstly, the types of video content should be broadly representative; secondly, the materials should be not those made for lab tests; thirdly, each content will last 2-10 minutes and be encoded with H.264/AVC (MPEG-4 part 10) standard. Testing tools includes mobile phones for displaying videos and voice recorders (/recorder software) for recording participants' responses.

4) What methods will be used? The user data collection will involve both qualitative and quantitative research. Following a long term survey which allows participants to assess their viewing experiences in field testing environments, interviews will be conducted for knowing user's requirements and their opinions of how to obtain better experiences on mobile videos.

4.2 QoE modelling

With the collected user data, data analysis can be performed in two ways: qualitative data analysis and quantitative analysis. The former tries to answer the question: what is "made-for-mobile content" in user's perspective? While, the later aims to answer the question: what is the correlation between all factors and UX?

In this study, qualitative analysis will use thematic analysis method, which focuses on identifiable themes and patterns of behavior or experience. Discrimnant analysis (DA) and multiple regression analysis (MRA) will be adopted for quantitative analysis. The purpose of DA is to select the features of impacting UX and to classify the rule of distinguishing typical scenarios. MRA suits to find out how numerical artefacts influence UX, so that the models of measuring quality of experience (QoE) can be built.

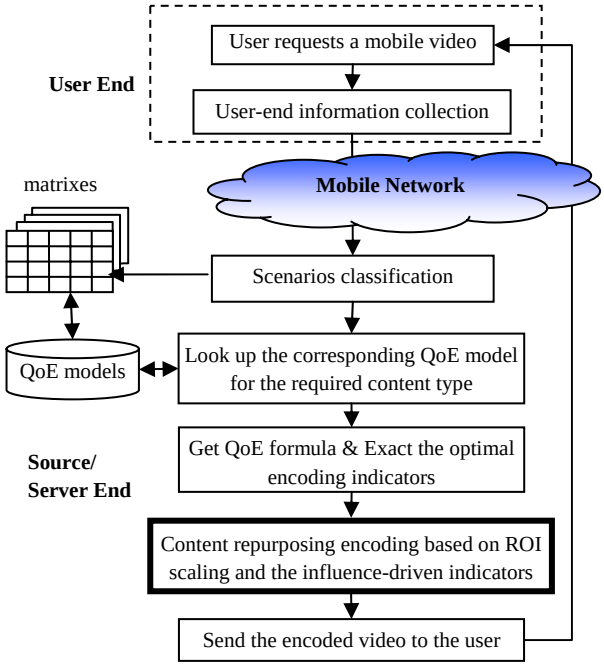

Figure 2. Adaptation process

4.3Adaptive strategy

Figure 2 gives the detail adaptive process. It consists of five steps.

Step1, when a user starts to request a certain video content, the user-end information is sent to the Server with the content request together. What user-end information needs to be collected depends on the results of data analysis. Step 2, as soon as user-end information arrives to the Server, it will be identified as a certain category by matching the pre-defined classification matrixes. Then, in line with the one-to-one mapping relationship between categories and QoE models, the corresponding QoE model can be easily picked up from the model pool. Step 3, from the selected QoE model two messages can be extracted: 1) the indicators influencing UX and their coefficients; and 2) the computing formula of UX. Step4, the extracted messages will be used to control the encoding process. Content repurposing is performed automatically in this step as well. Based on the features of visual perception and mobile devices, Region-of-Interest (ROI) will be detected, cropped and resampled. Then, the ROI will be encoded under certain principles of QoE control, which is designed according to the degree of influencing indicators and coefficients, in order to assure the value of QoE is greater than a specified threshold that indicates the level of user experience assigned. Step 5, the encoded video stream will be sent to the user with guaranteeing a good use experience.

4.4 Evaluation

The designed process of adaptation need be verified. It will be done in three aspects:

Firstly, for testing the consistency of QoE model with the real UX, several collected user data will be reserved without taking part in the QoE modeling. When testing, the estimated UX scale by QoE model will be compared with the user's rating scale. And the consistency is defined as variance is less than 0.5. Secondly, a subjective quality assessment with Pair Comparison (PC) method [20] will be conducted for evaluating whether the repurposed contents are better than the original contents. Thirdly, through another user study in a practical application, the significance of the whole solution will be valued. The effectiveness of the proposed approach will be judged with the criterion: the mean score of UX is not less than 3 (which is defined as good) and the variance is 0.5.

5. Preliminary Results

Technical factors have significant impacts on User Perceived Quality (UPQ) of video. In order to prove if some certain correlations exist and if they can be figured out, a pilot study on subjective video quality assessment was conducted between April and Jun of 2009. This assessment experiment employed H.264/SVC as the coding standard and involved a number of influence factors – content, bitrate, spatial, temporal and quality scalabilities (i.e., image size, frame rate, and quantization quality). In this experiment, eight representative contents were used as the testing materials, which cover different types of sports, panoramic, news, and persons; and three methods were employed: Absolute Category Rating (ACR) , Degradation Category Rating (DCR) and Pair Comparison (PC), recommended by ITU-T [20]. In spite of the lab environment and limited 26 participants with different age, gender, and experience with image processing, the findings from this study are meaningful [21].

First, there is an obvious correlation between video content and UPQ, but the degree of the correlation is affected by spatial resolution, quantization quality and frame rate. It supports the idea that multidimensional QoE mapping is necessary for gaining an optimal visual perception.

Second, motion, as an important characteristic of video content, exerts a great impact on UPQ. This impact is not only from motion intensity (fast or slow), but also the proportion of motion area and varying frequency of motion direction. This finding can contribute to the content repurposing.

Third, the results about bitrate and UPQ indicate that if proper encoding parameters are used in terms of content characteristics, bitrate saving can be achieved and bandwidth restriction can be met without decreasing perceptual quality significantly.

Finally, there is no evidence that personal preference for content type (e.g., sport) is related to the perceptual quality. However, it is not sure whether the same result can be obtained when the assessment is done outside of the lab. On the other hand, people's experience with image processing to the extent impacts on UPQ; and it is interesting that the impact is dependent on content. It reveals that user perceived video quality is also sensitive to non-technical factors and further field studies should be carried out to find out the correlation.

6. Summary

For meeting the challenge of optimising user experience (UX) on mobile video, this study proposes a QoE-based adaptive strategy, which employs QoE models as criteria to control the video coding and uses ROI-based content repurposing to improve user's visual perception. The preliminary study on user-perceived video quality has been partly proved the necessity and feasibility of the proposed approach. Since this research will be built upon a field user study, its outcomes will benefit user-centered mobile video applications. It is reasonable to imagine that whenever and wherever users watch videos on their mobile devices, they can gain optimal experiences: the content is edited specially for their display terminals; the clarity and smoothness of the video is designed for low bitrate bandwidth but keeping a good perceptual quality; and the dynamic adjustments are exerted on the coding processing for adapting to various viewing contexts or user profiles.

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