Understanding the role of social context and user factors in video Quality of Experience

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ABSTRACT

Quality of Experience is a concept to reflect the level of satisfaction of a user with a multimedia content, service or system. So far, the objective (i.e., computational) approaches to measure QoE have been mostly based on the analysis of the media technical properties. However, recent studies have shown that this approach cannot sufficiently estimate user satisfaction, and that QoE depends on multiple factors, besides the media technical properties. This paper aims to identify the role of social context and user factors (such as interest and demographics) in determining quality of viewing experience. We also investigate the relationships between social context, user factors and some media technical properties, the effect of which on image quality is already known (i.e., bitrate level and video genre). Our results show that the presence of co-viewers increases the user's level of enjoyment and enhances the endurability of the experience, and so does interest in the video content. Furthermore, although participants can clearly distinguish the various levels of video quality used in our study, these do not affect any of the other aspects of QoE. Finally, we report an impact of both gender and cultural background on QoE. Our results provide a first step toward building an accurate model of user QoE appreciation, to be deployed in future multimedia systems to optimize the user experience.

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1. Introduction

Online video services show a continuous growth. By 2010, over 71% of internet users had watched videos online, and this number grew from 33% in 2006 (Moore, 2011). These figures are forecasted to further grow in the coming years (Cisco, 2012; Moore, 2011). With a constantly increasing volume of streamed video data, maintaining a satisfactory video service to users at all times is challenging for internet and multimedia providers. Due to different technological limitations (e.g., bandwidth and storage constraints, network malfunctioning), visible artifacts (e.g., blockiness or blur due to compression, freezes or jerkiness due to transmission errors) can be introduced to any stage of the video delivery cycle (Pérez, Macías, Ruiz, & García, 2011; Wang, Speranza, Vincent, Martin, & Blanchfield, 2003). This, in turn, can severely degrade the user's satisfaction, and evidence shows that users intend to pay less if a service cannot meet their expectations (Naumann, Wechsung, & Hurtienne, 2010; Yamori & Tanaka, 2004). As a consequence, online video providers are eager to find ways to measure

and predict user's satisfaction with videos in order to optimize their video delivery chains.

Quality of Experience (QoE) is a concept commonly used to describe user's overall satisfaction (Le Callet, Möller, & Perkis, 2012), reflecting the degree of delight or annoyance of a user with a (multimedia) system, service or application. In the past decades, user's satisfaction with videos has been estimated mainly from a technical perspective, i.e., based on either the information gathered from the network and service conditions or from image and video analysis (Serral-Gracià et al., 2010). From a network management perspective, the concept Quality of Service (QoS) has often been equated to QoE. Here, network parameters, such as packet loss or delay (Asghar, Le Faucheur, & Hood, 2009), as well as video QoS parameters, e.g., the so-called join time at the start of playing the video or the buffering time during the video (Dobrian et al., 2011), were monitored; their compliance to given standards was considered enough to guarantee sufficiently high QoE. The signal processing community has instead relied more often on the analysis of information extracted from the decoded image/video signal to estimate the visibility of artifacts in it (Hemami & Reibman, 2010; Lin & Jay Kuo, 2011). Artifact visibility was considered to be inversely related to perceptual quality, and therefore to user satisfaction (Chikkerur, Sundaram, Reisslein, & Karam, 2011). In

both cases, user satisfaction was mainly associated to technical properties of the multimedia signal, service or system.

Lately, research has shown that this approach has limitations, and that other elements concur to guarantee user satisfaction when watching video (Le Callet et al., 2012; Zhu, Heynderickx, & Redi, 2014). For example, recent studies claimed that QoE should also be considered from a user perspective (De Pessemier, De Moor, Joseph, De Marez, & Martens, 2013): evidence has been provided that user's interest (Kortum & Sullivan, 2010) and personality (Wechsung, Schulz, Engelbrecht, Niemann, & Möller, 2011) influence QoE too. Such findings reveal the complexity of QoE: it is a combination of many influencing factors, not limited to QoS parameters nor artifact visibility.

Influencing factors on QoE are often grouped into three categories, i.e., system, user and context factors (Le Callet et al., 2012). *System* factors concern the technical aspects of a multimedia system (e.g., network parameters, media genre and media configuration). *User* factors refer to individual characteristics of the user who is experiencing the video (e.g., demographics, personal interest or personality). *Context* factors refer to the characteristics of the environment within which the video experience is consumed (e.g., physical features of the environment, economical factors related to the video fruition, presence or absence of co-viewers). As mentioned earlier, most research in the field has focused on system factors, leaving the contribution of user and context factors largely unexplored. However, the rise of online video fruition has created a shift from a passive viewing experience to a more active, personalized and shared experience, changing the traditional television market considerably (Tercek, 2011). Compared to traditional TV users who just watch scheduled programs, internet users are free to choose the content they want, at any point in time and space they want, through a variety of devices (e.g., tablets, smartphone or computers). Thus, it is expected that personal characteristics as well as context of fruition will play an important role in such viewing experiences. Moreover, the rise of social media has led to a new type of social viewing experience, where preferences for video content are clearly reported on social media platforms (through comments and ratings), and are visible to the rest of the (vast) online community. The social context in which the video is experienced is therefore expected to play a key role in the eventual user satisfaction.

As the optimization of online video watching requires a more in-depth understanding of the impact of user and context factors on QoE, we here want to contribute to the generation of this knowledge by considering the impact of social context in particular. Interestingly, very little is known about how social context (1) relates to QoE and (2) combines with system and user factors to determine the final user satisfaction with the viewing experience. We specifically focus on what we define as "direct" social context, that is, the presence or absence of co-viewers in the physical proximity of the user. We report the outcomes of an empirical study looking into the role played by direct social context in determining QoE when given system factors (i.e., video genre and bitrate) are in place. Furthermore, we analyze the interactions of direct social context with user influencing factors such as demographics, interest in the video genre and immersive tendency. We measure six different aspects of the viewing experience, namely perceived video quality, enjoyment, endurability, satisfaction, involvement and information assimilation. The outcomes should support building an accurate objective model for QoE on the longer term.

The paper continues by presenting the related work in Section 2, which we reviewed to define the hypotheses for the empirical study as described in Section 3. We then outline our experimental methodology in Section 4, followed by the analysis of the results in Section 5. We discuss our findings in Section 6, leading to the most important conclusions in Section 7.

2. Related work

In the past decades, the effectiveness of multimedia services has been linked to the notion of Quality of Service (QoS), defined as the "totality of characteristics of a telecommunication service that bears on its ability to satisfy stated and implied needs of the user of the service" (ITU-T, 1994). QoS is mainly operationalized in terms of system and network performance-related measures (e.g., packet loss ratio, jitter or delay). This approach has started showing its limitations, and was found to be poorly correlated to user satisfaction (Brooks & Hestnes, 2010). As a result, the Quality of Experience concept has emerged, being defined as "the overall acceptability of an application or service, as perceived subjectively by the end-user" by ITU-T (2007). Compared to QoS, the notion of QoE has taken a user-centric perspective, now keeping user perception into consideration. Remarkable work has been done in estimating QoE from a perceptual point of view (Hemami & Reibman, 2010; Lin & Jay Kuo, 2011).

Recently, the Qualinet White Paper (Le Callet et al., 2012) has proposed an even more compelling definition of Quality of Experience:

> "*Quality of Experience (QoE) is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state*".

Although both the ITU-T and the (Le Callet et al., 2012) definitions describe a similar concept, the latter seems more complete than the one of ITU-T, as it emphasizes how user-related factors, e.g., personality and current state, may have an impact on QoE. Given the evidence of the importance of such factors in properly estimating QoE (which will be explained in detail in Section 2.1), we use the Qualinet definition as operational definition of QoE throughout this paper.

2.1. Factors influencing QoE

Quality of Experience is a multifaceted quality, resulting from the interaction of multiple influencing factors, which are reviewed here in more detail, although not in an exhaustive way. As shown in Table 1, these factors can be arranged into in three categories, namely system factors, user factors and context factors (Le Callet et al., 2012).

System factors refer to the system, application and media "properties and characteristics that determine the technically produced quality of an application or service" (Jumisko-Pyykkö, 2011). Within video delivery services, system factors can influence QoE by altering the perceptual quality of the video (Serral-Gracià et al., 2010). For example, a given type of compression (e.g. H.264/AVC), aiming at obtaining a given bitrate for the video, possibly generates compression artifacts (e.g. blockiness, blur and ringing), which, if visible, result in annoyance for the user, lowering his/ her satisfaction. Similarly, network QoS parameters (Dobrian et al., 2011), and the media configuration (Gulliver & Ghinea, 2006) are known to have an impact on QoE. For example, it has been shown that the buffer ratio (i.e., the fraction of time spent in buffering over the total session time, including playing plus buffering) is inversely related to QoE (Dobrian et al., 2011), and similar conclusions were reached for other QoS parameters, such as the join time in multicast video delivery, the buffering duration, the rate of buffering events, the average bitrate and the packet loss rate (Ickin et al., 2012; Mok, Chan, & Chang, 2011). Besides the signal/network factors, user's QoE with video also may be influenced by the nature of the video content itself (Balachandran et al., 2012). Different genres