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Benchmarking handheld graphical user interface: Smoothness quality of experience☆

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ABSTRACT

With the rapid growth of smartphones in the market, the smoothness of smartphones, how quickly and well smartphones react to a user's input, becomes a crucial factor consumers consider when making buying decisions. However, there is no benchmark for comparing the smoothness of one phone against another. In this paper, a handheld smoothness evaluation over regression (HSER) model was developed to make a fair evaluation. A video was first made and the several key indexes were extracted to represent behavior-based smoothness quality of services (BQoS). We built up a relationship between BQoS and behavior-based smoothness quality of experience (BQoE), and converted BQoE to handheld smoothness quality of experience. Our experiment results show that maximal frame interval and number of frame intervals are the two most critical indexes that indicate smoothness. The proposed HSER model is able to fairly evaluate the smoothness of smartphones because the error rate of the HSER model is less than 9% for a single behavior.

1. Introduction

Nowadays, mobile applications become more and more pervasive in our daily life as the number of smartphones in use accelerates. Among the variety of mobile applications, the most essential ones include web browsers, instant messaging, multimedia entertainment, intelligent and adaptive agents and mobile games. The user interfaces of these mobile applications differ from that of traditional desktop applications. All these mobile applications are triggered by multi-touch gestures, such as tap, double tap, and scroll, rather than keyboard or mouse. The smoothness of touch screen response has become one of the crucial factors considered by consumers in making their buying decisions. In this work, smoothness of smartphones is how quickly and well smartphones react to a user's input. Smartphone manufactures and mobile app designers are also interested in how their products perform with respect human-computer interaction compared to others. It has therefore become opportune to develop a way to benchmark the quality of smartphones, particular in respect of smartphone-user interaction.

A simple and intuitive method to assess user experience in mobile GUI (Graphical User Interface) is to refer to hardware specifications, such as CPU speed, GPU speed and memory size. However, hardware specifications cannot fully represent the smoothness of human-device interaction because software implementation can also affect system performance. A smoothness benchmark should

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contain a set of user interface (UI) operations and appropriate performance indices to fairly evaluate the smoothness of smart-phones. Another method of accessing user experience is to conduct a survey using questionnaires. It will, however, be costly to conduct such a survey for each and every new smartphone. Our research goal in this work is to design a set of UI operations and representative indexes to measure the smoothness of smartphones.

1.1. Indexes of smoothness

Frame rate is the most commonly used index to measure the smoothness of a video. The higher the frame rate becomes, the better the quality of played-back video becomes. However, Tian et al. [1,2] found that two videos with the same average frame rate can provide very different user experiences, because one may abruptly drop a large number of frames while another may maintain an uniform frame rate. Some researchers adopted packet loss rate and network delay to evaluate the smoothness of an online game or of network streaming [3–6]. Although these indexes can reflect user experience of human-interactive applications, they were not able to cover all aspects of smoothness of smartphones, especially when the smartphones under test were carried out in the same network environment. Yoon [7] also found that the off-the-shelf hardware benchmark applications, such as AnTuTu-Benchmark and SmartBench, are not able to evaluate the interaction between smartphones and users, because both hardware specifications and software can affect system performance. Traditional hardware performance metrics can thus not fully evaluate the smoothness of smartphones. As a result, it has become necessary to develop a new method to measure the smoothness of smartphones.

1.2. Handheld smoothness evaluation over regression

In this work, behavior-based smoothness quality of experience (BQoE) was used to quantify the smoothness of an application. For example, making a phone call is a particular pattern of behavior, which includes a sequence of operations, such as browsing a list of contacts and tapping phone numbers. In order to measure BQoE, we first measured behavior-based smoothness quality of service (BQoS), which is service performance used to determine user satisfaction. In order to determine BQoS, a video was recorded and several key indexes were extracted. These key indexes included the mean of frame intervals (MFI), variance of frame intervals (VFI), maximal frame interval (MaxFI), frame no response (FNR) and times of maximal frame interval (TMaxFI). Since the indexes may not always be measurable, especially when the changes between frames are fast. A tool, named Ex-DOS (extraction of device operation sequence), was developed to obtain the necessary information. The previous data extraction process was repeated to obtain the same indexes from different videos that represented different user scenarios, such as calling a contact, downloading a web page or an application. Based on the BQoS obtained, we then designed a questionnaire to determine the relationship between BQoS and BQoE. Finally, the BQoE was converted to handheld smoothness QoE (HQoE) by considering how frequently each behavior is performed in daily life.

In order to evaluate the effectiveness of the proposed method, several experiments were conducted on three different smart-phones, HTC hero, Huawei U8860 and Nexus S. The applicability of our handheld smoothness evaluation over regression (HSER) model has been investigated in different user scenarios. Some user scenarios are time-critical, such as making a phone call, while others are not, such as browsing a web page. The correctness of the HSER model was validated by comparing it to our questionnaire results. The rest of this work is organized as follows. Section 2 motivates this work and reviews related work for comparison. Section 3 defines the variables we used in this work and describes our problem statement. Section 4 derives the mapping from BQoS to BQoE and illustrates its implementation. Section 5 presents an evaluation. Finally, Section 6 concludes this work and indicates future directions.

2. Background and related work

2.1. Challenges of benchmarking smoothness

As far as we know, there is no standard way to benchmark the user experience of a smartphone's smoothness. Response time and frame rate per second (FPS) are two commonly used indexes to evaluate the interaction of human with smartphones. According to Nielsen's [8] and Miller's [9] investigation, 0.1 s is the minimum delay that human can sense. When the delay increases to 1 s, it makes the application feel sluggish. Further, if the delay is longer than 10 seconds, users will switch to other tasks. Similar results can be found in [10], in which 0.2 s was found to be the minimum threshold for human to perceive a delay of an application.

For playing a video, a minimum of 20 FPS is recommended. Any speed below 20 FPS will result in a noticeable delay and the user will become aware of choppiness and discrete images. However, these indexes can only reflect the smoothness of one action; they are not able to evaluate the smoothness of the whole system. Furthermore, same operations with the same response time may lead to different user experiences because the changing frames displayed on a smartphone may be different, because some videos perform smoothly at an early stage while others may perform smoothly at a later stage.

2.2. Methods of recording changing frames

In order to automatically analyze the smoothness of a smartphone, it is necessary to record the interaction between a person and a smartphone. In previous work, we developed an automated GUI testing tool to test application user interfaces and to verify their functionalities [11]. Such interaction can be captured by either an internal recorder or an external camera. An internal recorder is a