Dissecting the End-to-end Latency of Interactive Mobile Video Applications

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ABSTRACT

In this paper we measure the step-wise latency in the pipeline of three kinds of interactive mobile video applications that are rapidly gaining popularity, namely Remote Graphics Rendering (RGR), Mobile Augmented Reality (MAR), and Mobile Virtual Reality (MVR). We show through extensive measurements that control input and display buffering have a substantial effect on the overall delay. Our results shed light on the latency bottlenecks and the maturity of technology for seamless user experience with these applications.

1. MEASUREMENT SETUP

The measurement setup uses an Arduino compatible board (Teensy LC) connected to the phone through a USB connection. The board is configured to act as a joystick in addition to a serial connection through the USB. This enables us to enter key presses to the mobile device. To simulate touch presses, we use a coin attached to a relay which closes a connection loop to the human tester when activated. This in turn enables us to precisely measure the time when a touch is initiated on the display as the coin conveys the touch input when the relay is activated without user interaction. In addition two photodiodes catch the time when a frame has been updated on the display of the mobile device. The measurement board has also an Ethernet shield attached for Internet connectivity. For the virtual reality application experiments a reference gyro value is attached to compare the responsiveness of the gyro sensor inside the mobile phone.

2. RESULTS

The measurements show that the two major components affecting the overall delay in latency-critical mobile video applications are control delay and frame display. This can be observed in the summary presented in Figure 1. The magnitude of the control delay is highly dependent on the type of input used by the application. A modern mobile device can send gamepad commands to a remote server in a matter of milliseconds while an AR application can wait up to 90 ms to even get a frame from the camera for processing. Top-of-the-line mobile phone (Samsung S7) can process touch and Bluetooth events in roughly 20 to 30 ms while the gyro sensor events arrive faster with an average of 12 ms of delay. Touch screen delays seem to get lower with each mobile phone generation. The gyro sensor delay is also very small with recent mobile phones. The camera feed to the application would however benefit from further optimizations.

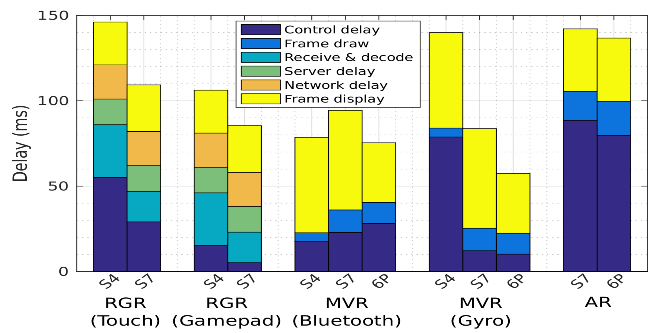

Figure 1: Summary of the measured delay scenarios.

Drawing and displaying a single frame is processed in approximately 25 ms in the RGR scenario where a video stream is received and decoded. Rendering a scene takes longer, we measured a delay of almost 60 ms to display a VR scene for both eyes in a head-mounted setup. Using the latest features of the Android OS, this can be lowered to 35 ms.

Previously, Deber et al. have characterized the Just Noticeable Difference (JND) and the impact of additional latency on task performance in user interaction with a touch device[1]. They found that the mean JND for a simple tapping task is 69 ms and 96 ms for direct and indirect touch, respectively. A comparison of these JND numbers to the results on touch, gamepad, and Bluetooth-based controls in Figure 1 reveals that only the VR case with Bluetooth-based control can reach end-to-end latency below the JND limit of tapping latency in the best case.

3. REFERENCES

[1] J. Deber, R. Jota, C. Forlines, and D. Wigdor. How much faster is fast enough?: User perception of latency & latency improvements in direct and indirect touch. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 1827–1836. ACM, 2015.

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