Example measurement report

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1 Introduction

This document is a measurement report that assesses the performance of Oculus Go virtual reality headset. OptoFidelity BUDDY-3 was used for the measurements, which is an instrument used to measure temporal performance of head-mounted displays.

In the document, section 2 shows the measurement procedure and results. Section 3 introduces the performance score, which is the way OptoFidelity rates the headsets, as well as shows the performance score of the headset in question.

2 Measurements

To determine the tracking quality of the HMD, a series of measurements were made. This section shows the measurements and their results. First, the motion-to-photon latency for both predicted and unpredicted movement was measured. After that we measured motion tracking related characteristics such as jittering, drifting and prediction overshoot.

The measurements were carried out using a calibrated OptoFidelity BUDDY-3. The calibration was done using Leica laser tracking system. Headset was firmly mounted on the robot, and the robot was placed on a sturdy table minimizing any vibration from the environment.

2.1 Motion-to-photon latency

Motion-to-photon latency is defined as the time it takes from the user movement to be reflected on the HMD display. Motion-to-photon latency was measured by continuously rotating the HMD one rotational axis at a time, be tween -30 deg and 30 deg. The HMD content orientation was compared to true robot orientation for each display refresh cycle, and motion-to-photon latency was calculated as a time offset between the robot and HMD content orientation curves.

The measured motion-to-photon latency for all three rotational axes is represented in table 1. Range shows the minimum and maximum value for latency during continuous movement.

Table 1: Motion-to-photon latency

Axis	Median latency	Range
Yaw	3 ms	2 ms to 6 ms
Pitch	3 ms	2 ms to 5 ms
Roll	3 ms	2 ms to 6 ms

In addition, a latency with a sudden movement was measured. This was done by keeping the HMD still for 10 minutes, after which the yaw axis was rotated at full speed and accuracy (600 $^\circ/s$, 3000 $^\circ/s^2$). Latency during a sudden movement was 17 ms.

2.2 Jitter

From the user's perspective, jittering makes it look like the virtual world is shaking. It can be detected as any sudden change in HMD content. To measure jitter, the robot orientation was substracted from HMD content orientation at each point to get the tracking error at each point. To filter out drifting and other slow effects, the error was passed through a high-pass filter with a cut-off frequency of 4 Hz.

The filtered signal shows any high-frequency changes in HMD orientation error. As BUDDY-3 accuracy is 0.1 degrees, anything change less than that was left out of the calculation. The resulting signal is used to estimate the jitter level. Two metrics are used to indicate the jittering severity:

– Mean absolute deviation, showing the mean jitter level over the whole measurement.

– Maximum absolute deviation, showing the largest sudden change in HMD pose.

Jitter level was measured both during movement and when stationary. The results are listed in table 2. The values are listed in millidegrees.

Table 2: Jitter level

Stationary jitter		
Axis	**Mean absolute deviation**	**Maximum absolute deviation**
Yaw	0.91 m°	0 m°
Pitch	0 m°	0 m°
Roll	19.1 m°	240 m°
Movement jitter		
Axis	**Mean absolute deviation**	**Maximum absolute deviation**
Yaw	1.12 m°	162.5 m°
Pitch	0.0 m°	0 m°
Roll	32.5 m°	338 m°

2.3 Movement accuracy

Movement accuracy was measured for drifting and prediction overshoot. Drifting refers to the HMD losing it's position over a period of time. Movement prediction overshoot happens when the user movement stops while HMD content continues moving.

Drifting was measured by moving the robot randomly for 1 minute, and then stopping for 10 seconds. Robot and HMD content orientation was recorded after the 10 second pause. This was repeated 15 times to get an overall estimate of the drifting. Overshoot was be measured by stopping the robot from full speed and recording the changes in robot and HMD orientations. Results are listed in table 3, where we show the total drift after 17 minutes as well as the minimum and maximum drift angle.

Table 3: Drifting

Axis	**Drifting range**	**Drift after 17 minutes**
Yaw	-4.3 ° to -1.3 °	-1.5 °
Pitch	0 ° to 0.21 °	0.0 °
Roll	-0.1 ° to 0.04 °	0.3 °

3 Performance score

From the measurement results, a performance score of the HMD tracking can be given. Six parameters are used for determining the score. The parameters are introduced in table 4. While the measurements were made using all three axes, we chose the worst axis for each parameter.

A result below the acceptable level is considered good enough for consumer VR products. As all the parameters describe an error or latency, the optimal value is zero, which corresponds to an ideal real-world scenario.

HMD measurement results were normalized against the acceptable levels described in table 4. A scale from 0 to 5 is used. The normalized parameters are listed in table 5 and visualized in figure 1.

Table 4: Performance score

Parameter	Acceptable level
MTP latency	20 ms
MTP latency with a sudden movement	32 ms
Jitter: mean absolute deviation	40 m°
Jitter: max absolute deviation	500 m°
Prediction overshoot with sudden stop	0.5 $^{\circ}$
Maximum drift	8 $^{\circ}$

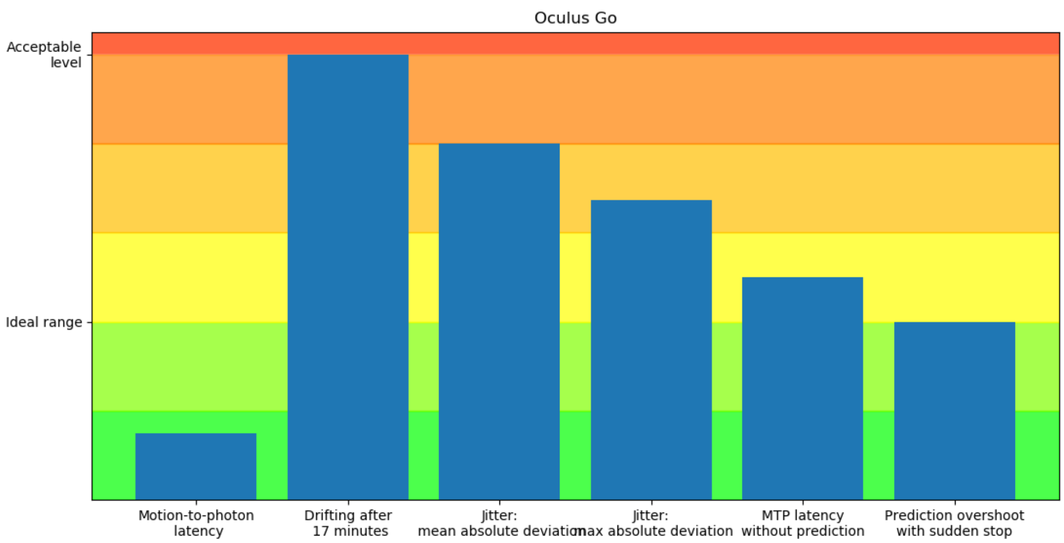

Figure 1: Normalized HMD parameters

Table 5: Performance score

Parameter	Score (0 - 5)
MTP latency	0.75 ms
MTP latency with a sudden movement	2.5
Jitter: mean absolute deviation	4.0
Jitter: max absolute deviation	3.37
Prediction overshoot with sudden stop	2.0
Maximum drift	5.0
Mean score	**2.94**

4 Conclusions

The measured device results are typical for consumer devices from the lower price range. The weakest performance was measured in drifting and jitter, while the latency was at a good level.