# Measurement of 3D-Velocity by High-Frame-Rate Optical Mouse Sensors to Extrapolate 3D Position Captured by a Low-Frame-Rate Stereo Camera

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**ABSTRACT**

The frame rate of existing stereo cameras is not enough to track quick hand or finger actions. It also requires lots of computational cost to find correspondence between stereo images to compute distance. The recently commercialized 3D position sensors such as TOF cameras or Leap Motion needs strong illumination to ensure sufficient optical energy for the high frame rate sensing. To overcome these problems, this paper proposes to use a pair of optical-mouse-sensors as a stereo image sensor to measure 3D-velocity and use it to extrapolate 3D position measured by a low-frame-rate stereo camera. It is shown that quick hand actions are tracked under ordinary in-door lighting condition. As 2D velocities are computed inside the optical-mouse-sensors, computation and communication costs are drastically reduced.

**Keywords**: high speed camera, stereo camera, optical mouse sensor, extrapolation, 3D position.

**Index Terms**: H.5.2 [Information Interfaces and Presentation]: User Interfaces; H.1.2 [Models and Principles]: User/Machine Systems

## 1 INTRODUCTION

Human actions should be tracked with a high degree of accuracy and a low degree of latency to improve the reality and usability of virtual reality applications [1]. Errors or latency in tracking causes stresses or frustrations to users. One of the factors affecting the errors and the latency is the frame rate when an image sensor is used for tracking [2]. The frame rate of existing stereo cameras is not enough to track quick hand or finger actions. It also requires lots of computational cost to find correspondence between stereo images to compute distance. The recently commercialized 3D position sensors such as TOF cameras or Leap Motion needs strong illumination to ensure sufficient optical energy for the high frame rate sensing. To overcome these problems, this paper proposes to use a pair of optical-mouse-sensors as a stereo image sensor to measure 3D-velocity and use it to extrapolate 3D position measured by a low-frame-rate stereo camera.

Comparing to the ordinary image sensors, the photo diode of the optical mouse sensor is much larger in its size and that makes it more sensitive to the light [3]. With the high sensitivity, the experiment in Sec.2 shows that., without strong illumination, and even under ordinary in-door lighting condition, a quick hand motion is detectable using the optical mouse sensor with proper lenses mounted on it.

Another merit of using the optical mouse sensor is in its embedded image processing capability. The sensor chip contains a processer that extracts the moving portion in its viewing area and computes 2D velocity of the portion. These tasks require a lot of computation particularly when the frame rate is high as vast numbers of images must be processed in a second. The main computer is freed from this heavy burden with the assists of the processors inside the optical mouse sensors. In addition, as only the sequence of velocities, instead of images, is sent from the sensor to the main computer, the communication cost is dramatically reduced.

To be benefited from these merits, Sec.3 describes a way to compute a sequence of 3D velocities from 2D velocities detected by a pair of optical mouse sensors at the frame rate as high as 1000 fps and, to obtain 3D positions at the high frame rate by extrapolating the 3D positions detected by a low frame rate stereo camera with the sequence of 3D velocities. Sec.4. evaluates the performance of the method.

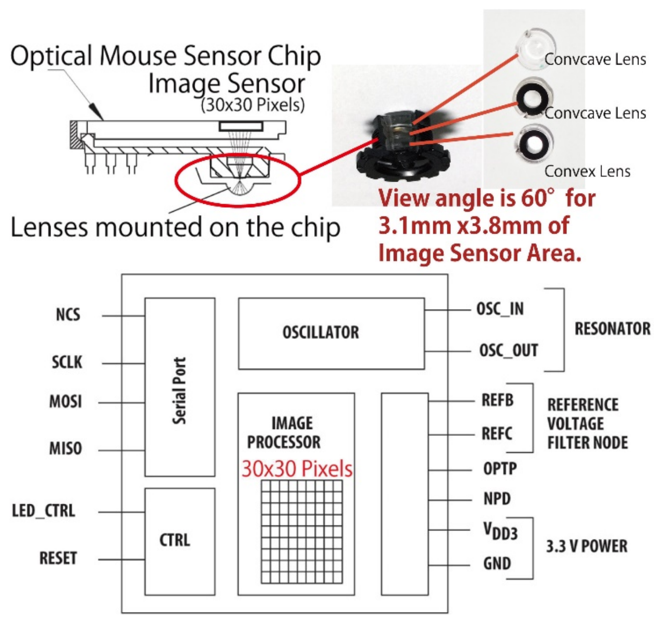


Figure 1: Diagrams of cross section and function (pin configuration) of Optical Mouse Sensor Chip (Avago ADNS3090) and lenses mounted on the sensor.

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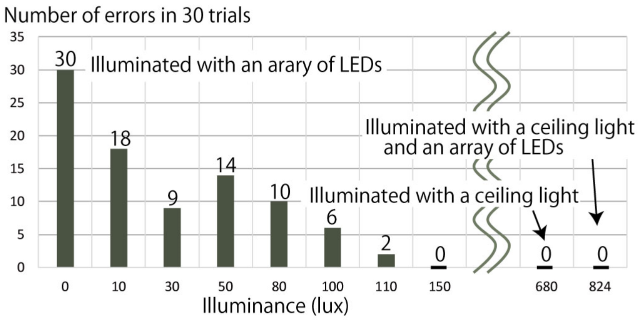


Figure 2: Errors in quick-hand-swing-action detection under various lighting conditions.

## 2 Performance of Optical Mouse Sensor for Hand Motion Detection

This paper deals with the optical mouse sensor mounted with lenses customized for quick hand motion detection. To evaluate its performance, an experiment to count the number of errors in detecting 2D direction of the hand motion is conducted. A quick hand swing is performed within 66ms for the range of 60 degree of angle over the sensor. 30 trials for each of 8 swing directions are conducted under various illumination conditions. The experimental result is shown in Fig.2. It is verified that the error can be zero even for 150 lux that is darker than the illuminance by a standard ceiling light.

## 3 Extrapolation of Low Frame Rate 3D Position with High Frame Rate 3D Velocities

A pair of optical mouse sensors with lenses is arranged as shown in Fig.3 and detects 2D velocities from different viewpoints. With the pair of 2D velocities and the target position, 3D velocity can be computed. As shown in Fig.4, the target 3D position is tracked by extrapolating the last target position detected by a low-frame-rate stereo camera with the sequence of 3D velocities detected by the high-frame-rate mouse sensors. A Leap Motion is used to detect the true 3D position of the target as a reference to evaluate the accuracy of the extrapolated position. Experimental results on the accuracy is shown in Fig.5.

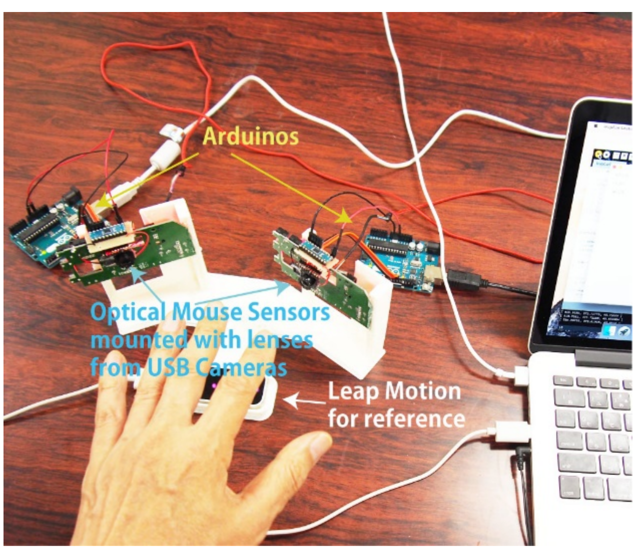


Figure 3: Arrangement of a pair of optical mouse sensors and Arduinos to detect 3D velocity of a hand motion.

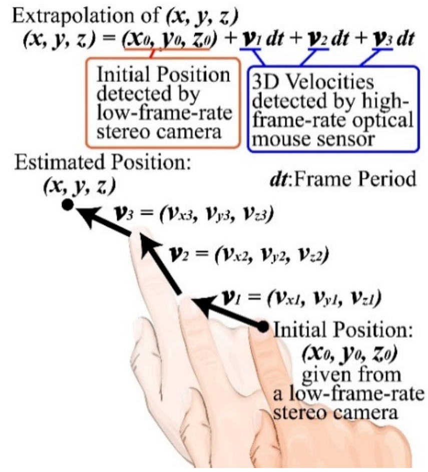


Figure 4: Extrapolation of 3D position using an initial position given from the low-frame-rate stereo camera every 25 msecs and 3D vectors detected by a pair of optical mouse sensors.

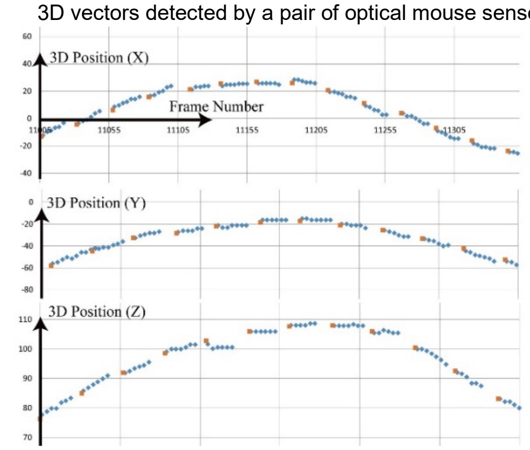


Figure 5: Experimental results: Red dots are 3D positions of a fingertip detected every 25 msec by Leap Motion. Blue dots are extrapolated 3D positions using 3D velocities of a hand swing motion detected by a pair of optical mouse sensors. It is verified that the last dot extrapolated from the previous red dot is very close to the next red dot. That means extrapolation is successful. The frame rate of the optical mouse sensors is 320 fps.

## 4 Evaluation and Conclusion

The experimental results in Fig.5 suggest that the extrapolation is successfully conducted and, even with a low-frame-rate stereo camera, high-frame-rate tracking of 3D position of a target is possible with the assist of a pair of optical mouse sensors. Its tolerance against low illumination is the most advantageous.

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