Lab 1: Exploring Computer Measurement

**ABSTRACT**

This lab is used to determine and characterize the capabilities and limitations of the Motion Detector and Photogate made by Vernier. We devised our own test, using objects of different sizes, textures, and positions as well as a Basketball Drop, Propeller Test, and wood block measurement. Our results show that the Motion Detector has an uncertainty of 4 cm and the Photogate has an uncertainty of 0.12 cm.

**INTRODUCTION**

In this lab, we observed how computers record measurements through the use of a Motion Detector and Photogate. We ran a series of our own experiments to test the accuracy and how effectively the Motion detector works, as well as a basketball drop to observe how it measures position and velocity over time. Also, we used the Photogate to measure the RPM of a spinning propeller and to measure the length of a block of wood. We ran the experiments to see how the two pieces of equipment work and to see how accurate the computers made the measurements

**THEORETICAL BACKGROUND**

This lab requires no theory.

**EXPERIMENTAL DESIGN AND PROCEDURE**

A. Equipment used

* Vernier Photogate (VPG-BTD): senses of object is blocking a beam of light
* Vernier Motion Detector 2 (MD-BTD): senses movement through ultrasound/sonar. Sends sound waves out and measures distance through the bounce-back.
* Protective wooden box: to protect Motion Detector during Basketball Drop
* Vernier LabPro: connection between sensors and computer
* Logger Pro: to measure and analyze data
* Computer: for logger pro
* Miscellaneous objects: eraser, pencil, wooden block, bag (for motion detector tests)
* Foam Basketball: for basketball drop
* Propeller: wooden blades spun during Photogate test.
* Aluminum track: for measurements and installation of sensors

Equipment set up on next page.

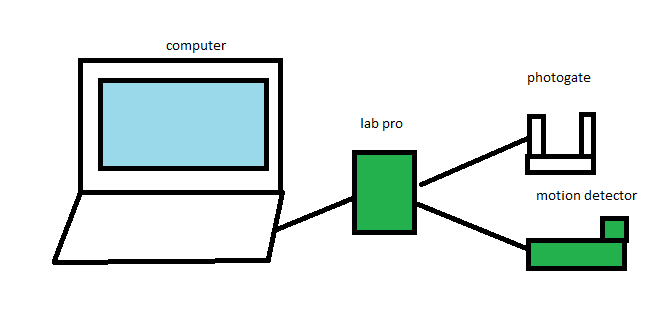
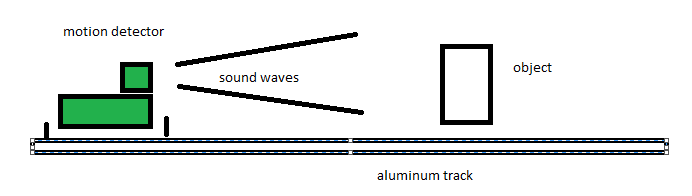
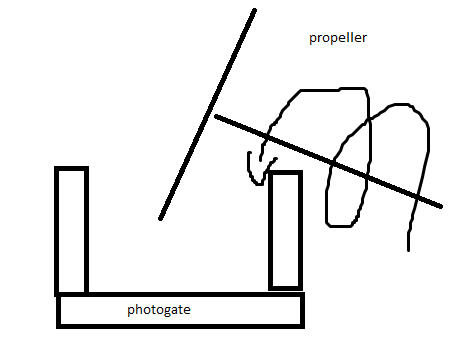
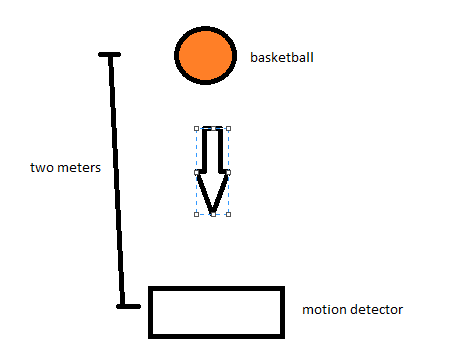
. Diagram 1: Computer Set up

Diagram 2: Motion Detector Set up



Diagram 3: Basketball Drop Diagram 4: Photogate and propeller



B. Procedure

A series of tests were run using the Motion Detector and Photogate.

First off, self made experiments were run to characterize the Motion Detector (set on tracking mode). The sensor was mounted on a bracket installed onto an aluminum track with centimeter increments (the sensor was set at 0 cm). To test for the accuracy of the Motion Detector, we placed a block of wood at various distances away from the sensor. First, the block was put 50 cm away from the sensor; then 40 cm, 30 cm, 20 cm, 10 cm, and 5 cm. We took two trials of measurements to maintain consistent results. Then, to test for how the size of the object affects the measurements, we used different objects of various sizes: woodblock side view, woodblock face view, eraser on flatside, and a pencil placed sideways, all 50 cm away from the sensor. Next, to test how the position (horizontal vs. vertical placements) affects the measurements, we placed a pencil and eraser horizontally and vertically and also a block horizontally all 50 cm away from the sensor. To test if surface affected the measurements, we used different textured objects placed 50 cm away. We used a transparent box, a wooden block, a notebook, and a fabric bag. Last, to test if objects near the target affected the measurements, we placed objects in front of and behind the target. The desired object (wooden block) was placed 50 cm away from the sensor, and we placed a pencil (then an eraser to double check) 45 cm away from the sensor. Then we put a camera bag 70 cm away from the sensor.

Next, for the Basketball drop, the motion detector (set on "people mode" was placed on the floor in a protective box. We then dropped a foam basketball 2 meters above the motion detector. Two trials were run to maintain some consistency, however, only one file was managed to be saved. The data plots: position and velocity over time were recorded and saved from Logger Pro.

For the Photogate experiments, we mounted the sensor onto the aluminum track.

A propeller was spun in the photogate, and time intervals were recorded every time the blades passed through the gate. A string was attached to the propeller and was coiled along the stem of the propellers. The string was then pulled to spin the propeller blades. Two trials were also run to maintain/check for consistency.

The length of a wooden block was measured through the Photogate by pushing it through the gate. We measured the initial and final positions of the tip of the block through the light indicator of the Photogate

**ANALYSIS**

A. Method of Analysis

For the self made experiments to characterize the Motion Director, we made data tables to keep track of measurements and to look for precision of the computer measurements. For the Basketball Drop, Logger Pro was used to record the position and velocity of the basketball over time, which is compiled to a graph. Logger Pro was also used to measure the time intervals for the Propeller experiment, which is also compiled to a data table.

B. Presentation of Results.

Self Made Experiments

Figure 1: Measured\* vs. Reported Distances

|  |  |  |
| --- | --- | --- |
| Distance (m) | Trial 1 (m) | Trial 2 (m) |
| 0.5 | 0.538 | 0.536 |
| 0.4 | 0.439 | 0.439 |
| 0.3 | 0.340 | 0.340 |
| 0.2 | 0.241 | 0.241 |
| 0.1 | 0.178 | 0.178 |
| 0.05 | 0.175 | 0.175 |

Figure 2: Different Sizes, Measured\* vs. Reported Distances

|  |  |
| --- | --- |
| items (different sizes) | measurement (m) |
| woodblock, sideview (width x height) | 0.535 |
| woodblock, face (length x width) | 0.534 |
| eraser, flatside | 0.541 |
| pencil, sideways | 0.545 |

Figure 3: Position, Measured\* vs Reported Distances

|  |  |
| --- | --- |
| items (different placement/postion) | measurement (m) |
| pencil, vertical | 0.534 |
| pencil, horizontal/flat | 0.521 |
| eraser, vertical | 0.532 |
| eraser, horizontal/flat | 0.531 |
| wooden block, horizontal/flat | 0.529 |

Figure 4: Different textures, Measured\* vs Reported Distances

|  |  |
| --- | --- |
| item (textures) | measurement (m) |
| block vertical | 0.525 |
| plastic/transparent box | 0.525 |
| notebook | 0.526 |
| fabric/camera bag | 0.521 |

Figure 5: Multiple object locations, Measured\* vs Reported Distances

|  |  |  |
| --- | --- | --- |
| item front/behind block of wood (m) | block of wood (m) | other object (m) |
| eraser, in front | 0.500 | 0.482 |
| pencil, in front | 0.500 | 0.482 |
| camera bag, behind | 0.500 | 0.527 |

\*objects 0.500 m away from Motion Detector

Figure 6: Basketball Drop, Distance vs Time

Figure 7: Propeller Test Trial 1. Velocity vs Time

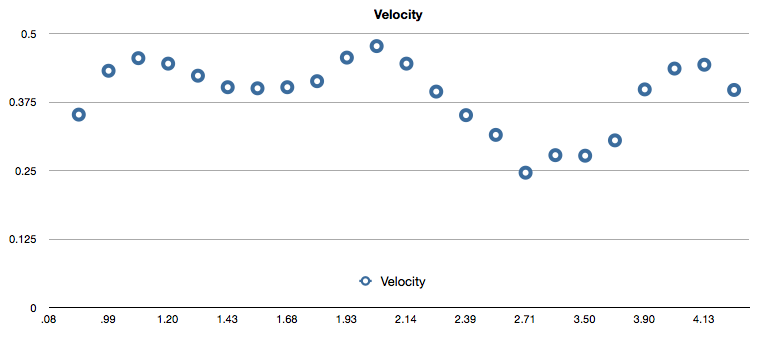


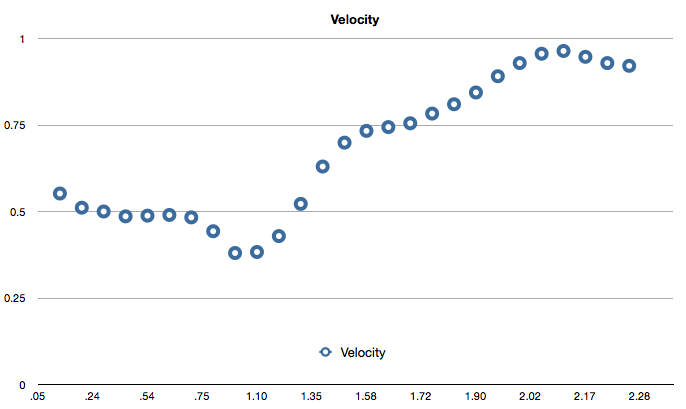
Figure 8: Propeller Test Trial 2. Velocity vs Time

Figure 9: Photogate Block Measurement

|  |  |
| --- | --- |
| time | measurement (cm) |
| initial | 80.35 |
| final | 93.22 |

C. Discussion of results

From Figure 1, the accuracy of the Motion Detector was observed through known distances and measured distances. According to our data, the Motion detector is about 0.370-0.400 m (3.7-4.0 cm) off. This may be due to our lab group forgetting to zero the sensor. We calculated the uncertainty was calculated from subtracting the recorded value by actual value. Judging from Trial 1 and two, we had about the same recorded measurements, so our data was rather consistent. Also, after 0.100 and 0.050 m, the Motion detector records a value of .175~0.178 m, showing that after a certain distance around (0.100 m), the motion detector gives flawed values. From Figure 2, using different object sizes gave us slightly different data. When using a wood block compared to an eraser or pencil layed flat, gave us different results at 0.500 m away. The Motion Detector gave a less of an accurate measurement, due to the smaller surface area. Bigger object sizes prompts more accurate results. The position/placement of the object also affects the measurements. On Figure 3, our data was rather flawed because we had better readings when the objects were placed horizontally as opposed to vertically. For example, the pencil placed horizontally/flat gave us a reading of 0.521 m while the pencil placed vertically gave us a reading of 0.534 m. Different results were seen with the eraser because both placements gave similar readings (0.532 and 0.531). As for texture and surface of the target, not much can be inferred from our tests. Figure 4 conveys that all of our objects tested gave rather consistent readings, about 0.525 m, besides the camera bag. Further experimentation is probably needed. With multiple objects in front or behind the target, the Motion Detector picks up the object closest to it. As shown from Figure 5, the sensor recorded the pencil or eraser (placed 0.450 m) as opposed to the wooden block (placed 0.500 m). Also, placing the camera bag 0.700 m away from the sensor and the block of wood 0.500 m away, the sensor picked up the block of wood.

As for the Basketball drop, only one graph (distance vs time) was made because the first trial was not exported. Figure 6 shows the second trial of the Basketball drop as well as the Model basketball using the equation:

eq 1.

In this case, y0 is 2.0 m since the basketball was dropped 2.00 ± 0.10 m (by hand) above the motion detector. Comparing our drop to the Model drop, our curve was similar to the Model drop curve, besides that a random small spike on our curve. Also, both drops took about the same time interval. The jagged lines before and after the curve were due to error and the ball bouncing, respectively. Judging from the graph, our data suggests that the Motion Detector is rather accurate.

Measuring the wood block using the Photogate, we obtained the initial and final positions of the tip of the block using the Photogate's light indicator (once the block passes/hits the light beam and once it exits). Subtracting the final from the initial measurement, we obtain the length of a wooden block, which is 12.87 cm. The actual length of the block of wood is 12.75 cm, showing that the uncertainty of the Photogate is about .12 cm, which suggests that the Photogate is accurate to 0.12 cm.

In order to measure the RPM of the propeller, we had the times the propeller hit the photogate divided by two and then multiplied a factor to convert to 1 minute. From Trial one, the propeller hit the Photogate 58 times over a 4 second interval, so the RPM was 435. For Trial two, the propeller hit the Photogate 60 times over a 2 second interval, so the RPM was 900. Our data was rather inconsistent because from Figure 8, our propeller speed grew faster, and from Figure 7, our propeller speed fluctuated/was not constant. Our results may have not been as accurate due to human error because we spun the propeller by hand.

D. Suggestions for improvements

For future experiments, we should probably plan ahead and attempt to do more trials to maintain accuracy. Equipment should also be zeroed before use, to achieve accurate measurements. Also, we should know somewhat of an idea of what the results should look like.

**CONCLUSION**

A. Summary of the results and pertinence of the results to the questions related to the introduction

In this lab, we tested two sensors. Through our own experiments, we found that the uncertainty of the Motion Detector to be about 4 cm. We also found that the Motion Detector also fails to measure objects 10 cm from the sensor. We also found that the sensor is not affected by the placement of the targets as vertically placed objects. Also, texture is affected somewhat significantly. However, size does play a small factor in the accuracy of each measurement. Multiple objects obstructing the targets also affected the sensor. Through the comparison of our Basketball drop and the Model basketball drop (eq. 1), our data reflects that the Motion Detector is capable of graphing position and velocity in respect of time. Through the Photogate experiments, our data shows that it has an uncertainty of .12 cm. Using the Photogate to calculate the RPM of the propeller may not be as accurate due to errors.