Design of Initial Arrow Velocity Measurement Using Accelerometer Sensor

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Abstract. The arrow glides through the air in a parabolic motion after it was shot with the bow. This arrow is installed with a device that measures its acceleration and speed. The device used for this measurement consists of an accelerometer sensor, Arduino Pro Mini, and a Micro SD card. Meanwhile, the sensor can test the acceleration, time, and elevation angle at 20°, 30°, as well as 45°. The results showed that the arrow maneuvres with an acceleration and initial velocity of 19.6 m/s^2 and 9.8 m/s respectively. It also indicated that the arrow speed, the farthest distance, and the time of the highest point have the same values.

Keywords: acceleration, velocity, accelerometer sensor, parabolic.

1 Introduction

Parabolic motion needs to be measured to examine the values of each parameter because it plays an important role in human life [1]. Currently, the measurements can be performed by using advanced technology such as a video recorder [2], phet app [1], Graphic User app Interface (GUI) Matlab [3], and sensors infrared [4].

This study only measures parabolic motion using simulation. Meanwhile, the use of an infrared sensor can still be refined by placing it on top of the object experiencing the motion. This study becomes perfect because it is essential to directly know the object's motion. However, this problem can be solved by developing the current sensor as the measurement device. The current sensor known as the accelerometer is used to measure the acceleration and elevation angle as it is indicated in an MPU6050 [5][6][7][8].

2 Design Hardware and Software

The device is designed using Arduino Pro Mini, MPU 6050 sensor module (integrated with accelerometer sensor), LED, battery, and Micro SD Card. Arduino Pro Mini will work as the device core, accelerometer sensor as input, and Micro SD Card as output. The

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design of the device can be seen in Figure 1.

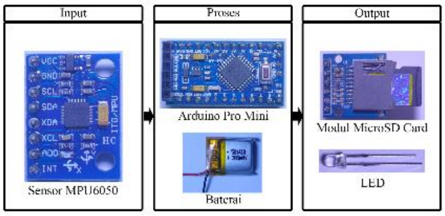

Fig. 1. Design hardware.

The arrow's body is designed from fiber, the front is made of aluminum, and the tail is made of rubber. The arrow has a length of 30 cm and a diameter of 8 mm. The dart is then added to the holder for the device at the front, 4 cm from the dart's front end. The holder's design for the device measures parabolic motion functions so that the device does not experience vibration, shifting, and damage during data collection. The device for measuring the motion of the parabola is placed on the arrow, laying the device can be seen in Figure 2.

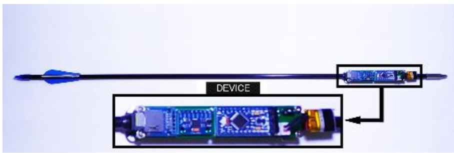

Fig 2. the device is placed on the arrow.

3 Parabolic Equation

Parabolic motion is included in the uniform straight motion and uniform motion in a straight line. This is due to the influence of the earth's gravitational force on the vertical direction of motion, and there is no influence of the earth's gravity on the horizontal motion[9]. The parabolic motion can be seen in Figure 2.

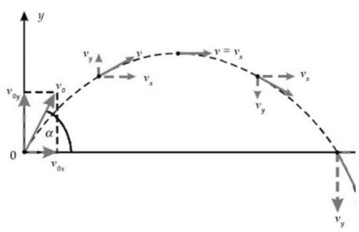

Fig 3. Parabolic.

To be able to measure parabolic motion parameters such as elevation angle, speed, farthest distance, highest point, and farthest travel time, it must be done separately. The equations for calculating parabolic motion parameters are as follows:

Initial velocity on the x-axis	$V_{0x} = V_0 \, . cos\, a$	(1)
Maximum distance on x-axis	$X_{max} = \frac{(V_0^2 \ \sin 2\, a)}{g}$	(2)
Highest distance travel time on y-axis	$t_{ymax} = \frac{V_0 \, . \sin a}{g}$	(3)
Longest distance travel time on x-axis	$t_{xmax} = 2 \ t_{ymax}$	(4)

4 Data Analysis

The accelerometer sensor will take the slope angle data in pitch and roll angle data, where the roll angle will be used as an elevation angle. The accelerometer sensor takes data on the acceleration of the arrow's motion on the x axes. The acceleration data from the accelerometer sensor is then processed to obtain speed data[10]. The acceleration of the accelerometer sensor is integrated to get the initial velocity (vo) of the arrow's motion. The initial velocity (vo) is the velocity v(t). The acceleration can be integrated so that the following equation obtains the velocity.

$$v(t) = \int_0^t a(t)dt \qquad (5)$$

All data obtained from sensors are a). acceleration, b). elevation angle, and c). time can be used to determine the characteristics of the arrow's motion in the form of a parabolic motion by using the equations of parabolic motion.

5 Experiment

Field tests were carried out to retrieve accelerometer sensor data in the form of acceleration of the arrow on the x-axis, pitch, and roll angle. It is performed by putting an arrow installed on the body of the bow as indicated in Figure 4. The field test experiment was carried out on elevation angles of 20°, 30°, and 45°.

Fig 4. Body of the bow.

The arrow glides through the air in a parabolic motion after it was shot with the bow. Figure 5a shows this object as it glides through the air. Also, the arrow fell and stopped hitting the styrofoam on the ground. This becomes the furthest distance on the y-axis of the accelerometer sensor that this object travels when experiencing a parabolic motion. Figure 5b shows the farthest distance measured using a meter.

Fig 5. a). Arrows as they glide through the air, b). Arrows landed styrofoam.

6 Result and Discuss

The accelerometer sensor can be used to examine the initial velocity of the arrow's motion. However, the acceleration value on the x-axes is 19.6 m/s² and this shows it has the same magnitude at the elevation angle of 20°, 30°, and 45°. This is because the same bow is used to shoot the arrow. Therefore, the initial velocity is known by integrating the acceleration value on the x-axis[10]. The following equation is used to find the value of the initial velocity:

$$v(t) = \int_0^t a(t)dt \tag{6}$$

$$v(t) = \int_0^1 19.6\,(t)\,dt$$

$$v(t) = \int_0^1 19.6\,(t)\,dt$$

$$v(t) = 9.8\,m/s$$

This equation is also used to find the farthest distance (xmax) and the time to reach the highest point (tymax). Several parameters such as the farthest distance (xmax), time to reach the highest point (tymax), and elevation angle help in indicating the initial speed. Table 1 shows the values of xmax, tymax, txmax, and elevation angle.

Table 1. Comparison of elevation angle, xmax, tymax, and txmax.

Angle	Comparison	xmax (m)	tymax (second)	txmax (second)
20°	Sensors	6.29	0.34	0.68
	Measurement	8.17	0.52	1.04
	Difference	1.88	0.18	0.36
30°	Sensors	8.48	0.5	1

	Measurement	9.23	0.7	1.4
	Difference	0.75	0.2	0.4
45°	Sensors	9.8	0.8	1.6
	Measurement	9.65	0.7	1.4
	Difference	0.15	0.1	0.2

The elevation angle such as 20°, 30°, and 45° is directly indicated by examining the roll readings. Table 1 shows that the distance on the xmax and tymax sensors is 1.88 m and 0.36 seconds longer at an angle of 20°. Meanwhile, the distance on the xmax and tymax is 0.75 m and 0.4 seconds longer when the elevation angle is 30°. The distance on the xmax and tymax sensor is 0.15 m and 0.1 seconds longer when the angle is 45°. This indicates that the sensor readings are more accurate when the elevation angle is greater.

The value of the initial velocity of the arrow's motion is 9.8 m/s from integrating the value of the acceleration of the arrow's motion. Therefore, the value of the initial velocity of the arrow by finding it using the xmax equation is as follows.

$$x_{max} = \frac{(V_0^2\ \sin 2\ a)}{g} \quad (7)$$

$$V_0^2 = \frac{g\ .Xmax}{\sin 2a}$$

$$V_0^2 = \frac{9.8\ \frac{m}{s^2}.\ 9.65\ m}{\sin 2\ (45°)}$$

$$V_0 = 9.72\ m/s^2$$

The value of the initial velocity of the arrow by finding it using the tymax equation is as follows.

$$t_{ymax} = \frac{V_0\ .\sin a}{g} \quad (8)$$

$$V_0 = \frac{g\ .tymax}{\sin a}$$

$$V_0 = \frac{9.8\frac{m}{s^2}.\ 0.7 detik}{\sin 45}$$

$$V_0 = 9.8 \text{ m/s}$$

The value of the initial velocity of the arrow obtained from 3 different ways did not have a significant difference. This shows that the accelerometer sensor can read the acceleration of the arrow motion well.

7 Conclusion

An accelerometer sensor is successfully used for measuring the movement of arrows. This device is placed on the object's body to read the acceleration and the elevation angle. Based on the results, there is a parabolic motion in the measurement which was carried out at the elevation angle of 20°, 30°, and 45°. It also showed that the value of the acceleration and initial velocity is 19.6 m/s^2 and 9.8 m/s respectively. In this study, the results indicated that the farthest distance and the longest time was at an elevation angle of 45°.

References

[1] L. Karanggulimu, D. N. Sudjito, and D. Noviandini, "Desain Modul Praktikum Mandiri Tentang Gerak Parabola Menggunakan Simulasi PhET" Projectile Motion"," 2017.

[2] I. Fitriyanto, "Penerapan software tracker video analyzer pada praktikum kinematika gerak," *Inovasi Pendidikan Fisika*, vol. 5, no. 3, 2016.

[3] J. Rajagukguk and C. S. Sarumaha, "Pemodelan dan analisis gerak parabola dua dimensi dengan menggunakan aplikasi gui matlab," *Jurnal Ikatan Alumni Fisika Universitas Negeri Medan*, vol. 4, no. 4, pp. 1–5, 2018.

[4] N. N. Susanto, "Pengembangan Perangkat Praktikum Materi Gerak Parabola Pada Mata Kuliah Praktikum Fisika Dasar 1," *Integrated Lab Journal*, vol. 9, no. 2, pp. 124–134, 2021.

[5] M. Mudarris and S. G. Zain, "Implementasi Sensor Inertial Meansurenment Unit (IMU) untuk Monitoring Perilaku Roket," *Aviation Electronics, Information Technology, Telecommunications, Electricals, Controls*, vol. 2, no. 1, pp. 55–64, 2020.

[6] F. Mangkusasmito, D. Y. Tadeus, H. Winarno, and E. Winarno, "Peningkatan Akurasi Sensor GY-521 MPU-6050 dengan Metode Koreksi Faktor Drift," *Ultima Computing: Jurnal Sistem Komputer*, vol. 12, no. 2, pp. 91–95, 2020.

[7] R. T. Asnada and S. Sulistyono, "Pengaruh Inertial Measurement Unit (IMU) MPU-6050 3-Axis Gyro dan 3-Axis Accelerometer pada Sistem Penstabil Kamera (Gimbal) Untuk Aplikasi Videografi," *Jurnal Teknologi Elektro*, vol. 11, no. 1, pp. 48–55, 2020.

[8] A. B. Sanjaya, D. Syauqy, and G. E. Setyawan, "Rancang Bangun Sistem Pembeda Gerakan Berlari dan Berjalan Untuk Atlet Lari Menggunakan MPU6050 dan Metode Klasifikasi K-Nearest Neighbor," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer e-ISSN*, vol. 2548, p. 964X, 2019.

[9] D. N. Afifah, D. Yulianawati, N. Agustina, R. D. S. Lestari, and M. G. Nugraha, "Metode sederhana menentukan percepatan gravitasi bumi menggunakan aplikasi tracker pada gerak parabola sebagai media dalam pembelajaran fisika SMA," 2015.

[10] C. Yuwono and A. Akhiruyanto, "Pengembangan accelerometer berbasis personal Computer untuk mengetahui karakteristik lari jarak Pendek menggunakan teknologi wireless," *Profesional*, vol. 8, no. 1, 2010.