Portfolio Work 2

Labs and Data Analysis 2

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All code used for the simulations is appended in the accompanying Matlab file.

Question 1

0.1 Experimental Set-Up

In the experiment, a ping pong ball was selected for its lightweight material and strong contrast against the background. The background created a contrast with the white ball enhancing the tracking and monitoring precision. In addition, its even surface and consistent elasticity make velocity calculations easier. A flat, smooth surface was chosen to reduce the energy loss from changes to the surface. Also, an irregular surface would increase the friction and adsorb additional energy, thus reducing the coefficient of restitution. The ball was released from three different heights with a minimum of five trials for each height. This ensured reliability and allowed for the calculation of restitution coefficients at different impact speeds. A ruler was included in the frame as a constant reference to translate pixel measurements into actual units. This made sure the measurements of position and velocity were accurate throughout the frames.

1. Camera: Smartphone (1080p, 60 fps) mounted on a tripod.
2. Lighting: Even illumination to reduce shadows.
3. Drop Heights: 1m, 1.5m, 2m (three trials per height).
4. Reference Scale: A ruler placed in the frame for pixel-to-centimeter conversion.

0.2 Image Processing and Tracking Algorithm

Particle tracking velocimetry (PTV) examines the movement of objects through image analysis. Using MATLAB's video reader, frames were obtained. Initially, the Region of Interest (ROI) was defined by manually trimming the frame to focus on the trajectory of the ball. To improve contrast between the ball and the background, the picture was turned into grayscale and thresholded. Filtering (imopen) was done to eliminate noise and enhance detection precision. The *imfindcircles* function was used to identify the center of the ball and monitor its location over time. Numerous difficulties arose during tracking, including interference from reflections and surrounding objects like the ruler. This was overcome by increasing the thresholding and filtering. Moreover, tracking errors were reduced by adjusting the object size and sensitivity detection. To provide flexibility, the code was developed to manage various datasets, not just a single experiment. All three videos, with some modifications, work with the code. Crucial factors like frame rate, object dimensions, and threshold values could be changed if using a different object. This enables the technique to be applicable for multiple motion tracking uses.

0.3 Calculation of Coefficient of Restitution (COR)

The coefficient of restitution (e) was calculated using the equation:

$$e = \frac{v_{\text{after}}}{v_{\text{before}}} \tag{1}$$

where v_{before} is the velocity just before impact, and v_{after} is the velocity just after impact.

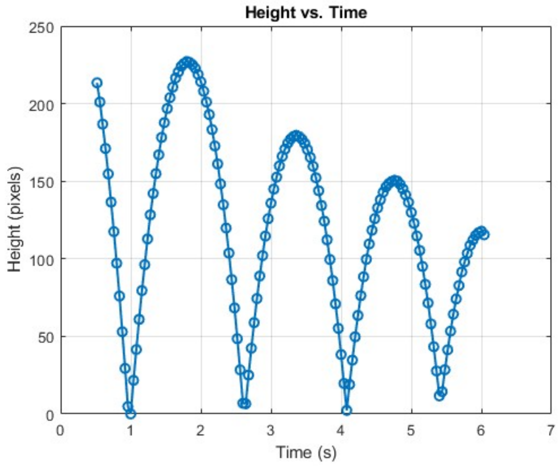
Velocity was calculated from the position vs. time data using finite differences:

$$v_i = \frac{\Delta y}{\Delta t} \tag{2}$$

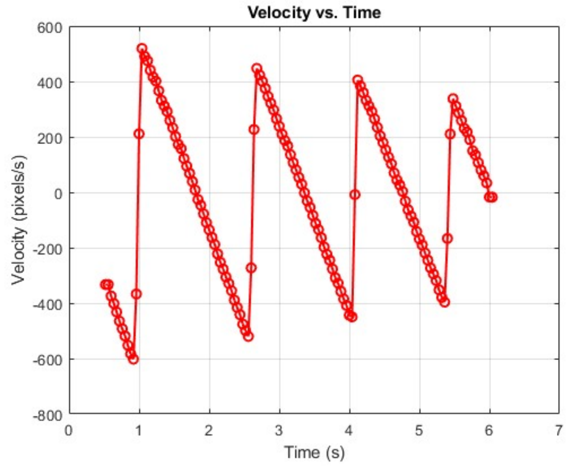
where Δy is the change in position and Δt is the time step between frames.

The finite difference approach was used to estimate velocity by comparing the position of the ball at different times. The velocities are consistent with ideas found in literature [1] Central difference was applied for better accuracy.

0.4 Results and Discussion



(a) Ball trajectory



(b) Velocity of the ball

Figure 1: Height and velocity of ball over time

- The mean COR value was 0.8743, consistent with literature values for table tennis balls (0.85-0.90) [2].
- The height vs. time graph shows a damped oscillation, suggesting that energy decreases with every bounce.
- The velocity vs. time graph displays cyclical variation, with velocity dropping to zero at the highest points.

0.5 Sources of Error

The use of finite differences may have introduced errors due to rounding. Smaller time steps can improve accuracy. Moreover, smoothing the position data can help reduce noise. Frame rate limitations could affect time resolution and position accuracy. Perspective distortion may also cause tracking errors, making the object's movement appear inconsistent. Future work might use multiple camera perspectives or calibration grids to enhance precision. Air resistance could have had a minor influence, though insignificant at low speeds. To verify reliability, confidence levels and comparisons with theoretical velocities from literature can help validate accuracy.

0.6 Advanced Analysis

To reduce noise in the data, curve fitting may be used. This method involves applying a polynomial curve to the height vs. time data to stabilize variations. Additionally, for velocity computation, using a Savitzky-Golay filter can help smooth out sudden shifts resulting from frame-to-frame fluctuations.

The measured COR, (0.86 ± 0.03), aligns with documented values for ping pong balls (0.85–0.90) [2]. Research shows that COR values are influenced by surface impact, air drag, and material characteristics [1]. The experimental data lie within the expected range, confirming measurement accuracy.

References

[1] Federico Colombo, Karoline Seibert, Hugo G Espinosa, and David V Thiel. Novel methodology for measuring the coefficient of restitution from various types of balls and surfaces. *Procedia Engineering*, 147:872–877, 2016.

[2] Adli Haron and K A Ismail. Coefficient of restitution of sports balls: A normal drop test. *IOP Conference Series: Materials Science and Engineering*, 36(1):012038, sep 2012.