1-2016

Systematic Errors in Intro Lab Video Analysis

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Abstract

In video analysis lab experiments, students frequently find large discrepancies between results based on self-filmed videos and expected values (e.g. for g determined by a fit to projectile motion data). These differences are frequently far larger than the uncertainty calculated from their fit. Using an inexpensive point-and-shoot camera with a 4x optical zoom to record video, we investigated two possible causes of this error: the effect of placing the reference meter stick at a different object-to-camera distance and the effect of the motion of interest being in a plane not perpendicular to the camera lens. When we observed these phenomena for wide angle, normal, and telephoto focal length settings we found systematic errors as large as 40%. Based on our findings, we make recommendations for minimizing these errors.

Keywords

laboratories, experiments, cameras, errors, measurement

Disciplines

Christianity | Laboratory and Basic Science Research | Physics

Comments

Presented by Dr. Zwart at the winter meeting of the American Association of Physics Teachers held in New Orleans on January 11, 2016. Previously presented with the co-authors at the Iowa Section of the American Association of Physics Teachers Meeting held in Des Moines, Iowa, on November 7, 2015.

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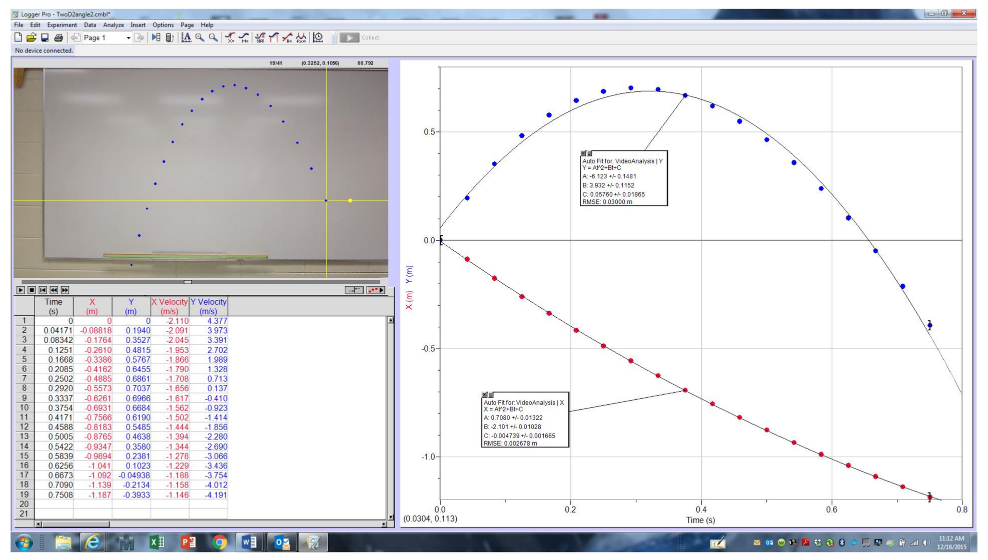
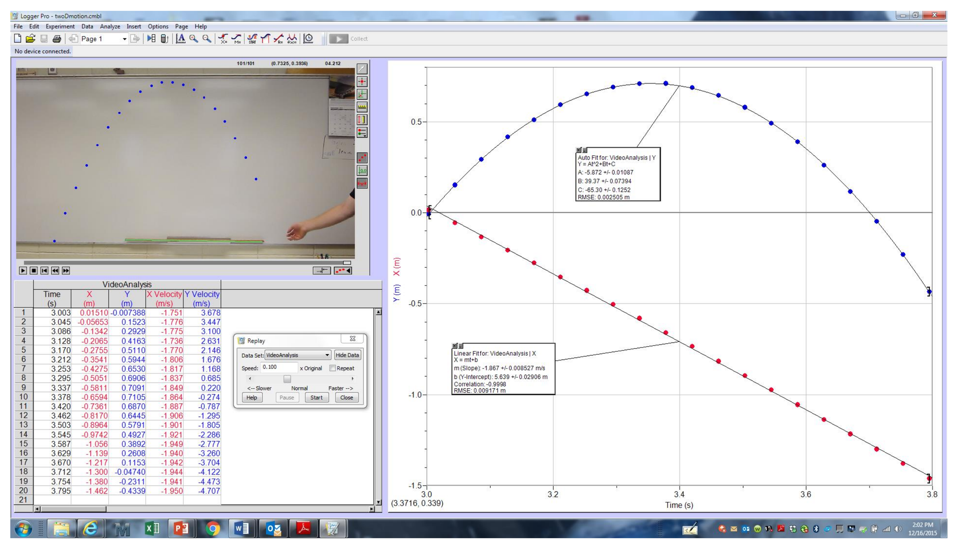
Introduction:

Video analysis is becoming a popular introductory lab activity. Careful experimentation will yield good numerical results, but we have noticed that student-shot video clips often yield results like those below, where the fits to data are poor.



(A) $a_x = 1.40 \pm 0.02$ m/s^2 $|a_y| = g = 12.2 \pm 0.3$ m/s^2



(B) $a_x = 0$ $|a_y| = g = 11.74 \pm 0.02$ m/s^2

Figure 1: Example data sets (A) Out of plane motion. (B) Reference meter stick offset.

These data sets display two common student experimental errors:

- Plane of motion angled slightly toward/away from the camera (Figure 1A)
- Reference length at a different distance from the camera than the motion (Figure 1B)

We have made quantitative measurements of these effects and have examined the role of camera focal length lens setting for each effect.

Reference Length Offset

- Set up an array of 5 meter sticks varying 20 cm apart horizontally (Figure 2)
- Took photos at wide angle, normal, and telephoto zoom settings (See Camera Figure 4) but changed distances from the camera to fill the frame
- Set scale with center meter stick and found apparent lengths of others

Figure 2: Meter stick array

Results: Apparent length varies significantly if the reference length is at a different distance from the camera than the motion of interest (Figure 3). This is responsible for the poor 'g' value in Figure 1B.

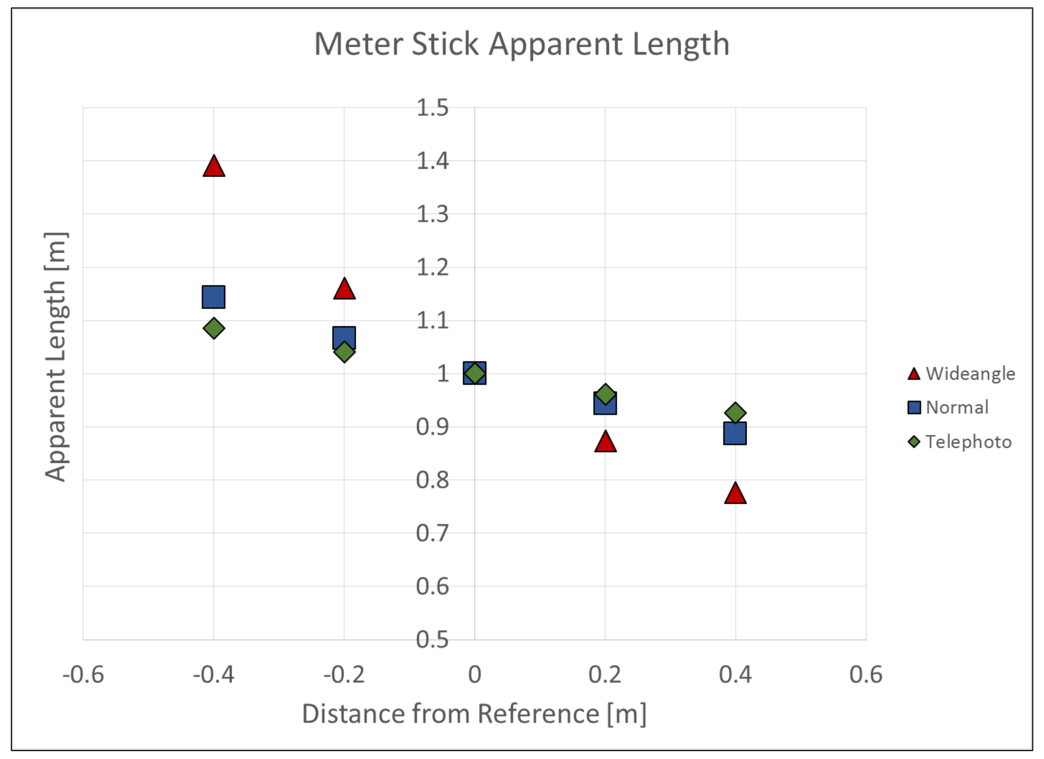


Figure 3: Results for offset meter stick reference lengths

The Camera: Cannon PowerShot A1200 with a 5.0 to 20.0 mm focal length zoom lens

- Used three different zoom settings (default is wide-angle, f = 5mm)

Wide angle f = 5mm 'Normal' view Telephoto f = 20 mm

Figure 4: From left to right: Wide angle, 'Normal', Telephoto

Effect of Angle Changes

- Created a target with known length segments (Figure 5A)
- Filled image frame with target
- Shot video clips with camera at normal incidence and then changed angle (Figure 5B) with camera at wide angle setting
- Measured apparent lengths relative to center horizontal segment
- Repeated for zoom at telephoto and 'normal' settings

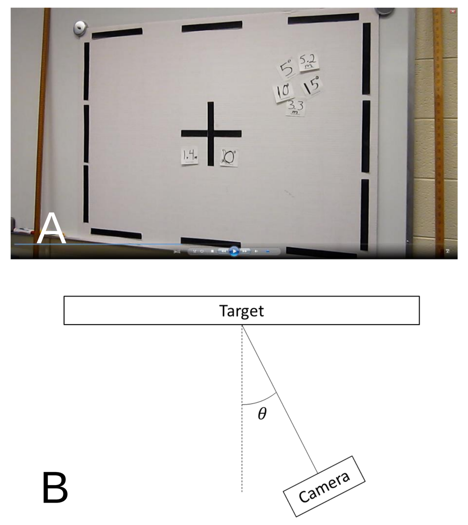


Figure 5: (A) Target. (B) Experimental set-up.

Results: There is significant variation in apparent travel distance if the plane of motion is not perpendicular to a line drawn to the camera (Figure 6). This is responsible for the non-zero x-component of acceleration and the poor value for 'g' from the y-value quadratic fit in Figure 1A.

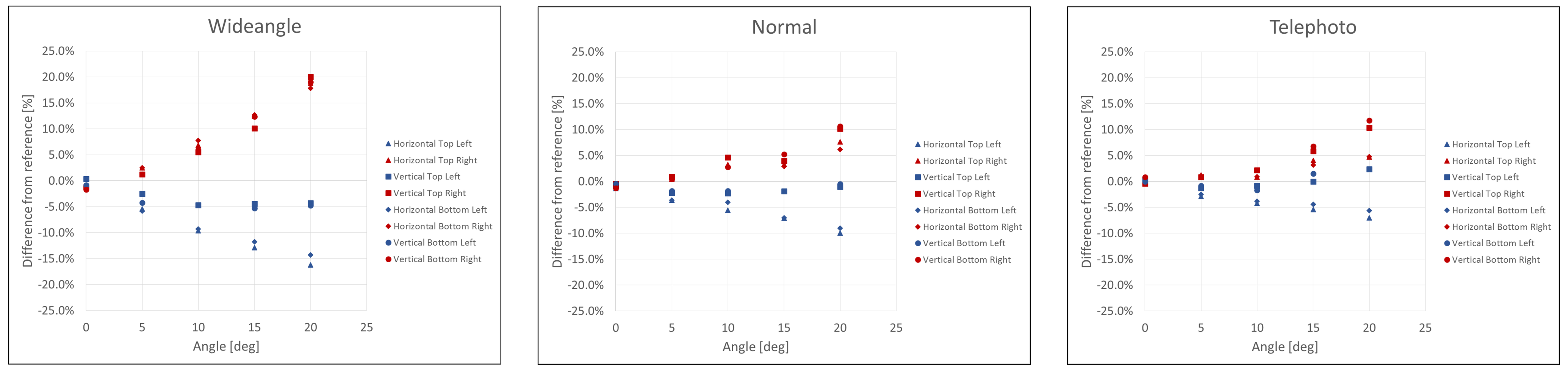


Figure 6: Results for angle changes (A) Wide angle (B) Normal (C) Telephoto

Conclusions:

- Motion in an angled plane introduces significant systematic errors
- If the plane of motion and reference length are at different distances from the camera significant systematic errors result
- Both sources of error are worse at wide angle (shortest focal length) lens setting
- Focal length setting has minimal effect if alignment is carefully done

Advice: Stay away from the wide angle focal length setting to reduce errors!

Acknowledgements: Thank you to the Dordt College Andreas Center for funding student Tim Martin's summer research and to Brittany De Ruyter and Laurey Zwart for helpful comments on the design of this poster.