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Systematic Errors in Intro Lab Video Analysis

John Zwart
Dordt College, john.zwart@dordt.edu

Kayt E. Frisch
Dordt College, kayt.frisch@dordt.edu

Tim Martin

Systematic Errors in Intro Lab Video Analysis

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

Laboratory and Basic Science Research | Physics

Comments

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John Zwart, Kayt Frisch, Tim Martin – Department of Physics & Astronomy, Dordt College

John.Zwart@dordt.edu

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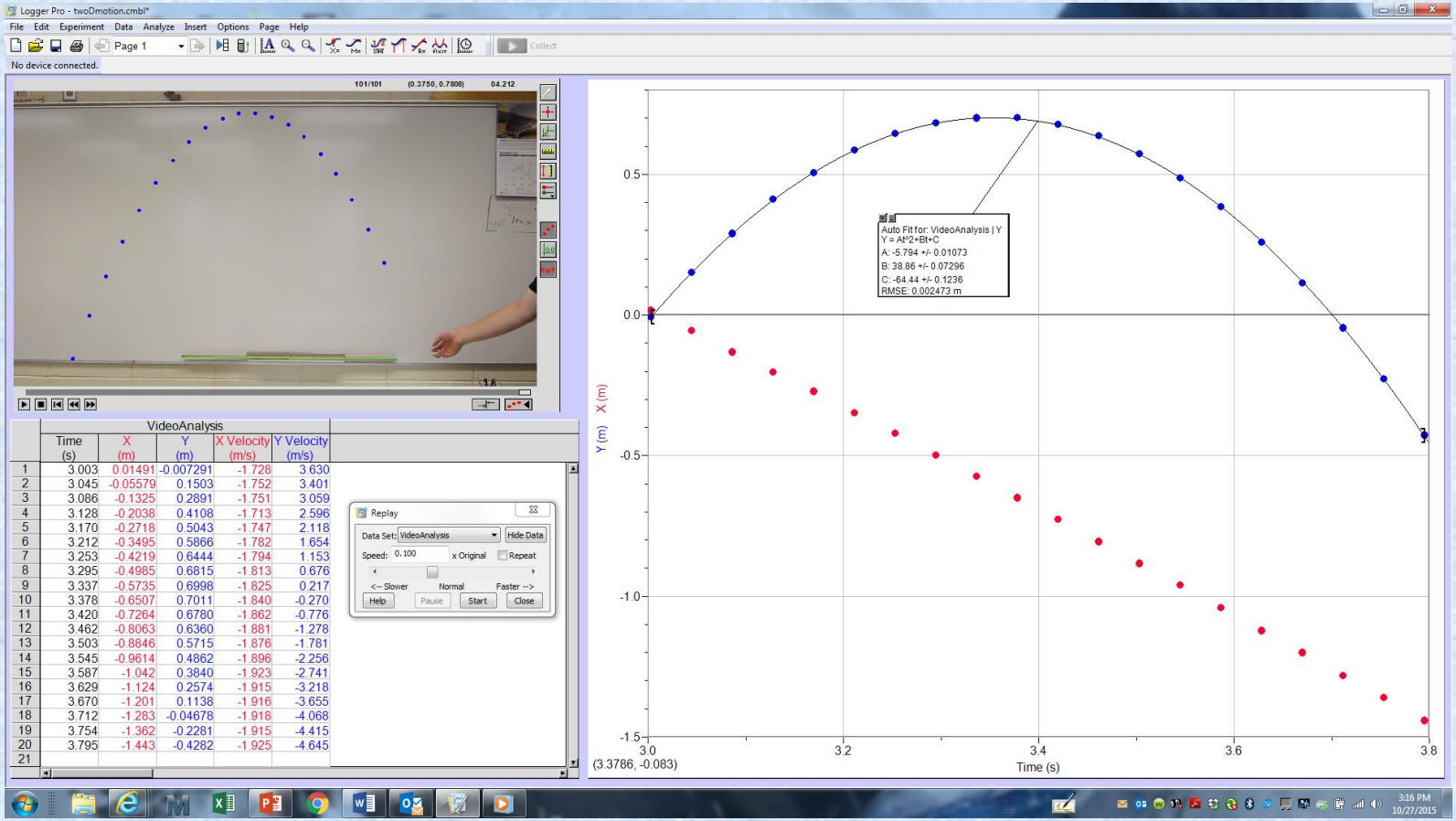
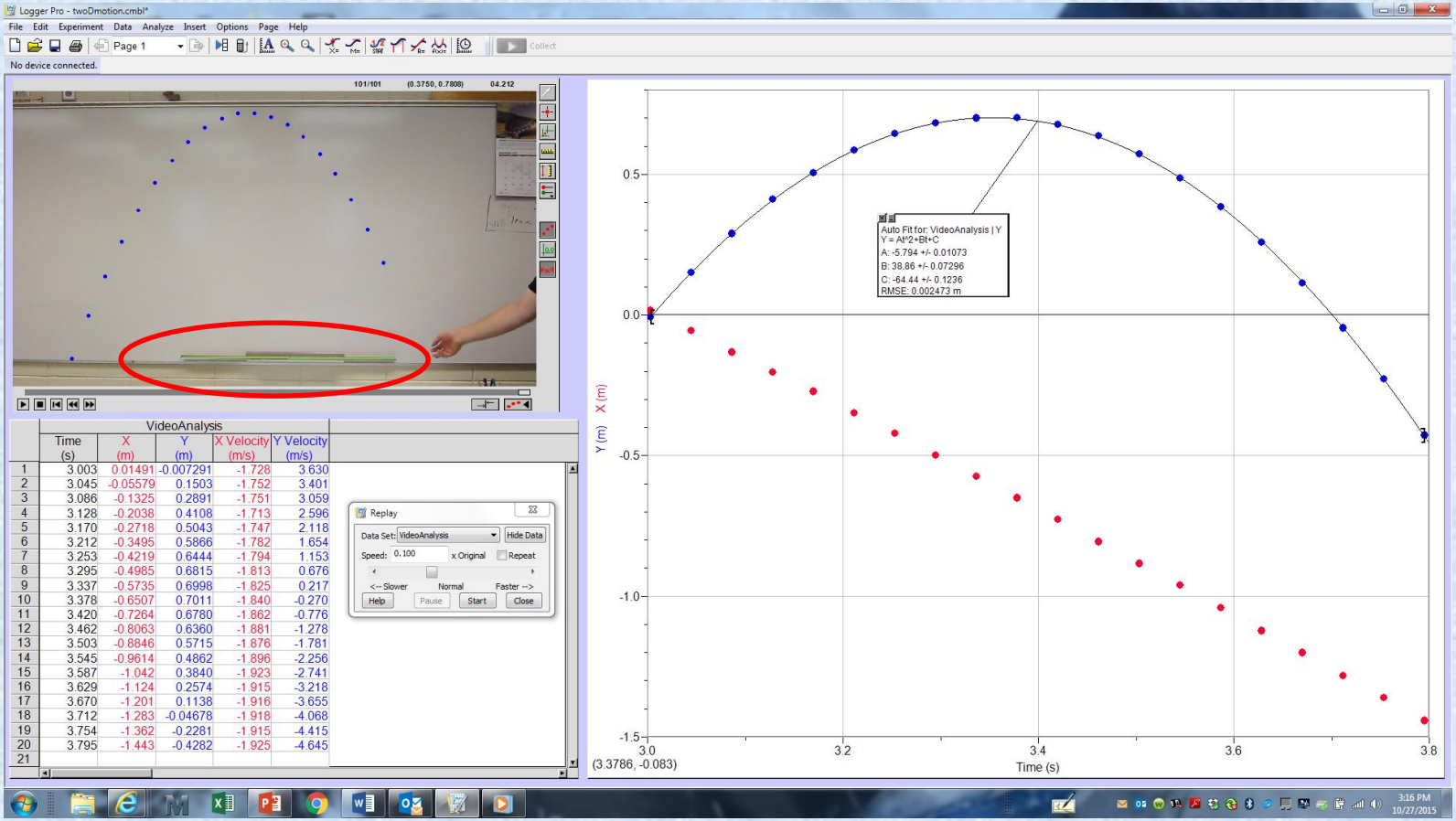

Logger Pro - twoDmotion.cmbl*
File Edit Experiment Data Analyze Insert Options Page Help
Page 1
No device connected.
101/101 (0.3750, 0.7808) 04.212
VideoAnalysis
Time (s) X (m) Y (m) X Velocity (m/s) Y Velocity (m/s)
1 3.003 0.01491 -0.007291 -1.728 3.630
2 3.045 -0.05579 0.1503 -1.752 3.401
3 3.086 -0.1325 0.2891 -1.751 3.059
4 3.128 -0.2038 0.4108 -1.713 2.596
5 3.170 -0.2718 0.5043 -1.747 2.118
6 3.212 -0.3495 0.5866 -1.782 1.654
7 3.253 -0.4219 0.6444 -1.794 1.153
8 3.295 -0.4985 0.6815 -1.813 0.676
9 3.337 -0.5735 0.6998 -1.825 0.217
10 3.378 -0.6507 0.7011 -1.840 -0.270
11 3.420 -0.7264 0.6780 -1.862 -0.776
12 3.462 -0.8063 0.6360 -1.881 -1.278
13 3.503 -0.8846 0.5715 -1.876 -1.781
14 3.545 -0.9614 0.4862 -1.896 -2.256
15 3.587 -1.042 0.3840 -1.923 -2.741
16 3.629 -1.124 0.2574 -1.915 -3.218
17 3.670 -1.201 0.1138 -1.916 -3.655
18 3.712 -1.283 -0.04678 -1.918 -4.068
19 3.754 -1.362 -0.2281 -1.915 -4.415
20 3.795 -1.443 -0.4282 -1.925 -4.645
Replay
Data Set: VideoAnalysis
Hide Data
Speed: 0.100 x Original Repeat
<-- Slower Normal Faster -->
Help Pause Start Close
Auto Fit for: VideoAnalysis | Y
Y = At^2+Bt+C
A: -5.794 +/- 0.01073
B: 38.86 +/- 0.07296
C: -64.44 +/- 0.1236
RMSE: 0.002473 m
0.5
0.0
-0.5
-1.0
-1.5
3.0
3.2
3.4
3.6
3.8
Y (m) X (m)
Time (s)
(3.3786, -0.083)
3:16 PM
10/27/2015



Fit to vertical motion shown yields g = 11.74 $\pm$ 0.02 m/s^2 !!!

But data/graphs/fits are:

-sensitive to motion that varies in distance from camera

-sensitive to correct scaling factor

How can we measure the effects of these two factors?

Does camera focal length play a role?

Cannon PowerShot A1200

Camera has:

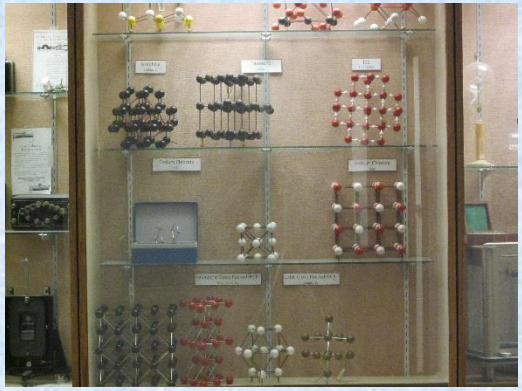
5.0 to 20.0 mm focal length zoom lens (4x optical zoom)

(35mm camera equivalent of 28 to 112 mm)

Video clip capability

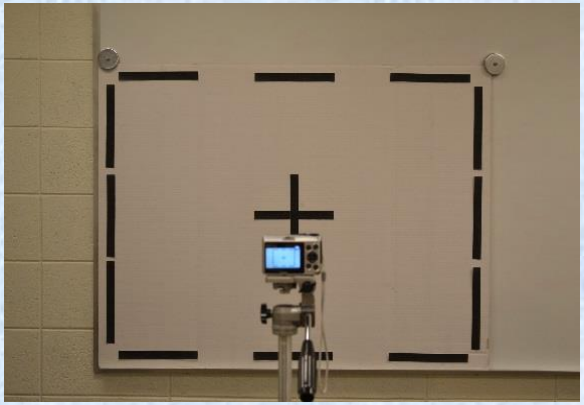
Wide angle f = 5mm

normal view

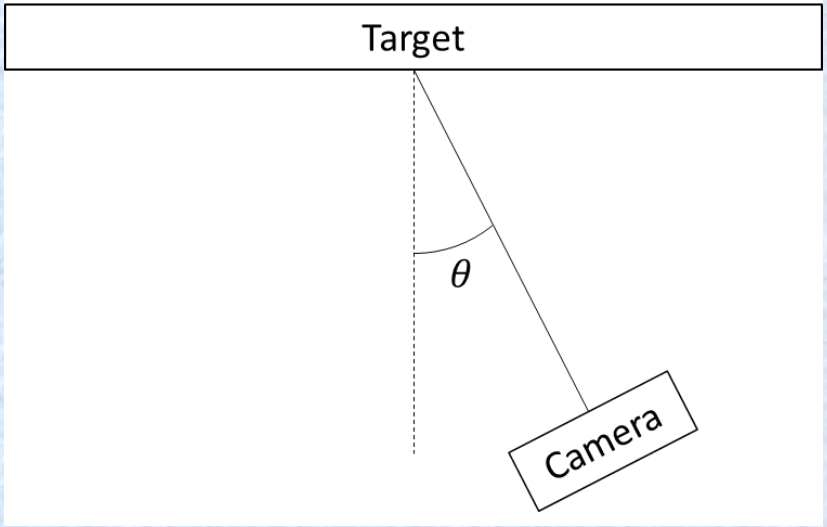


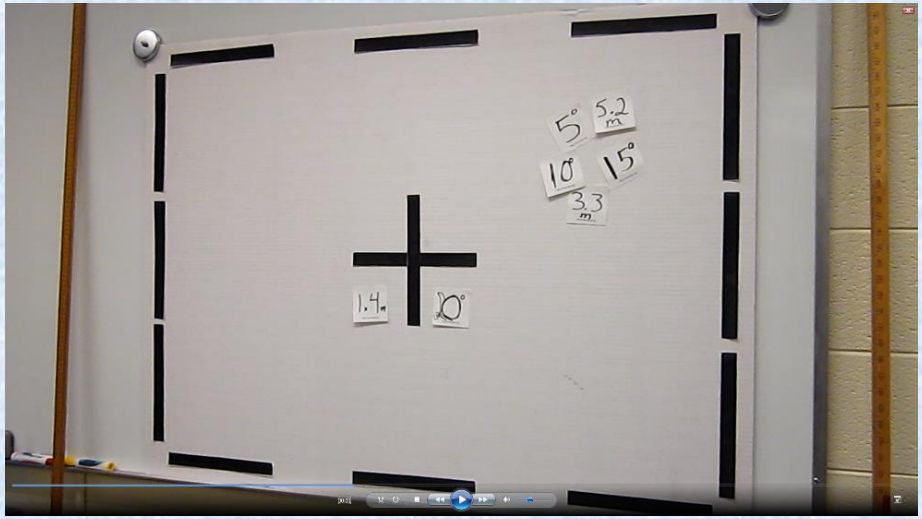
telephoto f = 20mm

Experiment 1:

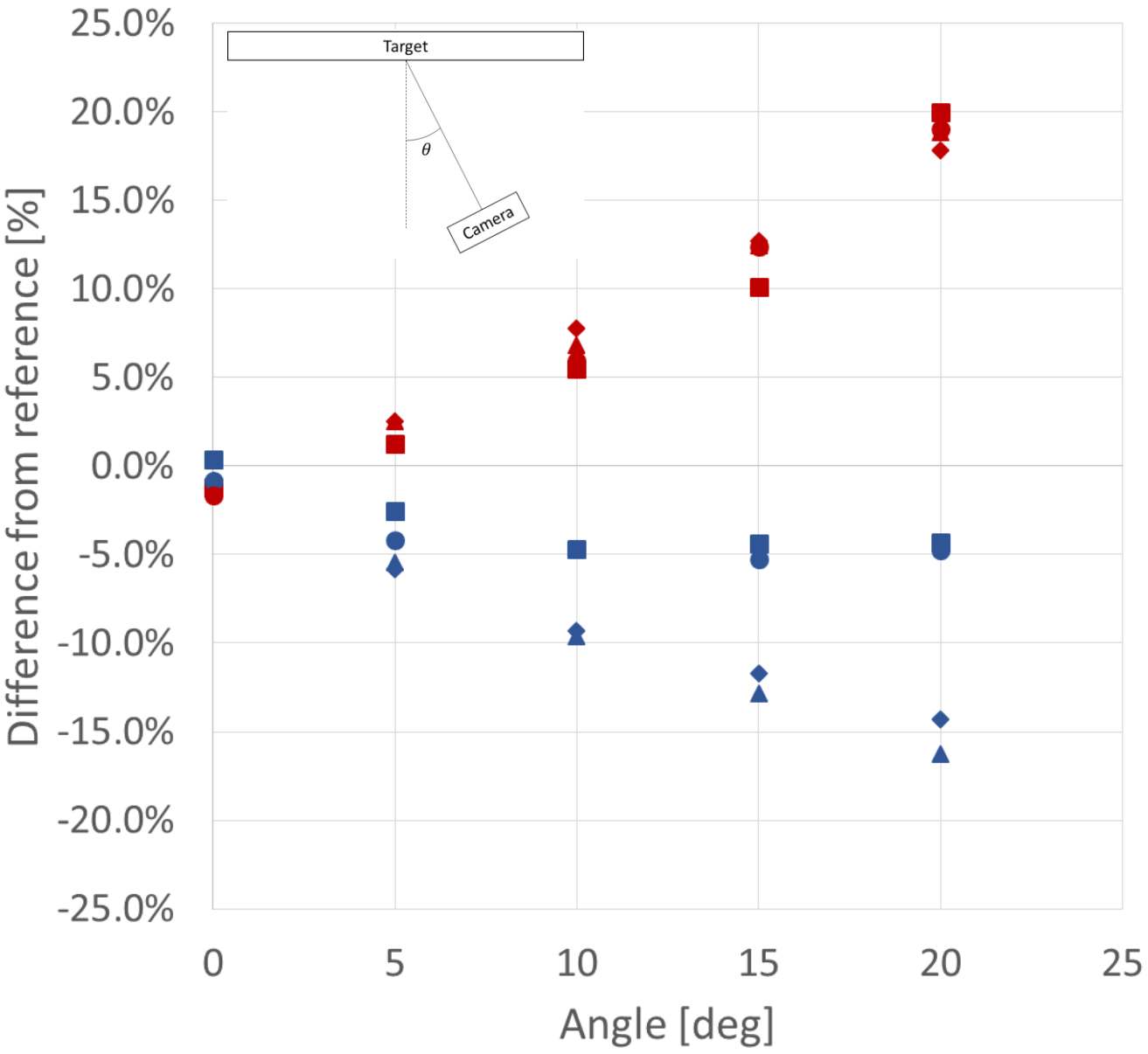


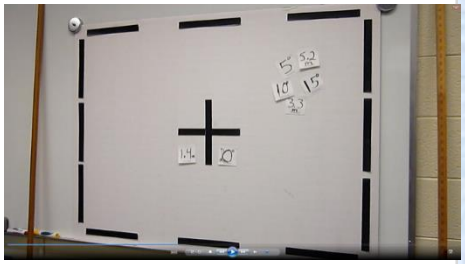
- Set zoom at wide angle and moved to fill frame with target
- Shot video clips with camera at normal incidence and then changed angle
- Repeated with zoom at telephoto and ‘normal’ settings
- Used center horizontal segment and found apparent length of other segments

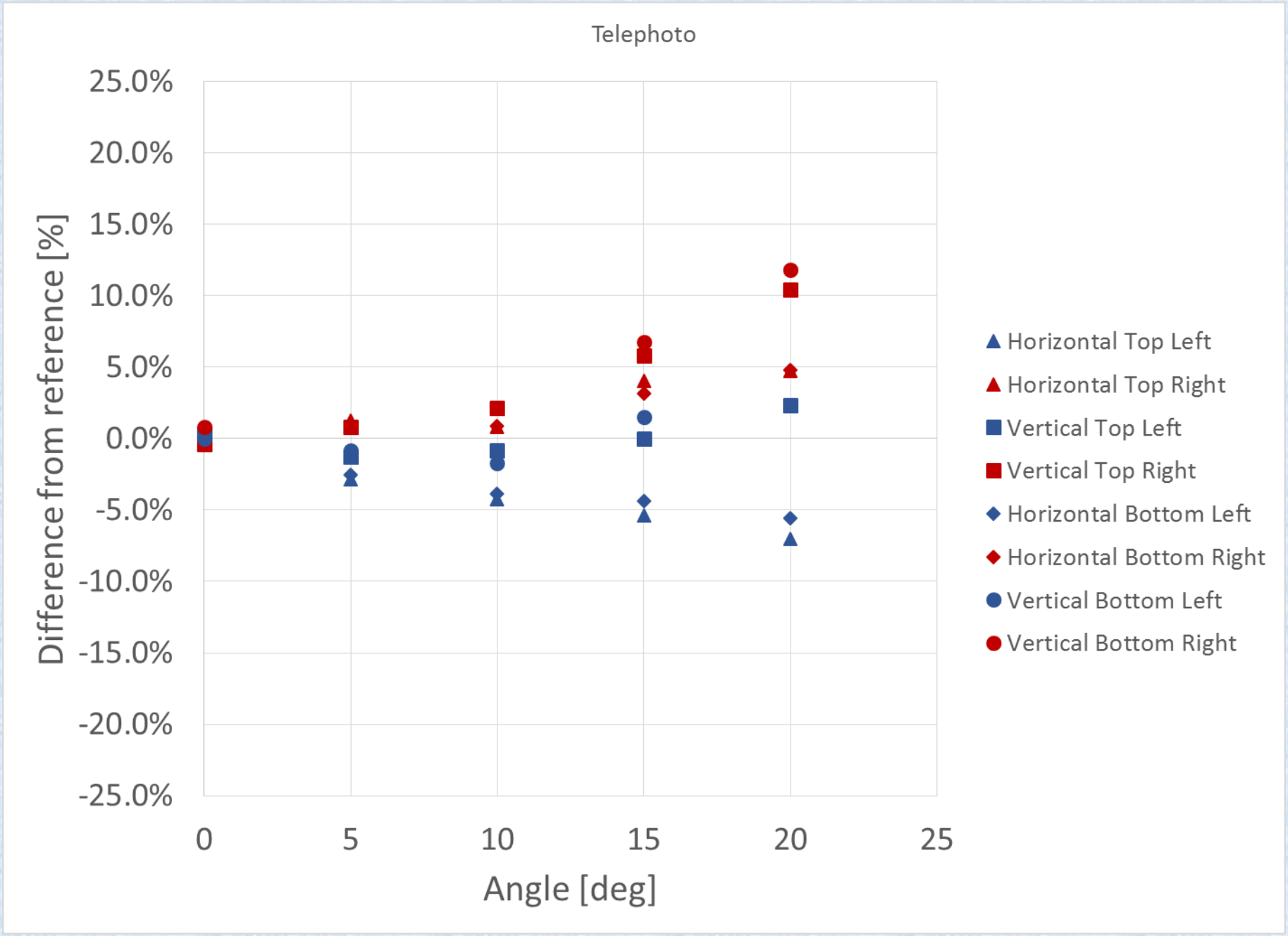


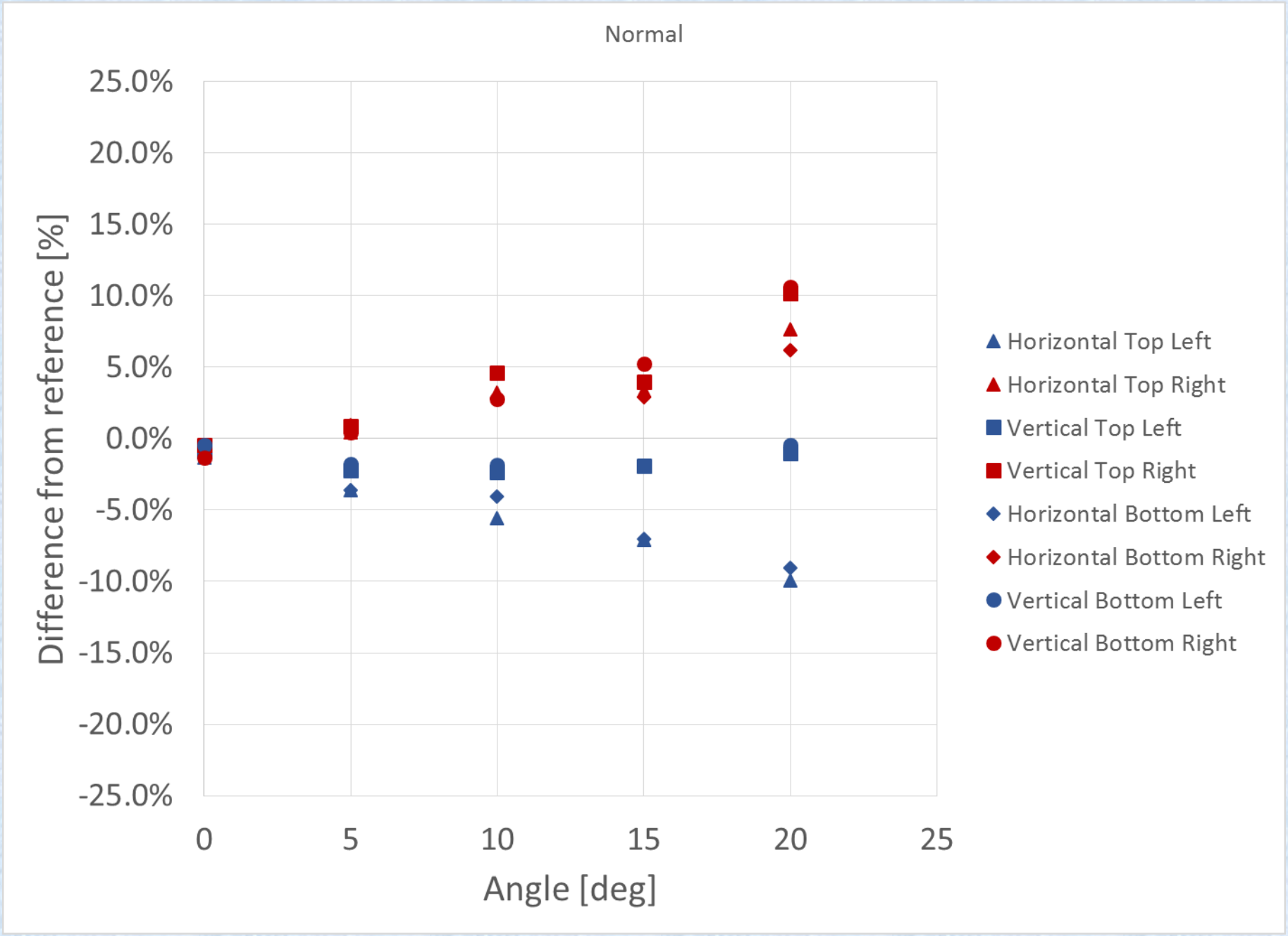


Wideangle


25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%
Difference from reference [%]
0
5
10
15
20
25
Angle [deg]
Target
θ
Camera
Horizontal Top Left
Horizontal Top Right
Vertical Top Left
Vertical Top Right
Horizontal Bottom Left
Horizontal Bottom Right
Vertical Bottom Left
Vertical Bottom Right




Telephoto
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%
Difference from reference [%]
0
5
10
15
20
25
Angle [deg]
Horizontal Top Left
Horizontal Top Right
Vertical Top Left
Vertical Top Right
Horizontal Bottom Left
Horizontal Bottom Right
Vertical Bottom Left
Vertical Bottom Right


Normal
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%
Difference from reference [%]
0
5
10
15
20
25
Angle [deg]
Horizontal Top Left
Horizontal Top Right
Vertical Top Left
Vertical Top Right
Horizontal Bottom Left
Horizontal Bottom Right
Vertical Bottom Left
Vertical Bottom Right

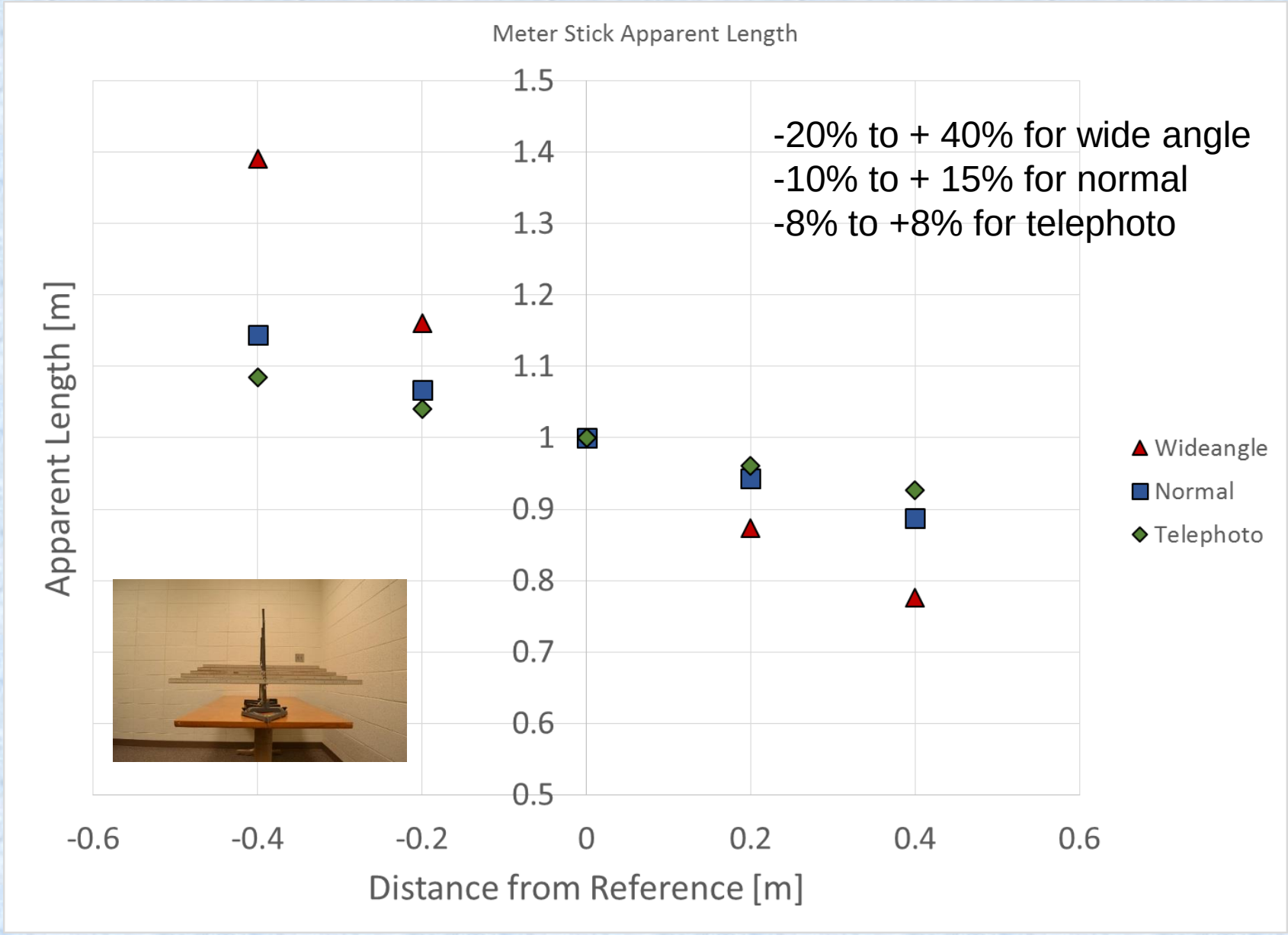
Results summary of apparent length change:

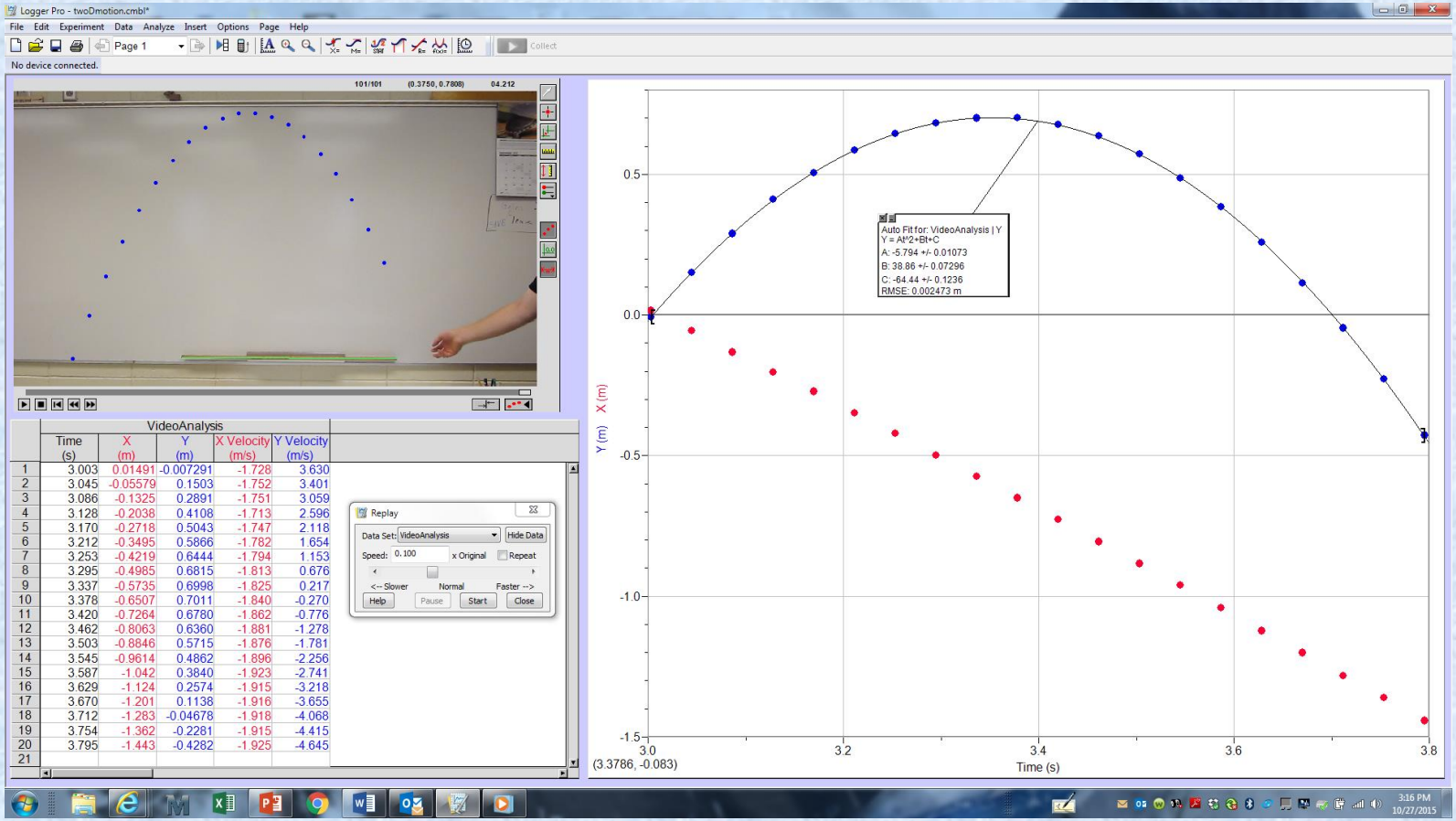
- – 16% to + 20% variation for wide angle (f = 5.0 mm)
- – 7% to + 11% variation for telephoto (f = 20.0 mm)
- --10% to + 10% variation for normal (f ~ 13 mm)

Experiment 2:

- Set up array of 5 meter sticks varying 20 cm apart horizontally
- Made measurements at wide angle, normal, and telephoto settings
- Set camera at same distances as Experiment 1
- Used center to set scale and measured apparent length of other sticks

Experiment 2:





Fit to vertical motion shown yields g = 11.74 $\pm$ 0.02 m/s^2 !!!

Moral of the story:

Try to keep motion plane perpendicular to camera

Try to have reference length same distance from camera as motion

Stay away from frame corners

Stay away from the wide angle setting for the camera lens

Questions?

See http://homepages.dordt.edu/zwart/ for detailed information on the material presented

Feel free to e-mail me with any questions john.zwart@dordt.edu