Exercise D (lab & field): Sensor positioning (height, field of view, view angle)

Tues., 13:05 – 16:50 (Time for two to three exercises)

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Logistics for Participants

- Teams of 4 to 6 people.
- Most of these activities will be conducted under the shaded part of the Ag Engineering building, north of the main MAC building.
- This exercise is run in parallel with Exercise E on data loggers and options under F as discussed after Wed. lunch.

Objectives

I. Illustrate issues of field of view (FOV) in sensors
   A. Digital camera illustrating lens length vs. FOV
   B. Measuring FOV for infrared thermometers

II. Illustrate issues of view angle with infrared thermometers

III. Illustrate issues of variation/error in sensor height under field conditions

IV.

V.

Activity 1 : Introducing field of view (FOV) in sensors.

I. Digital camera at fixed height, illustrating variation in FOV at varying focal lengths: Understanding how sensor height affects what is being measured is critical for obtaining accurate, unbiased data in the field. As an initial step, we'll explore variation in view angle at a fixed height
   A. The camera is positioned at 125 cm height (verify with the folding rule and adjust as necessary).
   B. View the target with concentric rings. Each ring corresponds to a specific angle as indicated on the target.
   C. Use the zoom to see how the angles that can be viewed. A shorter lens allows you to view wider angles.

II. Digital camera at four heights to illustrate measuring lens length vs. FOV:

Understanding how sensor height affects what is being measured is critical for obtaining accurate, unbiased data in the field. As an initial step, we'll explore how height and lens focal length interact to determine field of view.

A. The Canon SX 600 camera has a 1/2.3" (6.17 mm x 4.55 mm) sensor and a zoom lens that varies from 4.5 to 81 mm. From http://www.scantips.com/lights/fieldofview.html):

		Field of view (° angle)		
Lens length (mm)	35 mm equivalent lens (mm)	Horizontal	Vertical	Diagonal
4.5	25 mm	68.9	53.6	80.8
81.0	450 mm	22.6	17.1	18.1

B. The camera is aimed downward at a target with squares marked to help estimate the field of view.

1. Position the camera 40 cm above the target. There is a set screw on the post that requires an Allen wrench. Measure from the front of the camera to the target.
2. Zoom to the shortest lens length (widest view). Change the focal length by moving the silver ring around the shutter button. Measure the width and length of the field of view on the target. Record on the table below in units of centimeters (cm).
3. Zoom to the longest length (narrowest view) without going to "digital zoom." The display should show "18X." Measure the width and length of the field of view on the target. Record on the table below.
4. Re-position to a 60 cm distance, measure, and record.
5. Re-position to a 80 cm distance, measure, and record.
6. Re-position to a 100 cm distance, measure, and record. You should have to go slightly wider than the reference sheet for the shorter focal length.

C. On the datasheet, calculate view angle (θ) from basic trigonometry.

1. Tangent $(\theta/2) = d/(0.5 * y)$, where d is distance from camera sensor to target and y is either horizontal or vertical distance.
2. So:

   $\theta = 2*\text{Arctan}(d/(0.5 * y))$
3. Table 1 provides Arctan values in case your cell phone lacks trig functions. We'll use units of degress rather than radians.

Data sheet for calculating view angles using $\theta = 2*\text{Arctan}(d/(0.5 * y))$.

Lens length	Distance, d (cm)	Width, y (cm)	Angle (θ in degrees)	Height, y (cm)	Angle (θ in degrees)
4.5	40				
81.0	40				
4.5	60				
81.0	60				
4.5	80				
81.0	80				
4.5	100				
81.0	100				

Activity 2: Effects of view angle on infrared thermometer readings

Measuring effects of view azimuth and view zenith angle. Canopy temperatures are sensitive to viewing aspect, plant row orientation, solar zenith & solar azimuth. If temperature of different plant varieties are to be compared, the solar and view aspect need to be similar. This exercise examines the effects of changing view angles for a given solar position. Temperature variations with view angle are not as dramatic as for reflectance data, but they can still be large, commonly on the order of 2-4 C. This amount of variation could swamp any temperature x variety signal!

A. Establish compass directions

B. Hold inclinometer against IRT body

C. Aim IRT at view azimuth and zenith angles as noted in table below with IRT positioned approximately 1 m distance from potted plant.

D. Record temperature for each view aspect & note if sunlight or shadow dominates the particular view

E. Results will be collected, tabulated by instructors, and results reported.

Activity 3: Effects of camera height on images of crop canopies

Measuring effects

Activity 4: Review of sensor mounting options in platform

We will gather around the tractor to review geometric considerations for sensor mounting. Will discuss frame vertical motion, sensor height position, and variety of configurations.

Worksheet Exercise D, Activity 3: Infrared thermometers view angle relative to target

DATA SHEET FOR EXERCISE ON INFRARED THERMOMETER FIELD OF VIEW

IRT Model: _____ Height of IRT above target: _____cm

Date: _____ Person: _____

		Temperature		
Azimuth	Angle	Potted plants	Turf	Comments
Pointing South	South -60			
Pointing South	-45			
Pointing South	-30			
Pointing South	-15			
Straight Down	0			
Pointing North	15			
Pointing North	30			
Pointing North	45			
Pointing North	North 60			
Pointing East	East 60 from nadir			
Pointing East	45			
Pointing East	30			
Pointing East	15			

Straight Down	Nadir			
Pointing West	15			
Pointing West	30			
Pointing West	45			
Pointing West	60			

Table 1. Lots of Arctan values for section II

X	Arctan(a)	X	Arctan(a)	X	Arctan(a)	X	Arctan(a)	X	Arctan(a)
0.165	9.369	*0.325*	18.004	*0.485*	25.873	*0.660*	33.425	*1.3*	52.431
0.170	9.648	*0.330*	18.263	*0.490*	26.105	*0.680*	34.216	*1.32*	52.853
0.175	9.926	*0.335*	18.521	*0.495*	26.335	*0.700*	34.992	*1.34*	53.267
0.180	10.204	*0.340*	18.778	*0.500*	26.565	*0.720*	35.754	*1.36*	53.673
0.185	10.481	*0.345*	19.034	*0.505*	26.794	*0.740*	36.501	*1.38*	54.072
0.190	10.758	*0.350*	19.290	*0.510*	27.022	*0.760*	37.235	*1.4*	54.462
0.195	11.034	*0.355*	19.545	*0.515*	27.248	*0.780*	37.954	*1.42*	54.846
0.200	11.310	*0.360*	19.799	*0.520*	27.474	*0.800*	38.660	*1.44*	55.222
0.205	11.585	*0.365*	20.052	*0.525*	27.699	*0.820*	39.352	*1.46*	55.592
0.210	11.860	*0.370*	20.304	*0.530*	27.924	*0.840*	40.030	*1.48*	55.954
0.215	12.134	*0.375*	20.556	*0.535*	28.147	*0.860*	40.696	*1.5*	56.310
0.220	12.407	*0.380*	20.807	*0.540*	28.369	*0.880*	41.348	*1.52*	56.659
0.225	12.680	*0.385*	21.057	*0.545*	28.590	*0.900*	41.987	*1.54*	57.002
0.230	12.953	*0.390*	21.306	*0.550*	28.811	*0.920*	42.614	*1.56*	57.339
0.235	13.225	*0.395*	21.554	*0.555*	29.030	*0.940*	43.229	*1.58*	57.670
0.240	13.496	*0.400*	21.801	*0.560*	29.249	*0.960*	43.831	*1.6*	57.995
0.245	13.766	*0.405*	22.048	*0.565*	29.466	*0.980*	44.421	*1.62*	58.314
0.250	14.036	*0.410*	22.294	*0.570*	29.683	*1.000*	45.000	*1.64*	58.627
0.255	14.306	*0.415*	22.538	*0.575*	29.899	*1.020*	45.567	*1.66*	58.935
0.260	14.574	*0.420*	22.782	*0.580*	30.114	*1.040*	46.123	*1.68*	59.237
0.265	14.842	*0.425*	23.026	*0.585*	30.328	*1.060*	46.668	*1.7*	59.535
0.270	15.110	*0.430*	23.268	*0.590*	30.541	*1.080*	47.203	*1.72*	59.827
0.275	15.376	*0.435*	23.509	*0.595*	30.753	*1.100*	47.726	*1.74*	60.114
0.280	15.642	*0.440*	23.750	*0.600*	30.964	*1.120*	48.240	*1.76*	60.396
0.285	15.908	*0.445*	23.989	*0.605*	31.174	*1.140*	48.743	*1.78*	60.673
0.290	16.172	*0.450*	24.228	*0.610*	31.383	*1.160*	49.236	*1.8*	60.945
0.295	16.436	*0.455*	24.466	*0.615*	31.592	*1.180*	49.720	*1.82*	61.213
0.300	16.699	*0.460*	24.702	*0.620*	31.799	*1.200*	50.194	*1.84*	61.477
0.305	16.962	*0.465*	24.938	*0.625*	32.005	*1.220*	50.660	*1.86*	61.736
0.310	17.223	*0.470*	25.174	*0.630*	32.211	*1.240*	51.116	*1.88*	61.991
0.315	17.484	*0.475*	25.408	*0.635*	32.416	*1.260*	51.563	*1.9*	62.242
0.320	17.745	*0.480*	25.641	*0.640*	32.619	*1.280*	52.001	*1.92*	62.488

Logistics for lecturers

1. Folding rules
2. Cameras
3. Stands with cross braces
4. Allen wrenches fastened to stands
5. Target with cross hairs – preferably with exact centimeter squares
6. Ply wood to support targets
7. Calculators that do trig

Logistics for instructors:

I. Plant materials
   - A. Bean or other plants in pots …
   - B. Grass sod
   - C. Field plots

II. Worksheet
   - A. Clip boards
   - B. Two-meter sticks with cm markings?
   - C. Regular and colored pencils (?)

III. Still cameras with plants
   - A. Set up with monitor
   - B. Target printed and mounted?
   - C. Who will manage?

IV. IRT field of view
   - A. How many types of IRTs can we manage?
   - B. How to mount?
   - C. Contrasting temperature source
     1. "blue ice" bricks — multiple maintained in a freezer?
     2. Towels to mop up condensation
   - D.

V. IRT angle
   - A. Inclinometer mounted on IRT (Matt has one in our lab)

VI. Canopy cover in the field
   - A. Suzette's protocol with two meter sticks

B. Pictures to be retained for image analysis exercise