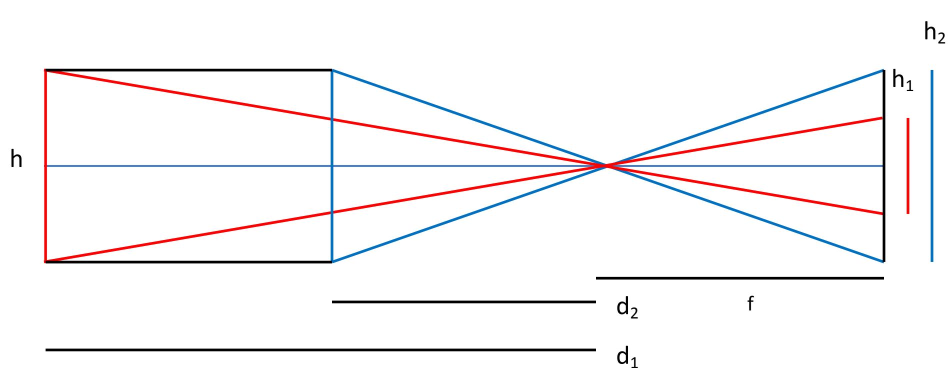
Vision Targeting Challenges

As you know, the FRC 2012 Challenge, Rebound Rumble, involves shooting foam basketballs into four hoops at various height and at a distance. During Autonomous period, the shooting distance is pretty much fixed because the robots will be parked at the key area. However, during TeleOp period, the robot can shoot anywhere. In order to give the robot more accuracy in shooting the hoops, it is desirable to use a camera and develop a vision targeting algorithm to assist this task. At first, this seems to be a complex problem. But if you break down the problem into some basic concepts, each of the concepts is not really that complex.

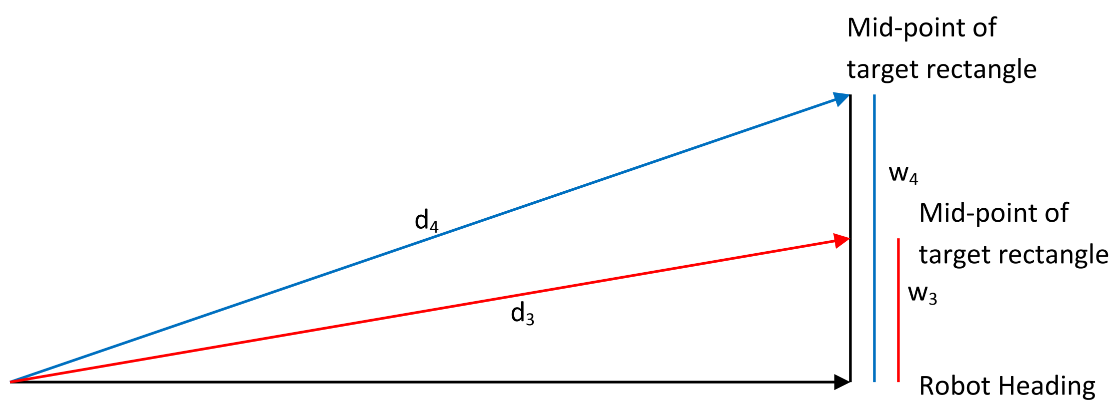
Above each hoop, there is a targeting rectangle with a known outside dimension of 24" x 18" made of 2" retro-reflective material with a background of black gaffers tape to enhance the contrast so that the camera can easily detect the edge of the rectangle. WPI also provides a vision processing module that will take a snapshot from the camera and scan the image for the target rectangles. Once found, it will return a list of "matching" objects, their locations (coordinates) and dimensions.

Therefore, our first challenge is: given the location and dimension of a rectangle on the screen, we need to determine how far away the target is. This is actually not that difficult but requires a bit of math. The closer we are to the target, the bigger the dimension of the rectangle is on the screen. For practical purpose, we will consider only the vertical dimension of the rectangle because it is less affected by perspective changes (i.e. no matter where the robot is on the field, as long as it is 20-ft away from the target, the vertical dimension of the target on screen does not change). With that consideration in mind, let's look at the drawing below. In the drawing, $\boldsymbol{h}$ represents the actual dimension of a vertical side of the target rectangle (18 inches). The converging point is where the lens of the robot camera is. On the right side of the converging point represents the camera sensor where the vertical edge of the target rectangle is projected onto. So $\boldsymbol{h_1}$ is the projected height on the screen at distance $\boldsymbol{d_1}$ and $\boldsymbol{h_2}$ is the projected height on the screen at distance $\boldsymbol{d_2}$. The focal length of the camera is represented by $\boldsymbol{f}$. Assuming we put the robot at a fixed known distance $\boldsymbol{d_1}$ from the target rectangle and note the $\boldsymbol{h_1}$ value on the screen, so they are known values. Then we randomly put the robot somewhere else at an unknown distance $\boldsymbol{d_2}$ from the target rectangle and note the $\boldsymbol{h_2}$ value on the screen. Your homework is to derive an equation to find $\boldsymbol{d_2}$ as a function of other known parameters. i.e. $\boldsymbol{d_2} = f(\boldsymbol{h}, \boldsymbol{h_1}, \boldsymbol{h_2}, \boldsymbol{d_1})$

Hint: You may not even need all the known parameters (feel free to ask your math or physics teachers for help).



Now that the distance from the target is determined (***d_2***), the next challenge is to determine how far off is the heading of the robot from the target so we can turn the robot such that the target is dead ahead (i.e. aiming). Again, let's look at the drawing below. Assuming we also do a "calibration" by putting the robot at a known angle **β_3** from the target rectangle and measure the distance ***d_3*** and note the horizontal distance of the target from the center of the screen ***w_3***, so these become known values. Then we randomly turn the robot to point to somewhere else at an unknown angle **β_4** from the target and note the ***w_4*** value of the target to the center of the screen. We can determine ***d_4*** from using the result of the previous challenge. Your homework is to derive an equation to find **β_4** as a function of other known parameters. i.e. **β_4** = f(***w_3***, ***d_3***, ***w_4***, ***d_4***, **β_3**)



$\tan\beta_1 = 0.5h/d_1 = 0.5h_1/f$ (red)

- ⇨ $h/d_1 = h_1/f$
- ⇨ $f = h_1\, d_1/h$

$\tan\beta_2 = 0.5h/d_2 = 0.5h_2/f$ (blue)

- ⇨ $h/d_2 = h_2/f$
- ⇨ $h/d_2 = h_2/(h_1\, d_1/h)$
- ⇨ $h(h_1\, d_1) = h(h_2\, d_2)$
- ⇨ $h_1\, d_1 = h_2\, d_2 = k_d$
- ⇨ $d_2 = h_1\, d_1/h_2$
- ⇨ $d_2 = k_d/h_2$

$\sin\beta_3 = w_3/d_3$ (red)

$\sin\beta_4 = w_4/d_4$ (blue)

- ⇨ $\sin\beta_4/\sin\beta_3 = (w_4/d_4)/(w_3/d_3)$
- ⇨ $\sin\beta_4 = \sin\beta_3(d_3/w_3)(w_4/d_4)$
- ⇨ $\sin\beta_4 = k_a(w_4/d_4)$
- ⇨ $\beta_4 = \mathrm{asin}(k_a(w_4/d_4))$

where:

$k_a = \sin\beta_3(d_3/w_3)$