Getting Started with FIRST Computer Vision

General

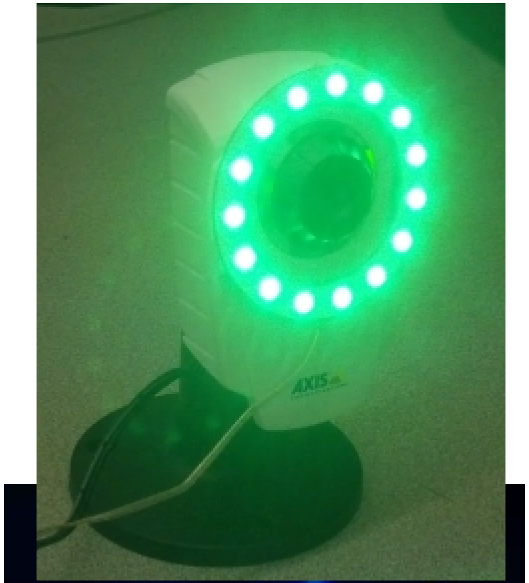
- Best teams do image processing
- Probably not a 1st year team
- More than one way
- Different tricks for different years

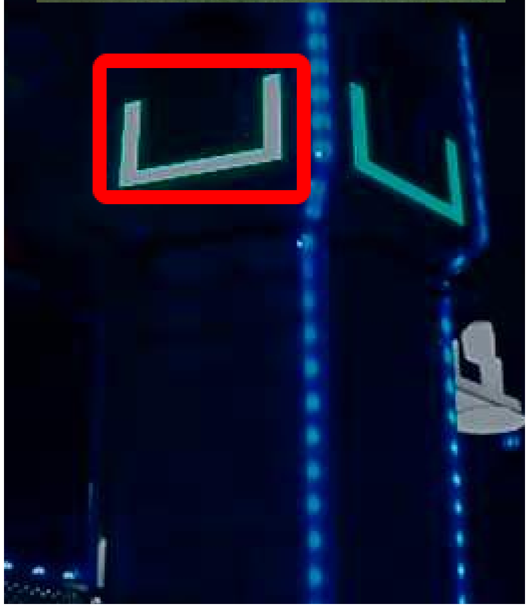
Things Vision Processing Can Do

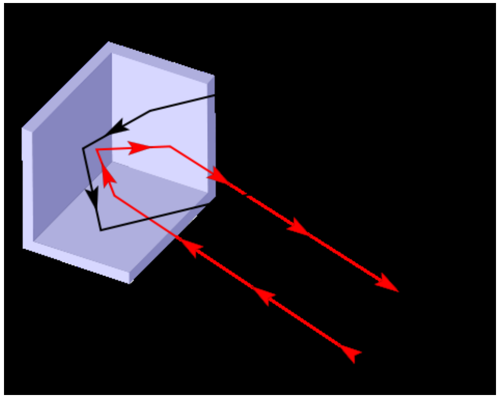
- Drive straight
- Stop at a line
- Aim at a target
- Set shooting force
- Find objects to pick up
- Measure height and distance
- Just getting you started, we won't cover all this!
- Don't worry if you don't understand it all at first!

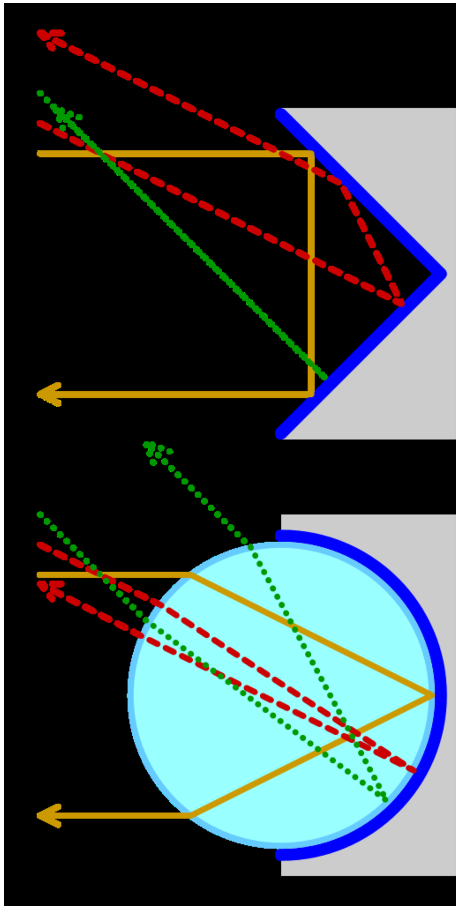
How FIRST Helps Computer Vision Retroreflectors

- Retroreflector throws light back at the source
    - Corner cube
    - Cat's eye
- Put your light near the camera – this is why you often see a ring of lights around the camera
- Targets or places to stop often have reflective tape









https://wpilib.screenstepslive.com/s/4485/m/24194/l/288983-target-info-and-retroreflection https://en.wikipedia.org/wiki/Retroreflector

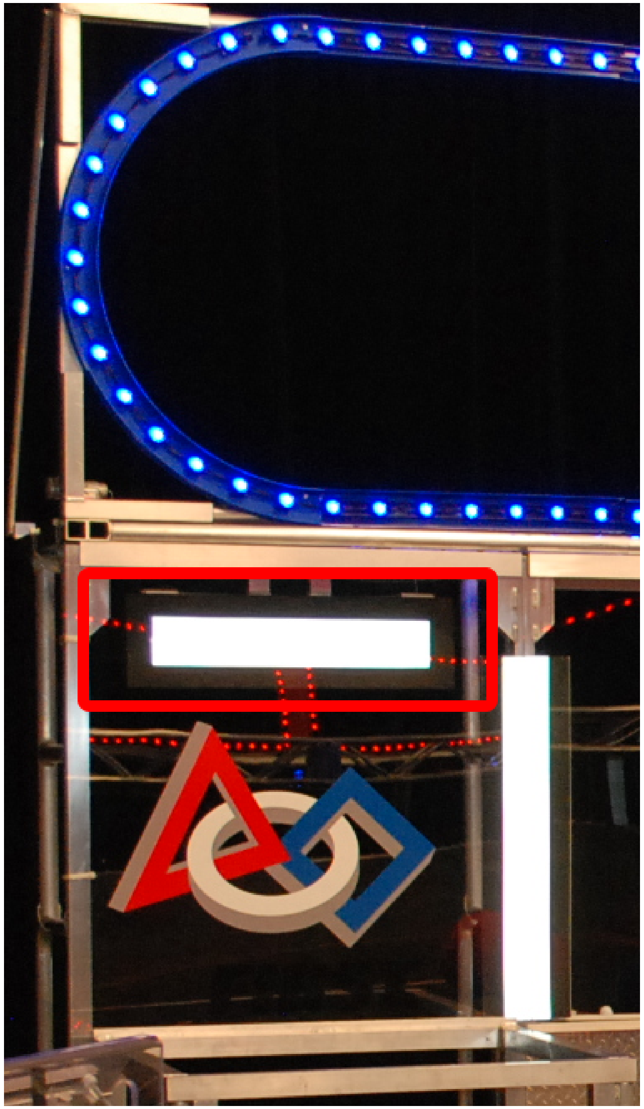
How FIRST Helps Computer Vision Green Light

- Playing field does not usually have green
- FIRST recommends green illumination
- Beware – some teams put on “decorative” green lights that might confuse your computer vision!
- Green uses a regular camera
- Green light is visible

http://wpilib.screenstepslive.com/s/3120/m/8731/l/90337-target-info-and-retroreflection

How FIRST Helps Computer Vision Blue Light

- Sometimes FIRST puts blue lights around a target
- For experts, image processing can filter on Blue to help find these targets



http://wpilib.screenstepslive.com/s/3120/m/8731/l/90337-target-info-and-retroreflection

How FIRST Helps Computer Vision White Light

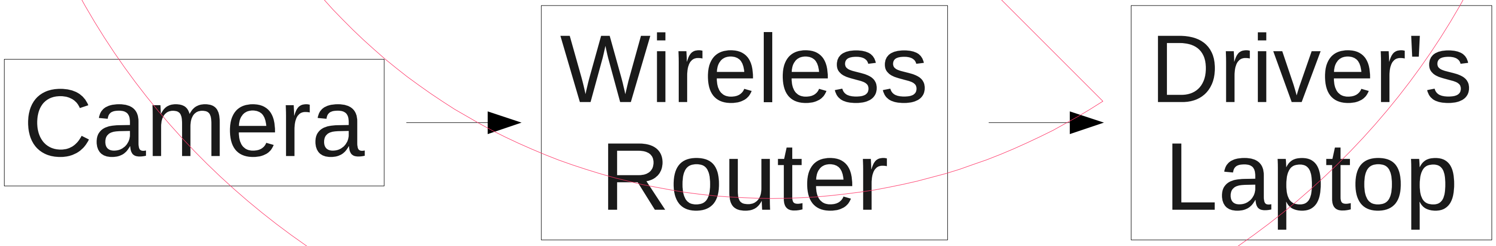
- Some advocate white light
- This can be mathematically best
- Good for finding any object (like a trash can or frisbee)

How FIRST Helps Computer Vision Infrared Light

- Some teams have had good results with infrared, but cameras are harder to find and more expensive
- Infrared works with reflector tape
- Infrared – match up 850 nm camera with 850 nm LED, or 940 nm with 940 nm
- DIY Infrared cameras online (put B&W film in place of IR filter)
- Infrared into a regular camera won't work well
- Still experimenting with ambient light vs. green light vs. green filter vs. IR

Things Not to Do
Image Process on Driver's Laptop

- Delay in getting video
- Poor resolution (FIRST limits bandwidth)
- Compression/decompression loses accuracy
- Vision code crashes → can't drive robot!
- Two subteams need same hardware



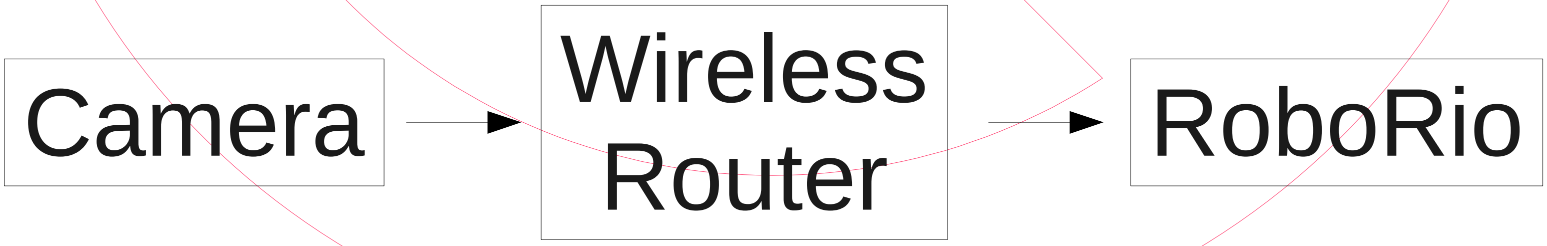
Camera

Wireless Router

Driver's Laptop

Things Not to Do
Process on the RoboRio

- RoboRio is not a very powerful computer
- Vision code crash = robot stops working
- Two subteams need same hardware



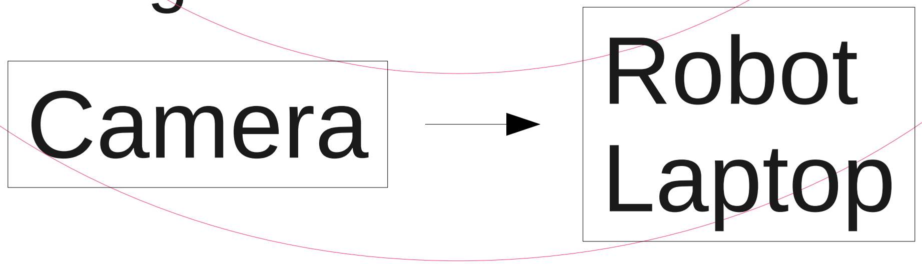
Camera

Wireless Router

RoboRio

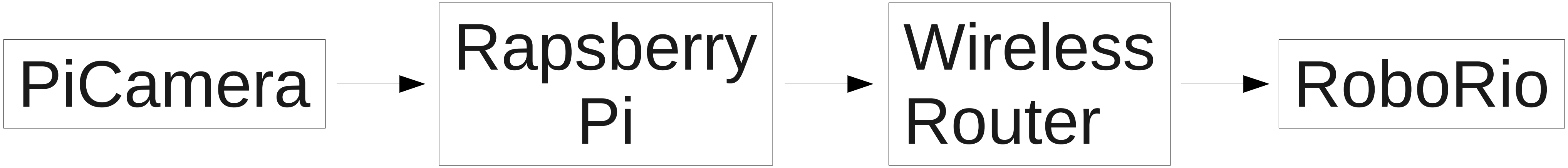
Good and Bad
Laptop on the Robot

- Laptop/tablet is expense
- Must have SSD (no high speed spinning parts)
- Laptop is 1 to 7 pounds
- Laptop might get damaged
- Does allow for parallel development, vision subteam can work on the laptop while the rest of the subteams keep going
- For experts, high computational power for heavy duty image processing



Best Compromise
Raspberry Pi + PiCamera

- Cheap $70 for Raspberry Pi and PiCamera
- RPi is a general purpose computer about ½ the power of a laptop
- Cheap enough to buy 2 or 3
- Very light
- Vision subteam can work in parallel with other subteams
- Many other teams do this
- Lots of web expertise for the Raspberry Pi
- PiCamera can do 90 frames/second!
- PiCamera NoIR does infrared imaging, infrared LEDs also available



Computer Programs

- Raspbian – OS for Rpi, has Python installed
- PiCamera – software to run PiCamera
- OpenCV-python – OpenCV image processing software accessible from Python
  - Used by Google
  - Used by many FIRST teams
- Matplotlib – display the pictures for coding and debugging
- Python or C++?
  - Python – easier, fast if high level OpenCV or PiCamera or Matplotlib commands are used
  - C++ – much slower and harder to code, but everything can run fast
- Just suggestions – there are several good options
- www.explodingdinosaurs.com/FIRST has my notes on software installation
- Took me about 8 hours to get my RPi software loaded and compiled

Computer Colors

- Computer does [red,green,blue]
- [0,0,0] = black
- [255,255,255] = brightest white
- [63, 0, 0] = red, 1/4 intensity
- [0,63, 0] = green, 1/4 intensity
- [0, 0,63] = blue, 1/4 intensity
- To computer, American flag is red, red+green+blue, and blue
- Caution, sometimes it is [blue,green,red]

Data from Raspberry Pi to RoboRio

- https://github.com/robotpy/pynetworktables
- Haven't tried it yet!

Take a Picture

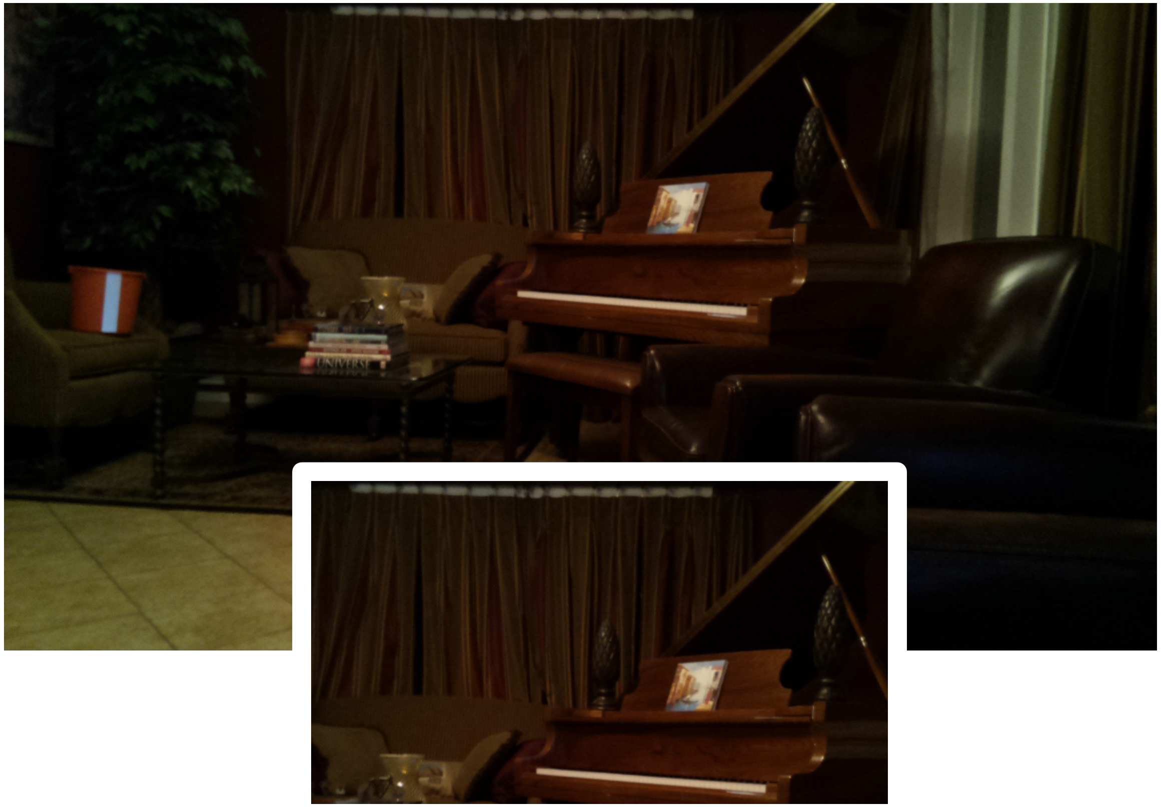
- See picamerasnappic.py and usbcamsnappic.py at http://ExplodingDinosaurs.com/FIRST
- Don't get greedy with resolution!
  - Around 640x480 is plenty
  - Fewer pixels = faster processing
  - Accuracy = distance / pixels
  - 5 m / 480 pixels = 1 cm, plenty accurate for shots
- Thresh.py shows an example of reducing the resolution

Crop the Picture

- Focus on area of interest, like high target or stripe on ground
- Faster processing
- Less likely to get confused, can cut out things like another robot with green lights
- See trimimage.py at http://ExplodingDinosaurs.com/FIRST
- image = image[0:(nrow/2),(ncol/4):(3*ncol/4),:]

Crop the Picture

Upper left is (0,0)



```
image = image[0:(nrow/2),(ncol/4):(3*ncol/4),:]
```

Upper half of rows

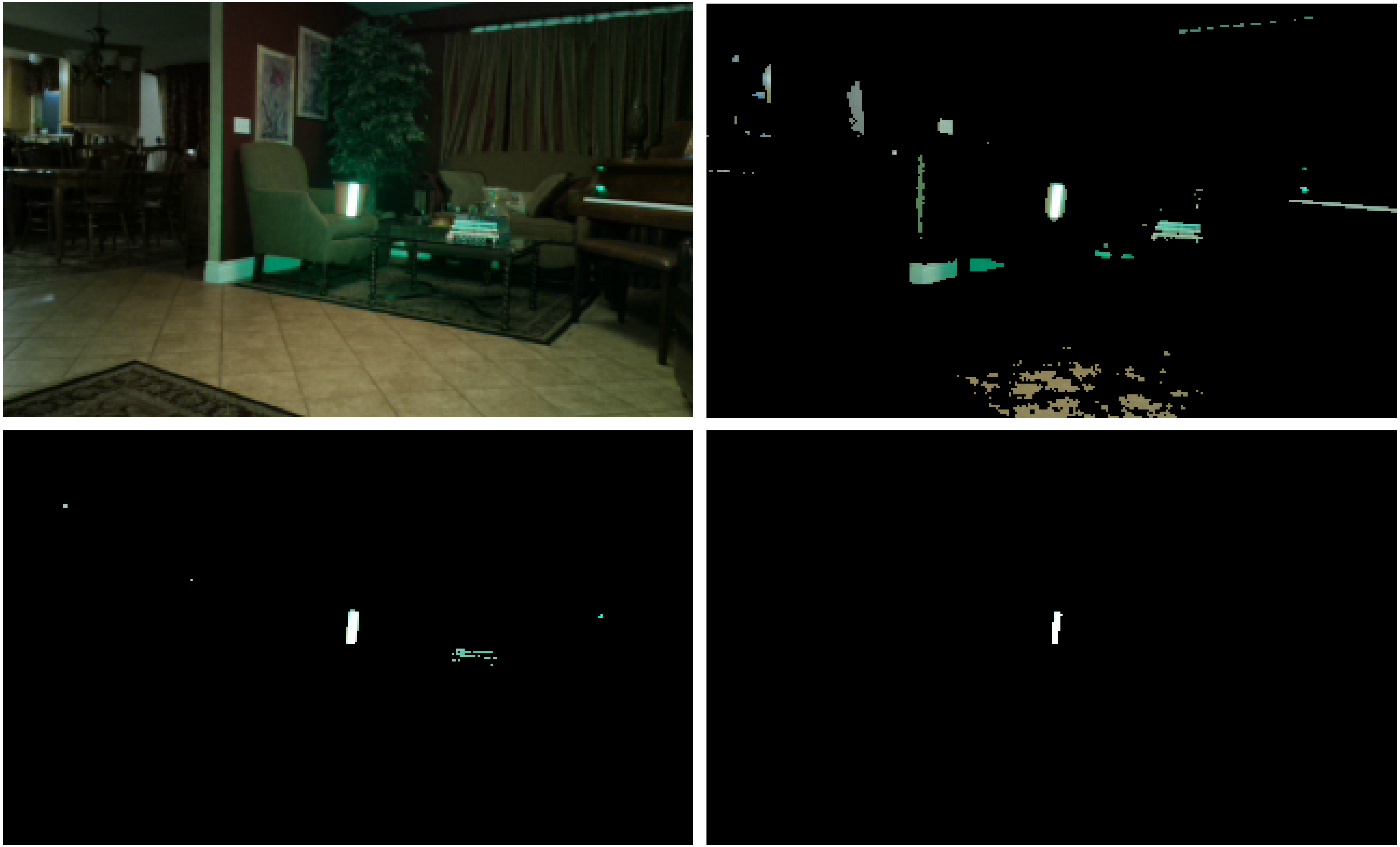
Middle half of columns

: means all 3 colors

Threshold and Center-of-Mass

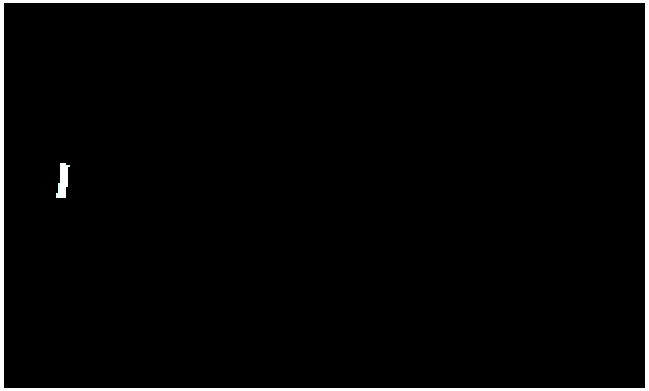
- Find the bright pixels, like the reflective tape
  - Crop image
  - Vary threshold until just reflective tape left
  - For experts, fancy statistical methods
- Recalibrate your threshold levels at the regionals! Different lighting, paints, etc. can change thresholds. FIRST offers a camera calibration time.
- Make below threshold pixels zero, and bright pixels max value
- Clever thresholds can show just the reflective tape
- Averaging the bright pixel locations gives the location of the target "Center-of-Mass"
- See thresh.py at http://www.Explodingdinosaurs.com/FIRST

Threshold and Center-of-Mass
Different Threshold Levels



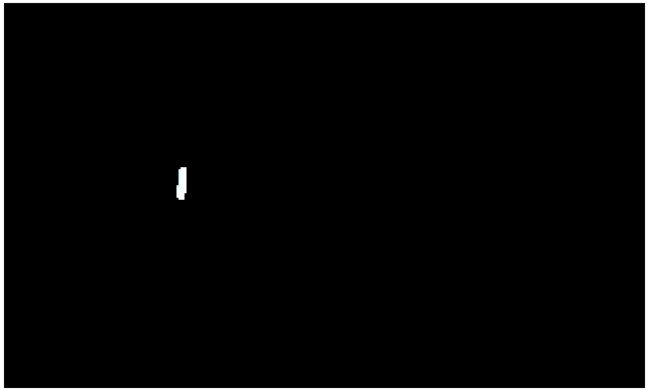
Threshold and Center-of-Mass

(0.09, 0.46)



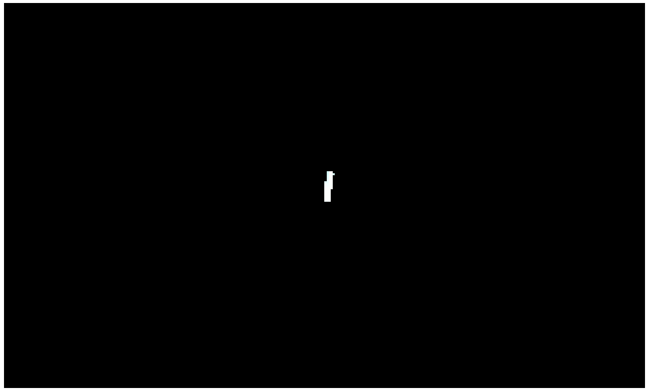
Turn left

(0.28, 0.47)



Keep turning left

(0.50, 0.47)



Target is centered, shoot!

As the target and/or the camera moves, the center-of-mass algorithm automatically finds the target location.

Finding a Template

- Take a picture
- Crop it
- Use it as a template to find it again
- Theoretically mathematically best
  - Uses the same thing to find the thing
  - Uses all the data, doesn't throw away data
- Need different templates for different positions, or to get fancy with math
- cv2.matchTemplate(image,template,cv2.ccorr)
- Still working on this one

Calibrate Shooter

- Put robot in position
- Record computer vision position on screen
- Find out RPM or shooter angle or whatever that makes the shot
- Repeat for new positions
- Create a lookup table

Summary

- Raspberry Pi + PiCamera
- OpenCV
- Reflective tape and green light
- Find position of target or stopping line
- Send to RoboRio
- React to position
- Win games!

Extra Slides

Image Subtraction (Optional)

- Stop robot
- Light on
- Take a picture
- Light off
- Take a picture
- Subtract the pictures
- Makes the retroreflective tape stand out
- Will also make moving robots stand out!