

PARKING LOT/CLASSROOM OCCUPANCY DETECTION USING RASPBERRY PI

I. Sakiotis
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Project 1: Parking Lot Occupancy

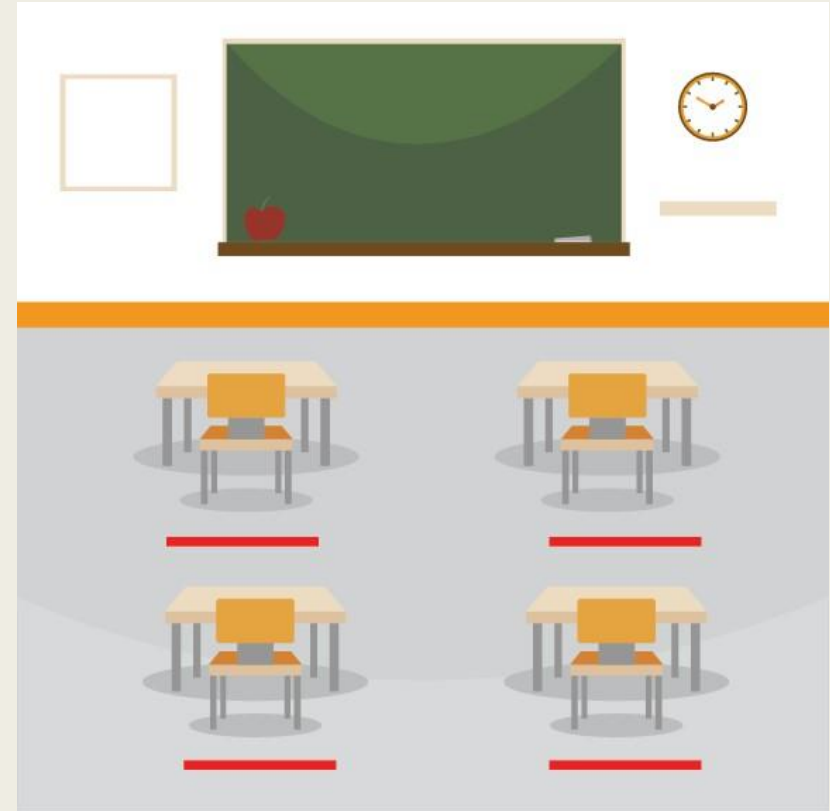
- Detect the presence of an empty parking spot
- Indicate availability by turning on green LED light



https://www.freepik.com/premium-photo/top-down-aerial-view-many-cars-parking-lot-supermarket-sale-car-dealer-market_10866185.htm

Project 2: Classroom Occupancy

- Confirm required social distancing in classroom
- Detect required vacant seats among students
- Indicate acceptable conditions by turning on green LED light



<https://www.cdc.gov/coronavirus/2019-ncov/global-covid-19/schools.html>

Required Equipment

- Raspberry Pi Kit (minimum version: 3)
- Raspberry Pi Camera
- Green LED light
- Resistor
- Jumper wires
- Breadboard
- Toy cars/people

Raspberry Pi

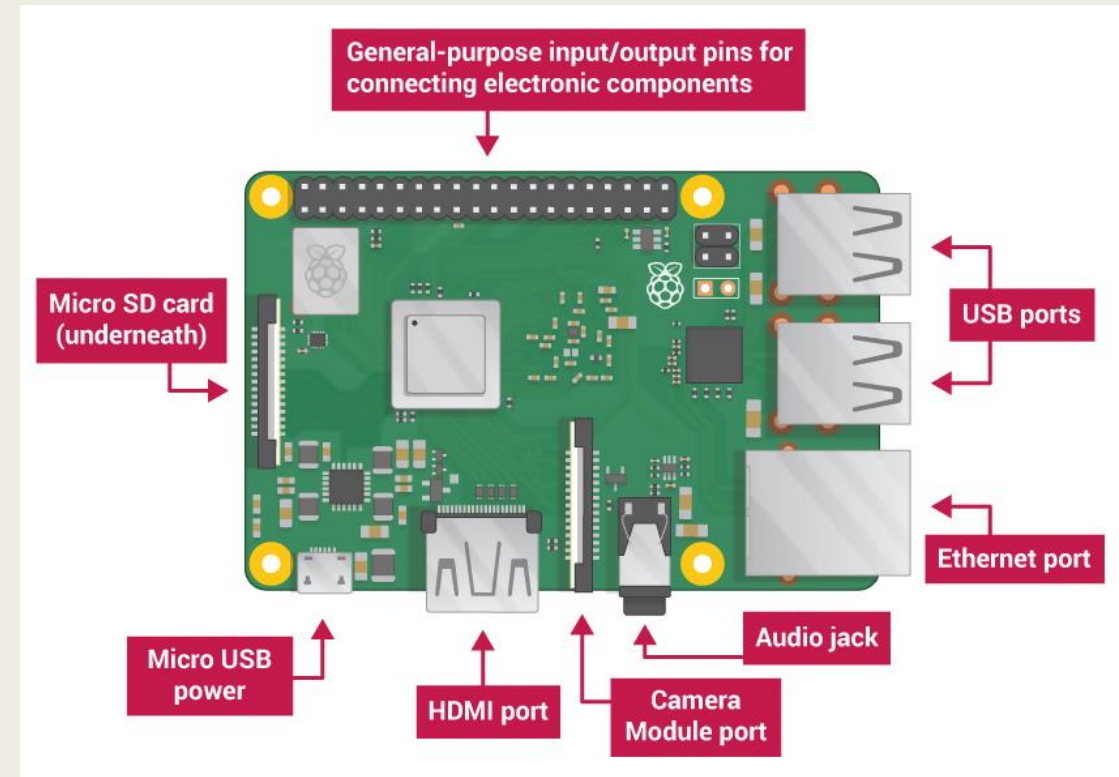
- Low-cost single board computer
- Free operating system
- Wi-Fi card
- Power adapter
- Connect to hardware (sensors, lights, etc.) through general purpose input/output (GPIO) pins
- Connect to monitor through HDMI cable
- USB-ports for keyboard/mouse
- Dedicated port for Raspberry Pi camera



<https://www.raspberrypi.org/products/raspberry-pi-3-model-b-plus/>

Raspberry Pi

- Raspbian operating system on SD card (make sure it is inserted in its respective port)
- Connect power adapter cable to micro-USB port
- Connect HDMI cable to monitor and mouse/keyboard to USB ports
- Press button on power-adapter cable to turn on
- Can use Wi-Fi/ethernet
- Execute programs from the command-line
- Can install software libraries
- Default username: pi
- Default password: raspberry



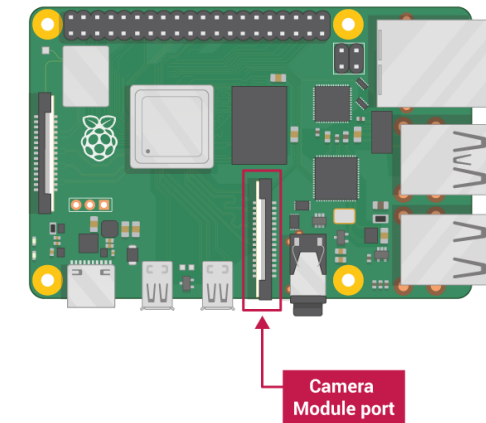
<https://thepihut.com/blogs/raspberry-pi-tutorials/the-raspberry-pi-tutorial-beginners-guide>

Pi Camera Module

- Both projects require the use of a dedicated camera
- Details on the camera itself, how to connect to the raspberry Pi, and how to configure it can be found in the link below
- <https://projects.raspberrypi.org/en/projects/getting-started-with-picamera/2>



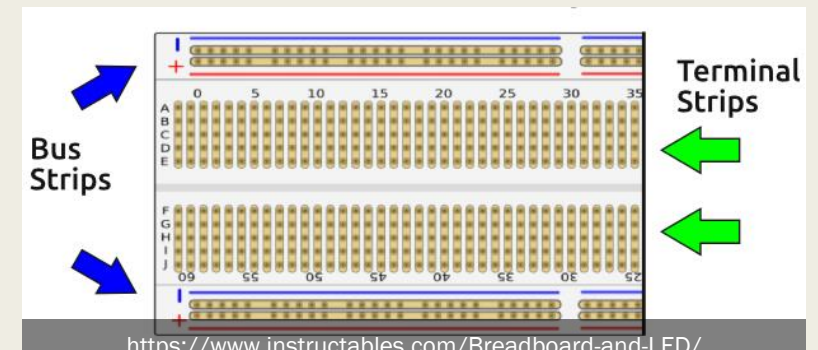
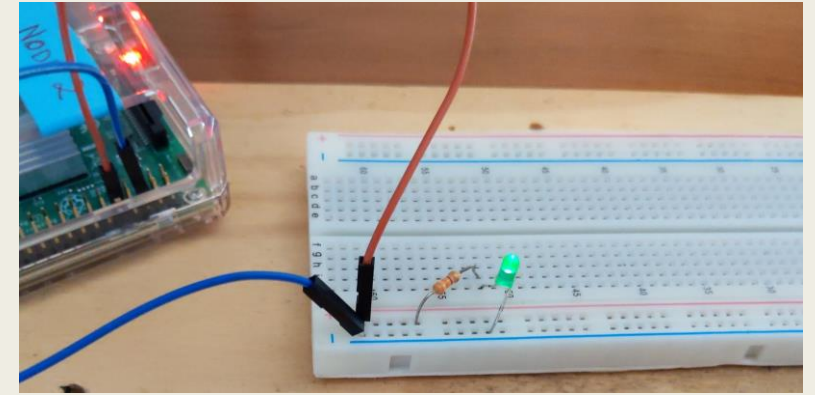
<https://projects.raspberrypi.org/en/projects/getting-started-with-picamera>

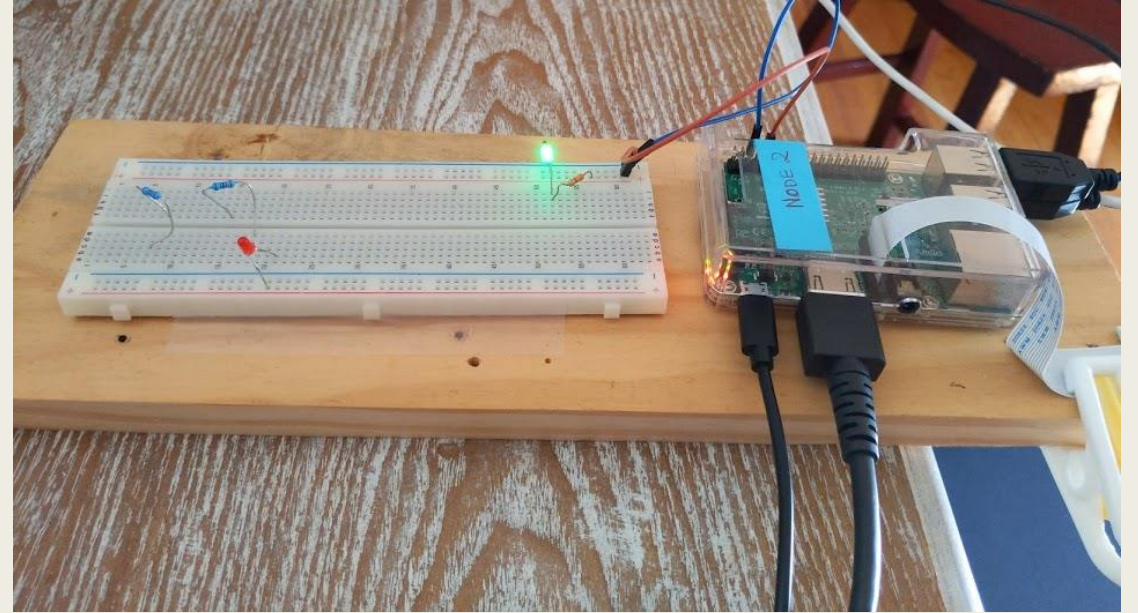
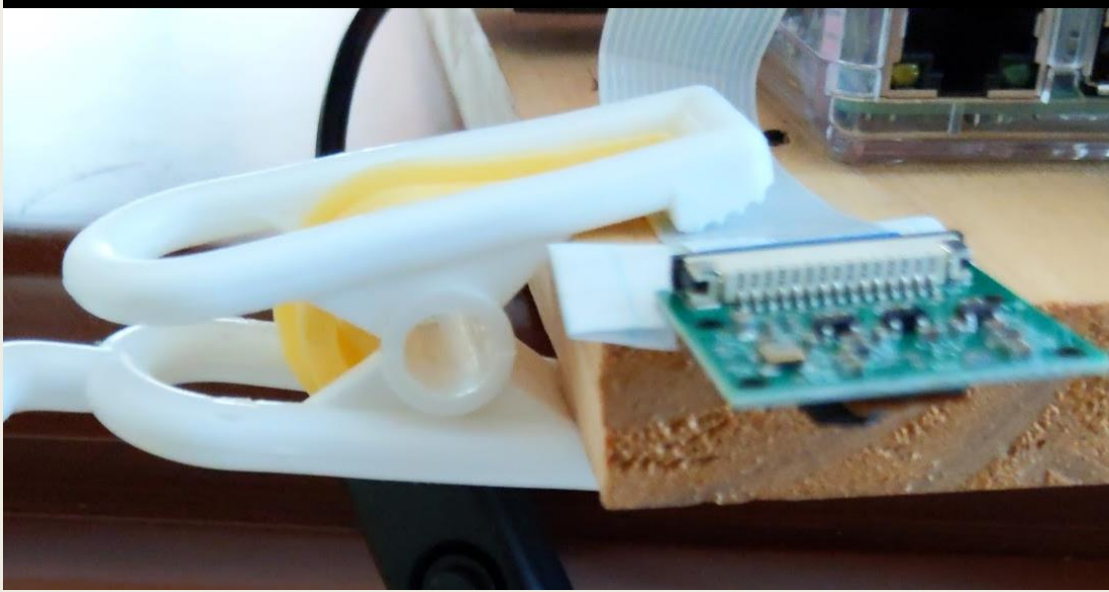


<https://projects.raspberrypi.org/en/projects/getting-started-with-picamera/1>

Breadboard & LED lights

- LED lights are placed on the breadboard
- Breadboard is connected to raspberry Pi through the jumper wires which are attached to the GPIO pins
- **ALWAYS** use resistor when using LED as raspberry Pi can be damaged
- An extensive guide on how to use LEDs with a raspberry Pi can be found on the link below
- <https://thepihut.com/blogs/raspberry-pi-tutorials/27968772-turning-on-an-led-with-your-raspberry-pis-gpio-pins>





Physical Setup

- Camera must be held firmly at position
- Suggestion: Attach clip to camera's strip

Parking Lot Occupancy

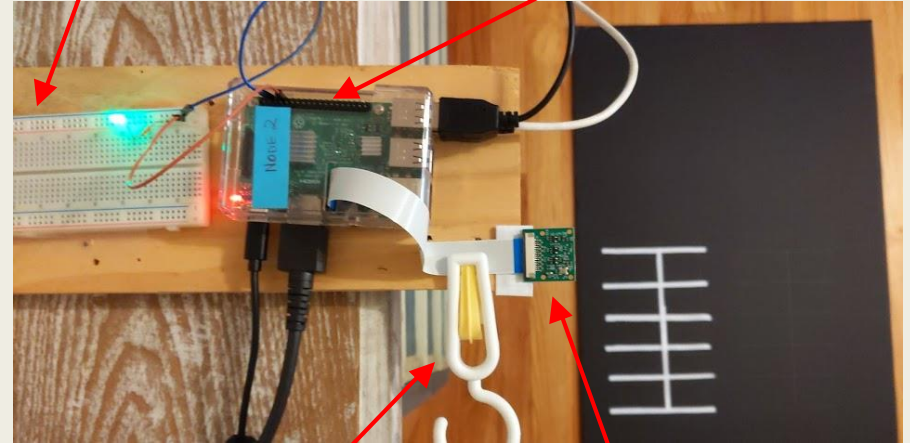
- Goals
 - *Detect the presence of an empty parking-spot*
 - *Turn on green LED if at least one parking-spot is available*
- Methodology
 - *Capture top-down photo of parking lot when empty*
 - *Capture real-time top-down photo of parking lot*
 - *Compare pixel values on the photograph's segments where parking spots are placed*
 - *“Significant” pixel difference indicates that the spot is occupied*
 - *“Little” pixel difference indicates that the spot is available*
 - *Sleep for 5 seconds after turning on/off LED*
 - *Repeat*

Assumptions

- Static camera position
- Lighting is consistent among photos
- Pixel values are never identical even if all spots are empty
- Need a heuristic threshold value to distinguish what “little” and “significant” pixel difference means

BREADBOARD

GPIO PINS



STABILITY-CLIP

FIXED CAMERA POSITION

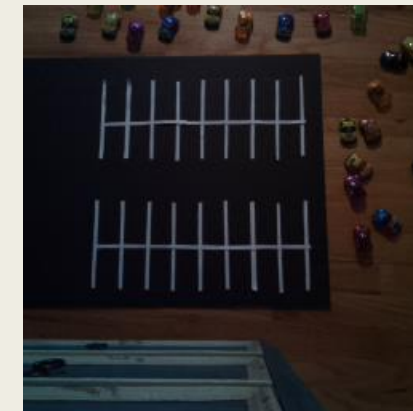
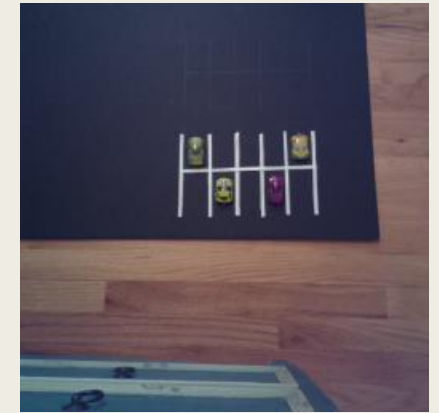
Requirements

- Must be able to adapt to different kinds of parking lots
 - *BAD: hardcoded solutions (number of spots, threshold value, locating parking spots)*
 - *OK: Command-line arguments, manual configuration files/scripts*
 - *Suggestion: Simple script (for each different parking-lot) invoking core functionality*
- Demonstrate working program on two different parking lots
- Capability to check pixel differences that determine LED's on/off status

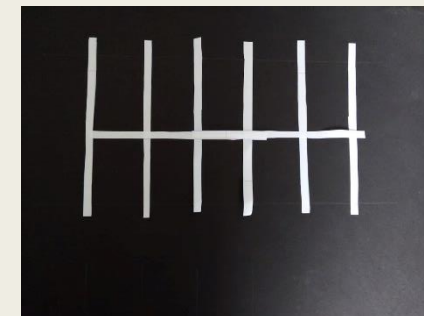
Creating Parking Lot

- Cardboard for pavement
- Paper-strips for marking parking spots
- Can use markers to draw boundaries

Pi Camera captures



Non-Pi-Camera captures



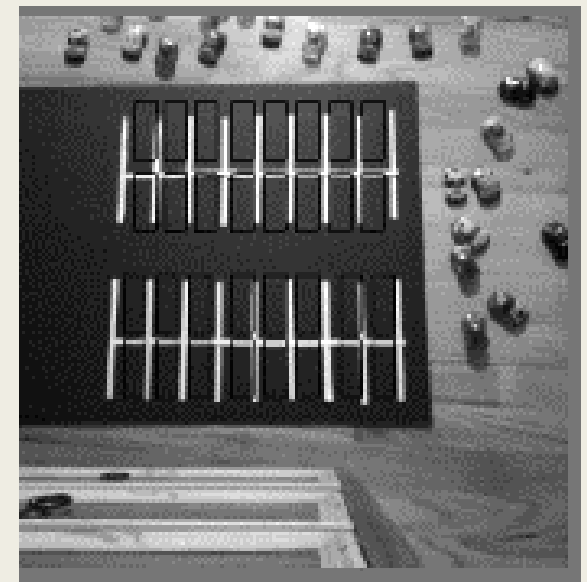
Approach to Image Processing

- Convert all images to gray-scale
 - *No advantage to using colored photo*
 - *Reduce complexity*
 - *Easier to choose threshold*
- Extract 2D array of pixel values for each parking spot from empty parking lot photo
- Extract 2D array of pixel values for each parking spot from real-time photo
- Compare 2D arrays and sum pixel differences

Original Image



Drawn bounds



Software

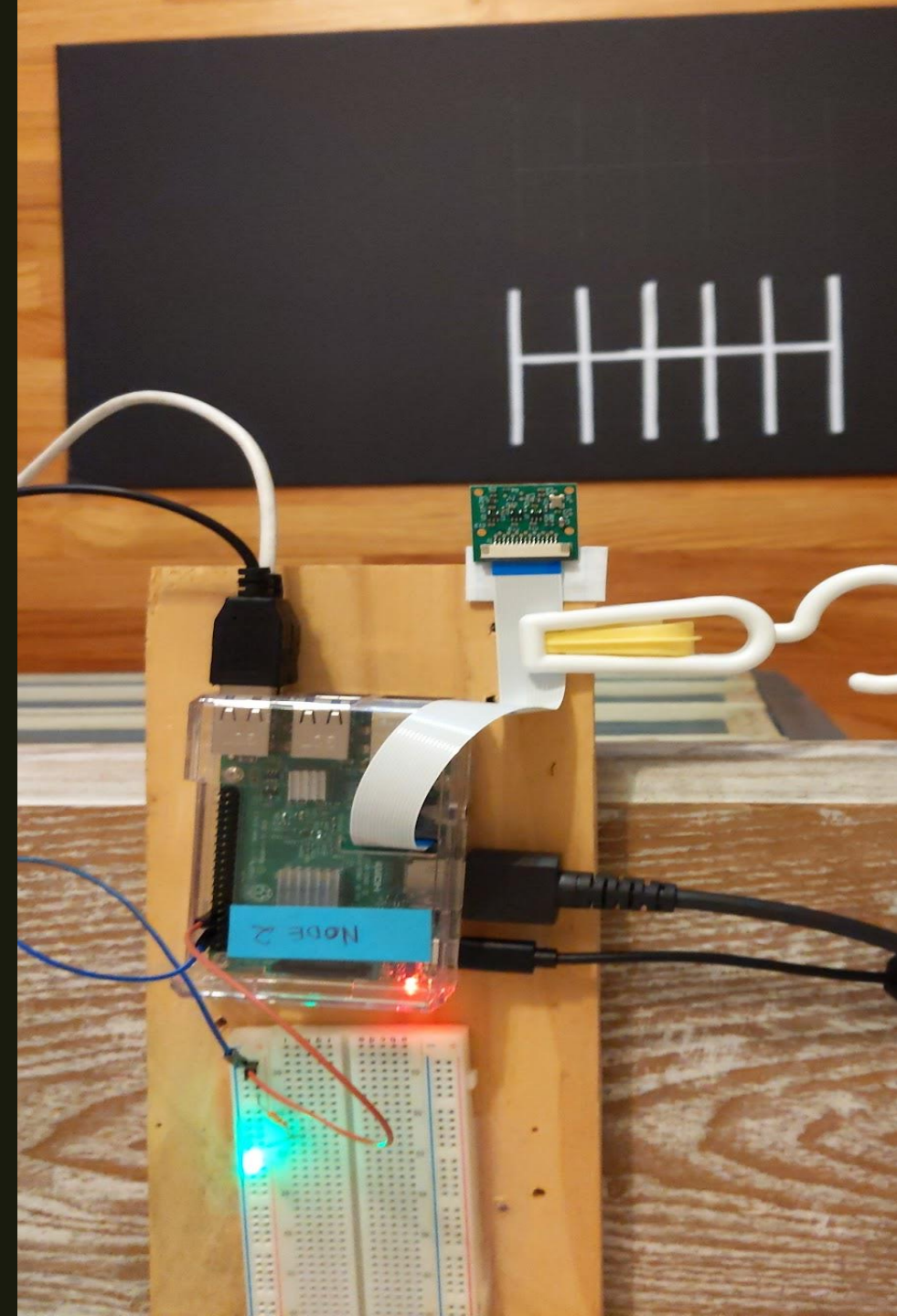
- Suggestion: Python
 - *Picamera package: capture photo*
 - *PIL library: Image objects, save/display photos, convert array to image*
 - *Numpy: array manipulation*
 - *Gpiozero: control LEDs*

- Alternative programming languages are acceptable

Test Set

- Threshold set to 650
- All empty spots
- Green LED light turns on
- Pixel differences are still non-zero
- Parking spot ids 0, 1, 2 refer to the pixelblock sets within each entry

('Difference in parking spot ', 0, 365.95200000000023)
('Difference in parking spot ', 1, 379.30600000000027)
('Difference in parking spot ', 2, 387.51400000000035)
('Difference in parking spot ', 0, 225.10100000000008)
('Difference in parking spot ', 1, 261.00399999999991)
('Difference in parking spot ', 0, 339.44)
('Difference in parking spot ', 1, 351.29400000000004)
('Difference in parking spot ', 0, 277.02399999999994)
('Difference in parking spot ', 1, 264.65800000000002)
('Difference in parking spot ', 2, 257.95300000000003)
('Available spots ', 10)



Test Set: Empty parking lot on natural light

- Natural light causes inconsistencies in the pixel values as it varies in intensity
- Repeated captures (seconds apart) on the same parking-lot display this problem
- We see below big pixel differences of two separate runs, executed seconds apart
- Suggestion: use artificial light and block natural light for consistent results

('Difference in parking spot ', 0, 16903.190999999999)	('Difference in parking spot ', 0, 16744.248000000003)
('Difference in parking spot ', 1, 16197.892999999998)	('Difference in parking spot ', 1, 16069.053000000002)
('Difference in parking spot ', 2, 14476.270999999999)	('Difference in parking spot ', 2, 14296.253000000001)
('Difference in parking spot ', 0, 10262.683999999999)	('Difference in parking spot ', 0, 10115.327999999998)
('Difference in parking spot ', 1, 9920.8100000000013)	('Difference in parking spot ', 1, 9834.5409999999993)
('Difference in parking spot ', 0, 17192.970999999998)	('Difference in parking spot ', 0, 17162.438000000002)
('Difference in parking spot ', 1, 16736.114999999998)	('Difference in parking spot ', 1, 16589.083999999999)
('Difference in parking spot ', 0, 13134.062999999998)	('Difference in parking spot ', 0, 12997.5)
('Difference in parking spot ', 1, 12693.259999999998)	('Difference in parking spot ', 1, 12602.109999999997)
('Difference in parking spot ', 2, 12344.885999999997)	('Difference in parking spot ', 2, 12236.519999999997)
('Available spots ', 0)	('Available spots ', 0)

Test Set

- No empty spots
- Green LED light is off

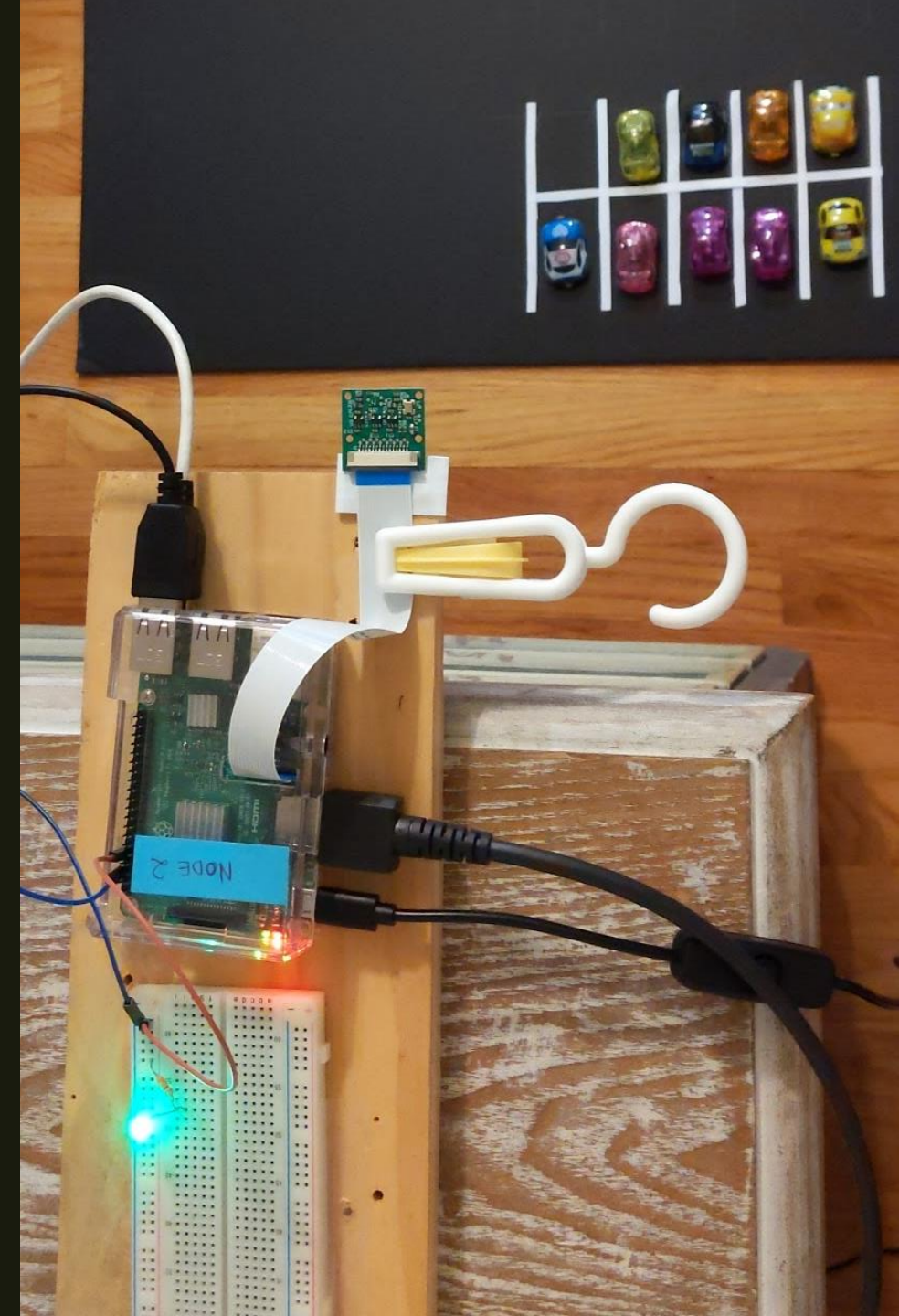
('Difference in parking spot ', 0, 6075.59800000000009)
('Difference in parking spot ', 1, 7460.20899999999989)
('Difference in parking spot ', 2, 5491.57799999999995)
('Difference in parking spot ', 0, 8044.63099999999985)
('Difference in parking spot ', 1, 4094.558)
('Difference in parking spot ', 0, 4959.71599999999994)
('Difference in parking spot ', 1, 7646.10299999999992)
('Difference in parking spot ', 0, 6689.04100000000002)
('Difference in parking spot ', 1, 8707.29399999999999)
('Difference in parking spot ', 2, 10656.74699999999999)
('Available spots ', 0)



Test set

- One empty spot
- Green LED light is on

('Difference in parking spot ', 0, 485.524)
('Difference in parking spot ', 1, 9114.358000000000002)
('Difference in parking spot ', 2, 4144.173999999999991)
('Difference in parking spot ', 0, 6672.229999999999996)
('Difference in parking spot ', 1, 11530.784)
('Difference in parking spot ', 0, 7203.879999999999992)
('Difference in parking spot ', 1, 6045.674)
('Difference in parking spot ', 0, 3823.241999999999993)
('Difference in parking spot ', 1, 4101.835999999999993)
('Difference in parking spot ', 2, 9050.265999999999996)
('Available spots ', 1)



Test set

- Two empty spots
- Green LED light is on

('Difference in parking spot ', 0, 4930.9709999999995)
('Difference in parking spot ', 1, 9245.9399999999998)
('Difference in parking spot ', 2, 4372.3919999999998)
('Difference in parking spot ', 0, 6589.8449999999993)
('Difference in parking spot ', 1, 430.236000000000022)
('Difference in parking spot ', 0, 7387.049)
('Difference in parking spot ', 1, 6262.1299999999992)
('Difference in parking spot ', 0, 3979.1169999999993)
('Difference in parking spot ', 1, 3996.4659999999994)
('Difference in parking spot ', 2, 478.840000000000003)
('Available spots ', 2)



Test set

- Seven empty spots
- Green LED light is on

('Difference in parking spot ', 0, 8650.00400000000008)

('Difference in parking spot ', 1, 481.02400000000011)

('Difference in parking spot ', 2, 474.59299999999985)

('Difference in parking spot ', 0, 291.77599999999984)

('Difference in parking spot ', 1, 10671.258)

('Difference in parking spot ', 0, 413.48500000000001)

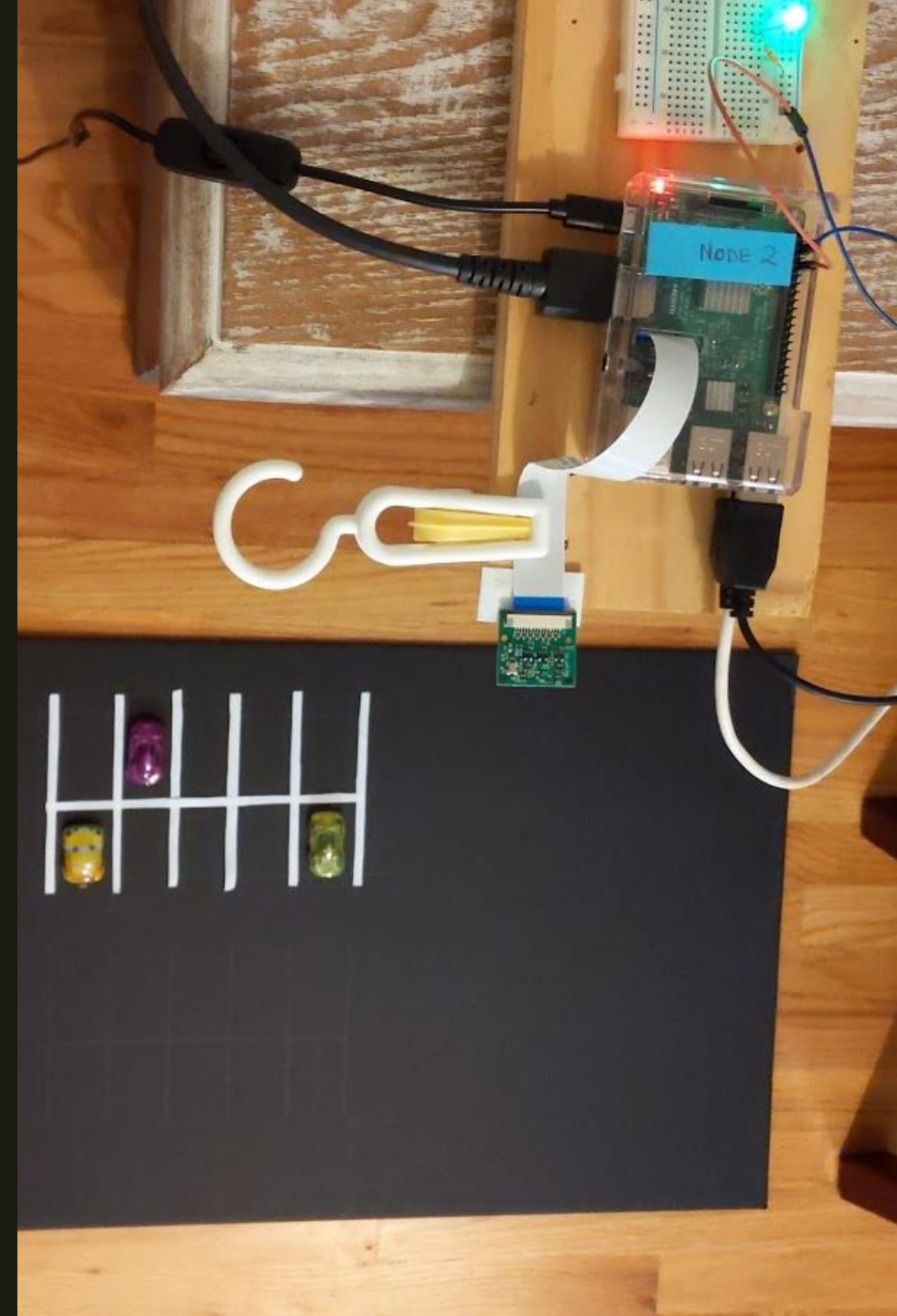
('Difference in parking spot ', 1, 463.96300000000008)

('Difference in parking spot ', 0, 328.06400000000019)

('Difference in parking spot ', 1, 2865.3579999999997)

('Difference in parking spot ', 2, 298.61200000000008)

('Available spots ', 7)



Test set

- Six empty spots
- Green LED light is on

('Difference in parking spot ', 0, 8670.65400000000005)

('Difference in parking spot ', 1, 603.737999999999983)

('Difference in parking spot ', 2, 499.787999999999956)

('Difference in parking spot ', 0, 320.436000000000015)

('Difference in parking spot ', 1, 10747.0679999999999)

('Difference in parking spot ', 0, 508.261000000000008)

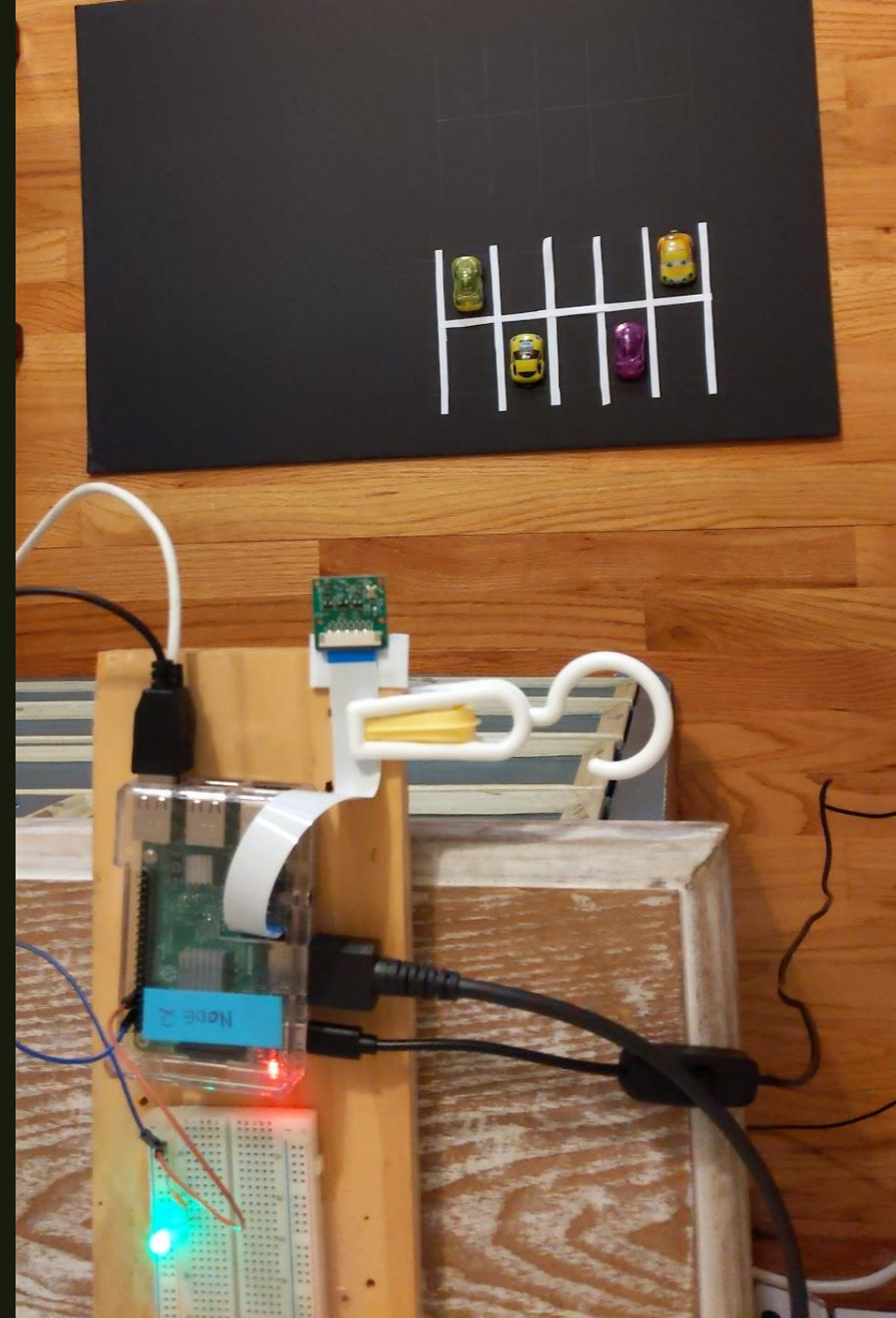
('Difference in parking spot ', 1, 10348.3699999999999)

('Difference in parking spot ', 0, 341.644999999999987)

('Difference in parking spot ', 1, 2871.436000000000001)

('Difference in parking spot ', 2, 253.909000000000022)

('Available spots ', 6)



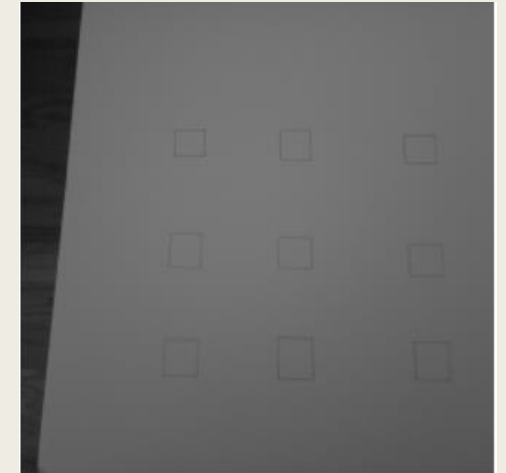
Classroom Occupancy

- Goals
 - *Verify that the seating of the students does not violate social distancing*
 - *Students are not allowed to sit to adjacent seats*
 - *Determine the number of students at risk*
 - *Turn on Green LED light if zero students are at risk*
- Methodology
 - *Capture top-down photo classroom with no students seated*
 - *Capture real-time top-down photo of classroom*
 - *Compare pixel values on the photograph's segments where student seats are located*
 - *"Significant" pixel difference indicates that the seat is occupied*
 - *"Little" pixel difference indicates that the spot is vacant*
 - *Sleep for 5 seconds after turning on/off LED*
 - *Repeat*

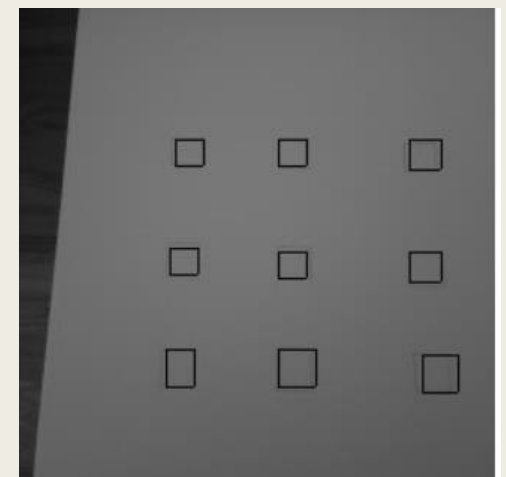
Approach to Image Processing

- Convert all images to gray-scale
 - *No advantage to using colored photo*
 - *Reduce complexity*
 - *Easier to choose threshold*
- Extract 2D array of pixel values for each seat from empty parking lot photo
- Extract 2D array of pixel values for each seat from real-time photo
- Compare 2D arrays and sum pixel differences

Original Image



Drawn bounds



Methodology

- Setup and general workflow are identical to Parking Lot Occupancy
- Identical assumptions on camera rigidness
- Return array integer flags representing vacancy(1) and occupancy(0)
- Map integer flags to 2D grid to easily check the adjacency of occupied seats
- Chosen threshold of 2000
- LED is off



Pixel diff 5005.374

Pixel diff 2318.7739999999999

Pixel diff 7097.59

Pixel diff 692.77599999999992

Pixel diff 6445.9090000000001

Pixel diff 1087.76000000000011

Pixel diff 7518.7560000000001

Pixel diff 4667.046

Pixel diff 12826.2370000000001

Returned Array

[0, 0, 0, 1, 0, 1, 0, 0, 0]

2D grid

[[0 0 0]

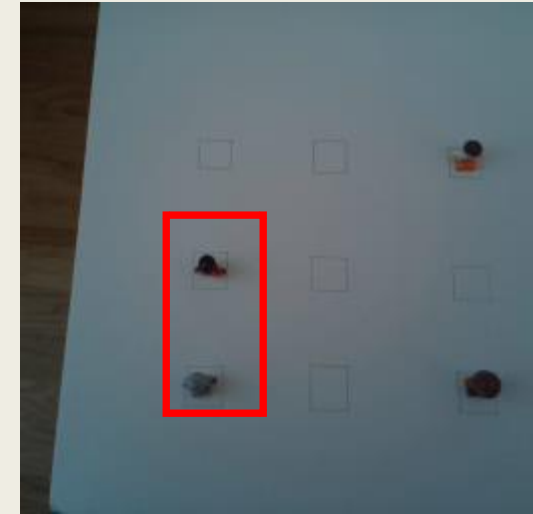
[1 0 1]

[0 0 0]]

People at risk 7

Test Set

- The two people on the left-most columns are on adjacent seats
- Chosen threshold of 2000
- 2 people at risk
- Green LED off



Pixel diff 1116.7139999999997
Pixel diff 992.2160000000001
Pixel diff 7135.92
Pixel diff 7204.6280000000001
Pixel diff 459.22399999999965
Pixel diff 1005.1839999999999
Pixel diff 7633.654
Pixel diff 735.5560000000004
Pixel diff 12851.429

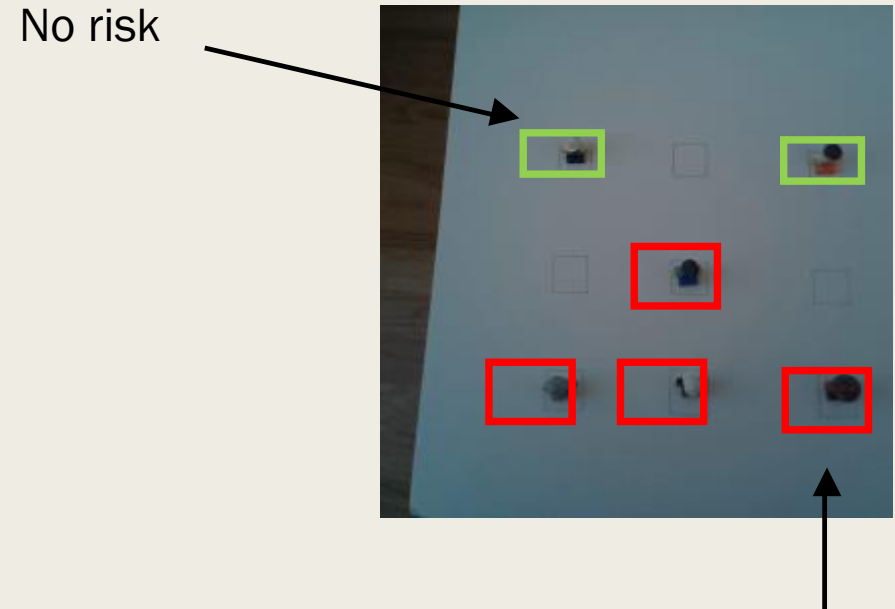
Returned Array
[1, 1, 0, 0, 1, 1, 0, 1, 0]

2D grid
[[1 1 0]
[0 1 1]
[0 1 0]]
People at risk 2

Test Set

- Chosen threshold of 2000
- 4 people at risk
- Green LED off

Pixel diff 5001.932
Pixel diff 1182.9840000000004
Pixel diff 7009.2620000000001
Pixel diff 783.10999999999996
Pixel diff 6419.35
Pixel diff 1222.0600000000004
Pixel diff 7566.822
Pixel diff 4542.582
Pixel diff 12778.699



Returned Array
[0, 1, 0, 1, 0, 1, 0, 0, 0]

2D grid
[[0 1 0]
[1 0 1]
[0 0 0]]
People at risk 4

At risk

Test Set

- Chosen threshold of 2000
- 0 people at risk
- Green LED on



Pixel diff 4980.487999999999
Pixel diff 1352.7479999999982
Pixel diff 6933.242
Pixel diff 974.8059999999999
Pixel diff 6287.182
Pixel diff 1320.3560000000002
Pixel diff 7306.170000000001
Pixel diff 1043.2879999999986
Pixel diff 12501.561000000002

Returned Array
[0, 1, 0, 1, 0, 1, 0, 1, 0]

2D grid
[[0 1 0]
[1 0 1]
[0 1 0]]
People at risk 0

Test Set

- The two people on the left-most columns are on adjacent seats
- Chosen threshold of 2000
- Everyone is at risk
- Green LED off



Pixel diff 4962.339999999999
Pixel diff 2411.1079999999993
Pixel diff 6960.164
Pixel diff 7258.8920000000001
Pixel diff 6306.849
Pixel diff 5320.366
Pixel diff 7326.276
Pixel diff 4366.2280000000001
Pixel diff 12543.194

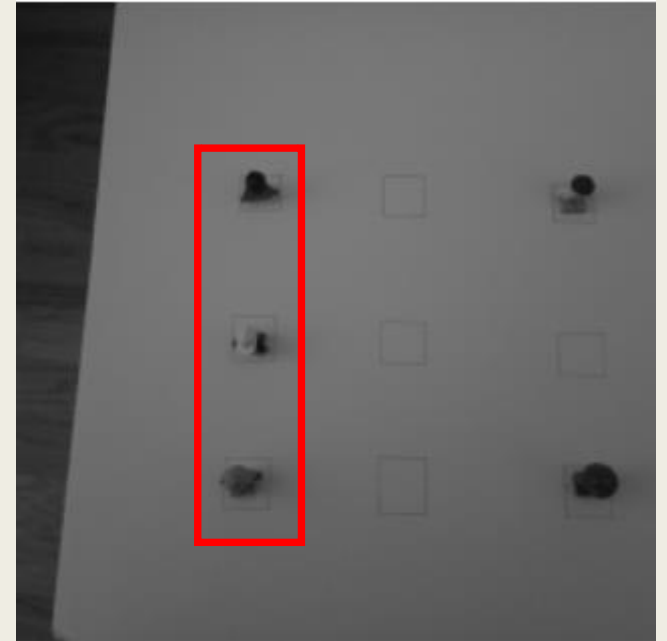
Returned Array
[0, 0, 0, 0, 0, 0, 0, 0, 0]

2D grid
[[0 0 0]
[0 0 0]
[0 0 0]]

People at risk 9

Test Set

- Chosen threshold of 2000
- 3 people at risk
- Green LED off



Pixel diff 8383.408

Pixel diff 745.1319999999992

Pixel diff 7258.3080000000001

Pixel diff 2739.0839999999999

Pixel diff 349.15799999999933

Pixel diff 772.4519999999998

Pixel diff 7748.0940000000001

Pixel diff 728.03600000000011

Pixel diff 12926.303

Returned Array

[0, 1, 0, 0, 1, 1, 0, 1, 0]

2D grid

[[0 1 0]

[0 1 1]

[0 1 0]]

People at risk 3

Test Set

- Testing on the reference image
- Chosen threshold of 2000
- 0 people at risk
- Green LED on



Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Pixel diff 0.0

Returned Array

[1, 1, 1, 1, 1, 1, 1, 1, 1]

2D grid

[[1 1 1]

[1 1 1]

[1 1 1]]

People at risk 3

Conclusion

- Pixel difference approach requires careful configuration
- Requires stationary camera angles
- User-defined pixel difference threshold
- 100% success rate
- Configuration scripts and .csv files provide adaptability
- Scripts to test with/without camera