Chess Game Tracking Using Computer Vision and Deep Learning

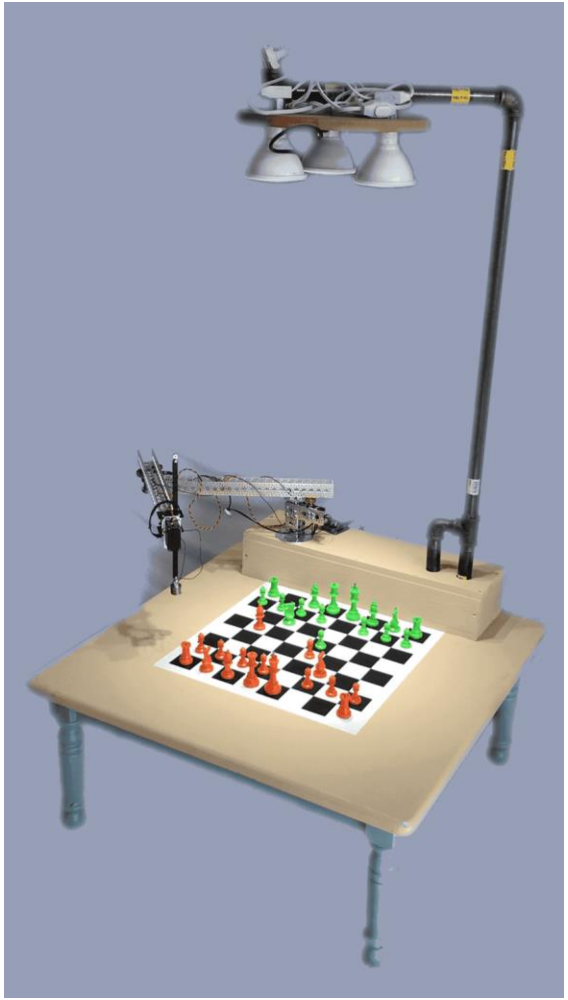
Jerry Liu

Motivation

- In tournaments, players must manually record every move played
- There are specialized chess sets that automatically record every move played, but they are expensive
- Tracking each game with computer vision is an inexpensive solution

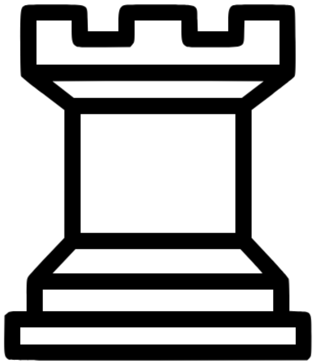
Previous Work

- Previous work has used an overhead view of the chessboard
    - Difficult to distinguish between certain pieces (e.g. pawns and bishops)
- Specialized colored chess sets (e.g. red and green pieces)



My Project

- Track a chess game using computer vision
  - Camera mounted over chessboard
    - 45 degree angle
  - Piece Detection
    - Pickle Module and Keras Library
  - Board Detection
    - OpenCV Library



Piece Detection

- Convolutional Neural Network
  - Training with database of chess pieces
    - Google Images
    - Manual Collection
  - Keras

Database of Pieces

- 7 folders of images corresponding to each piece
  - Empty square, pawn, knight, bishop, rook, queen , king
- Started off using only sample images scraped from Google Images
- Later, added pictures manually taken at angles

Google Images Pictures

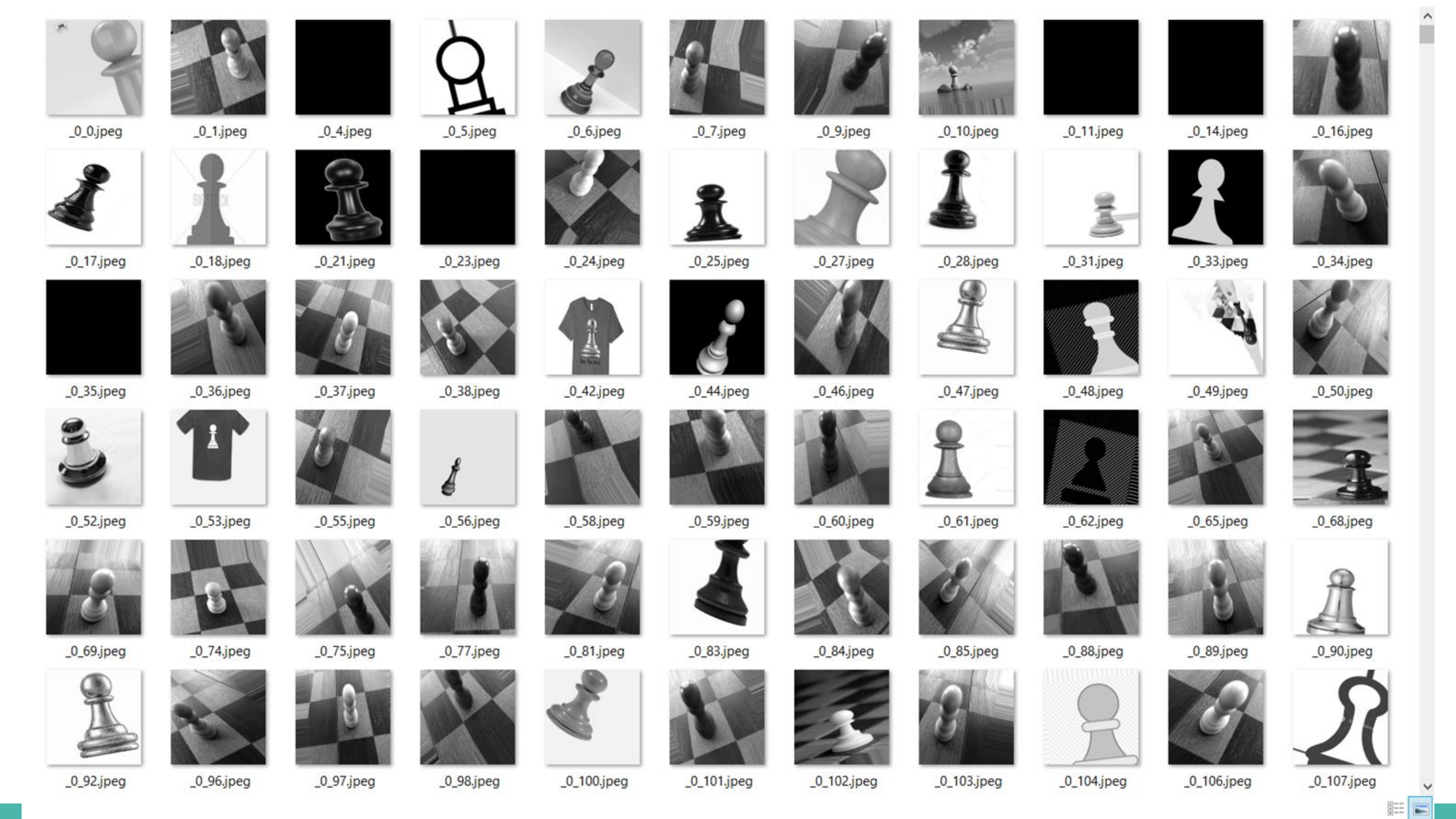
- Google Images as source
  - Used Javascript to create a txt file of all the urls of the images for each piece
  - Used Python to download the images into folders of respective pieces
- Folders containing images of each chess piece
- Filtered bad images to approx. 200-300 base examples for each folder

Manual Collection

- Pieces from Google Images were not representative of the pieces I wanted to test
- Manually collected data at 30 - 60 degree angles
  - 200 samples per piece

Data Standardization and Magnification

- Using Keras to standardize and augment training examples
  - Standardized to 100 x 100 grayscale .jpg files
  - Reflections and Rotations
  - Augmented to approx. 4500-6000


_0_0.jpeg
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_0_9.jpeg
_0_10.jpeg
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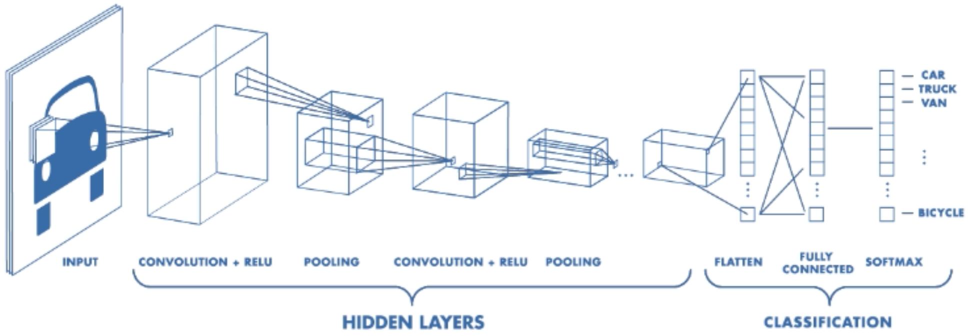
_0_103.jpeg
_0_104.jpeg
_0_106.jpeg
_0_107.jpeg

Saving my Data

- I used the Python pickle module to save the files of my training folders into individual files
- Each category of piece corresponded to a label
  - e.g. empty = 0, pawn = 1, knight = 2 etc.
- x.pickle contained each image and y.pickle contains the corresponding label

Convolutional Neural Network (CNN)

- A convolutional neural network is a type of deep neural network, most commonly applied to analyzing pictures and visual data
- Uses hidden [illegible]es from an image



Training

- Training remotely to the Duke Computer in Rm 202
  - Strong GPU - shorter training time
- CNN structure:
  - 6 convolutional layers - RELU activation function
  - 5 dropout layers
  - Fully-connected layer with 1000 neurons - RELU
  - Fully-connected layer with 7 neurons (corresponds to each piece) - Softmax
- To about 92% accuracy

```
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 100, 100, 32)      896
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 50, 50, 32)        0
_________________________________________________________________
dropout_1 (Dropout)          (None, 50, 50, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 50, 50, 64)        18496
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 25, 25, 64)        0
_________________________________________________________________
dropout_2 (Dropout)          (None, 25, 25, 64)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 25, 25, 128)       73856
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 12, 12, 128)       0
_________________________________________________________________
dropout_3 (Dropout)          (None, 12, 12, 128)       0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 12, 12, 256)       295168
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 6, 6, 256)         0
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conv2d_5 (Conv2D)            (None, 6, 6, 512)         1180160
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 3, 3, 512)         0
_________________________________________________________________
dropout_4 (Dropout)          (None, 3, 3, 512)         0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 3, 3, 4024)        18546616
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 1, 1, 4024)        0
_________________________________________________________________
dropout_5 (Dropout)          (None, 1, 1, 4024)        0
_________________________________________________________________
flatten_1 (Flatten)          (None, 4024)              0
_________________________________________________________________
dense_1 (Dense)              (None, 1000)              4025000
_________________________________________________________________
dense_2 (Dense)              (None, 7)                 7007
=================================================================
Total params: 24,147,199
Trainable params: 24,147,199
Non-trainable params: 0
```
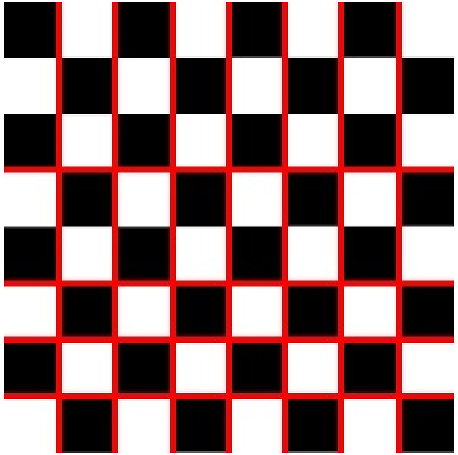

Saving the Model

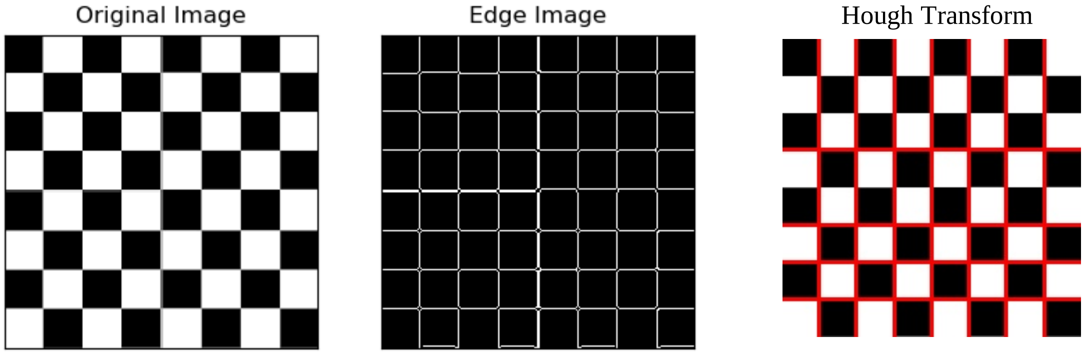
- I saved my neural network in a file called chess.h5
- Using this file, I created a python classifier program that when given an image, classifies it as one of 7 categories (i.e. empty, pawn, knight...)

Board Detection

- Line Detection
  - Canny Edge Detector
  - Hough Transform
- Corner Detection
  - Intersections between perpendicular lines
  - Non-maximum suppression



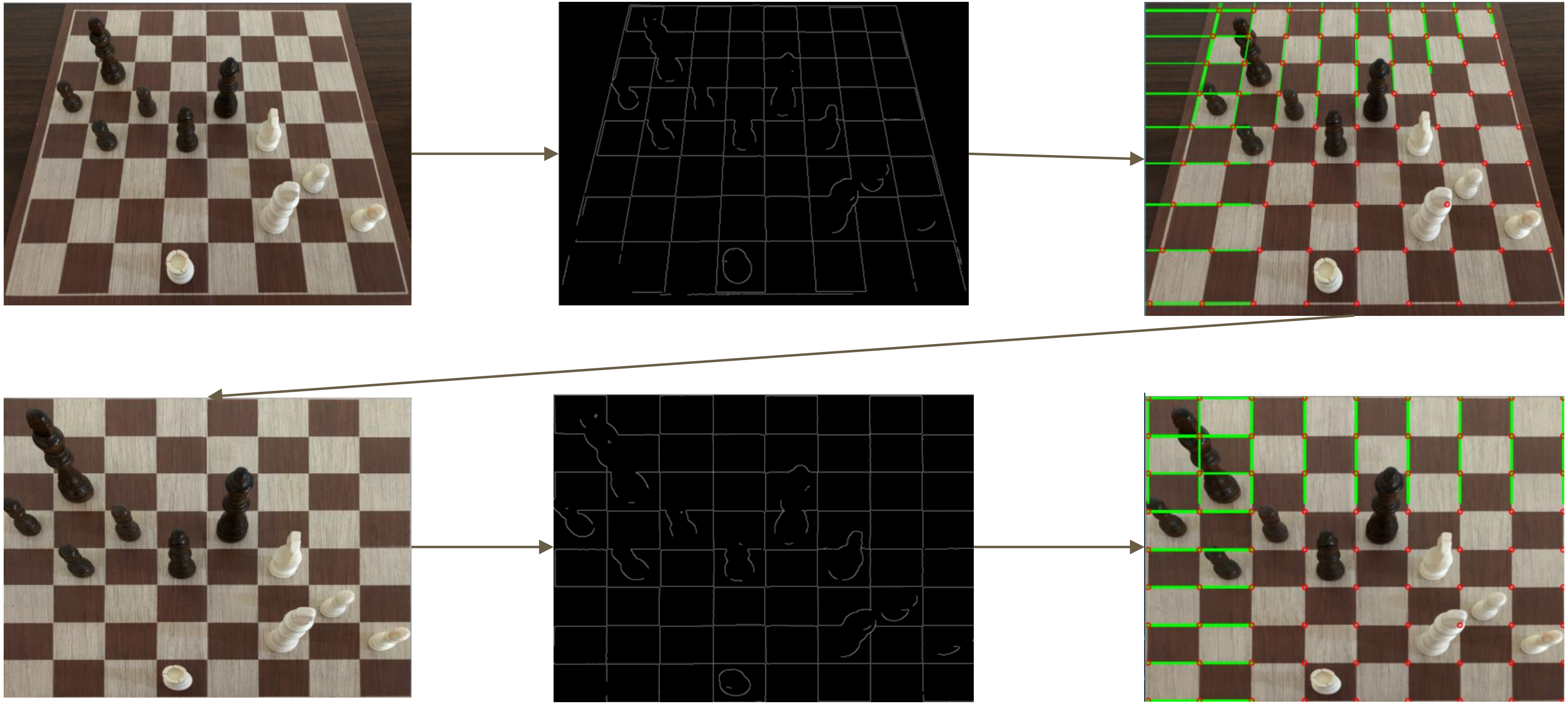
Canny Edge Detector and Hough Transform



Perspective Transform

- I used the far corners of the board to create a perspective transform of the image
- Then, I found the lines and corners again in the new image

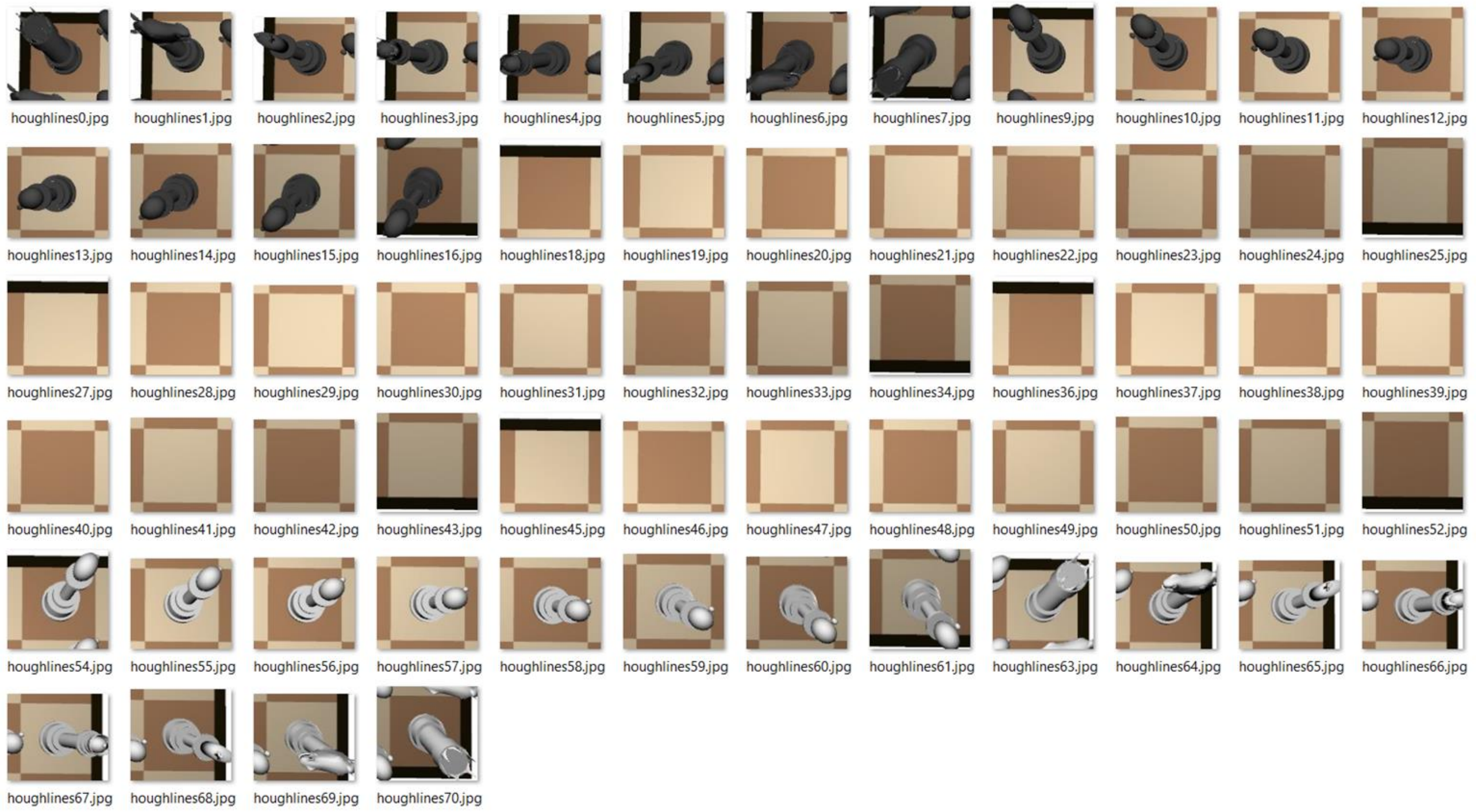
Perspective Transform



Process

- 64 images are cut out and processed - uses corners
- Each picture is run through the classifier to predict the piece (or if it's an empty square)
- The predicted board is then constructed using this information

Demonstration


houghlines0.jpg
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houghlines2.jpg
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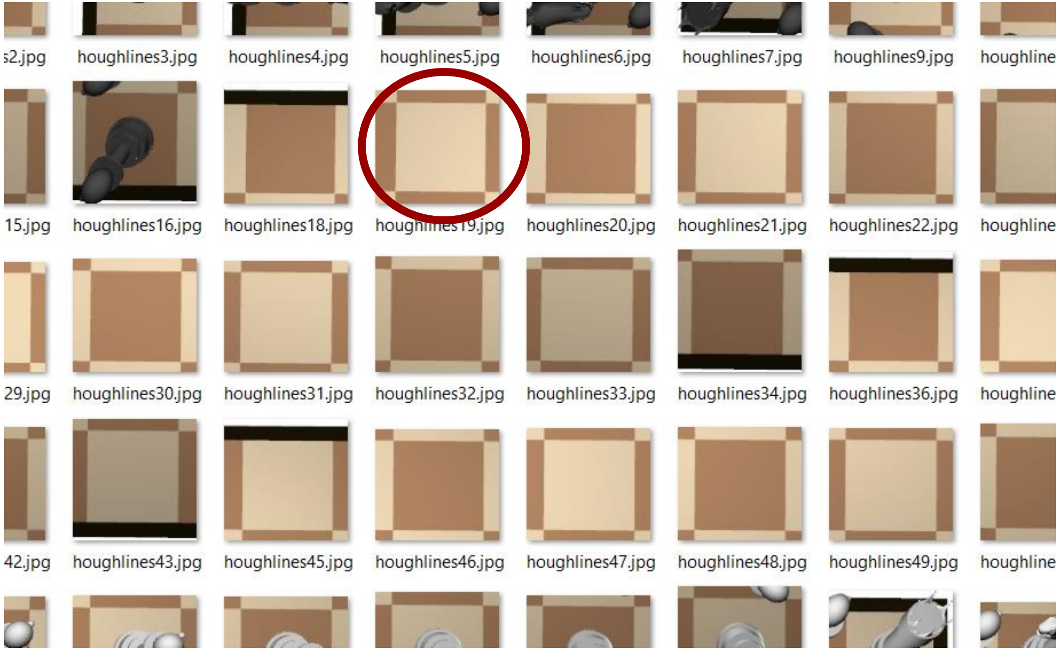
houghlines67.jpg
houghlines68.jpg
houghlines69.jpg
houghlines70.jpg



s2.jpg
houghlines3.jpg
houghlines4.jpg
houghlines5.jpg
houghlines6.jpg
houghlines7.jpg
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houghline
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houghlines48.jpg
houghlines49.jpg
houghline

empty: 100.00%
pawn: 0.00%
rook: 0.00%
bishop: 0.00%
queen: 0.00%
knight: 0.00%
king: 0.00%

```
('A1', 'pawn')
('B1', 'rook')
('C1', 'empty')
('D1', 'rook')
('E1', 'rook')
('F1', 'rook')
('G1', 'rook')
('H1', 'pawn')

('A2', 'knight')
('B2', 'bishop')
('C2', 'empty')
('D2', 'pawn')
('E2', 'empty')
('F2', 'pawn')
('G2', 'knight')
('H2', 'pawn')

('A3', 'knight')
('B3', 'bishop')
('C3', 'pawn')
('D3', 'empty')
('E3', 'empty')
('F3', 'empty')
('G3', 'empty')
('H3', 'empty')

('A4', 'empty')
('B4', 'empty')
('C4', 'empty')
('D4', 'empty')
('E4', 'empty')
('F4', 'empty')
('G4', 'empty')
('H4', 'empty')

('A5', 'empty')
('B5', 'empty')
('C5', 'empty')
('D5', 'empty')
('E5', 'empty')
('F5', 'empty')
('G5', 'empty')
('H5', 'empty')
```

Problems

- Inaccurate Classification
- Piece obstruction
- Difficulty in piece capture for each square
  - Multiple pieces in one picture

Unfinished Work

- Neural network needs fine tuning
- Needs ability to distinguish pieces by color

Acknowledgements

- I would like to acknowledge my Computer Systems Research Lab director, Dr. Zacharias

Questions?