Università di Pisa

Chess Board Position Digitalization

Intelligent Systems Course Project

Master's degree in Computer Engineering

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The Problem

Our objective is to obtaining a computer-friendly representation of a chess board state from an image of a physical board

This could be useful for different applications, such as:

- To register moves during competitions, especially in low time formats
- To quickly feed a position to a chess engine for analysis
- As a component for chess playing robots

(Input) Chess Board Image

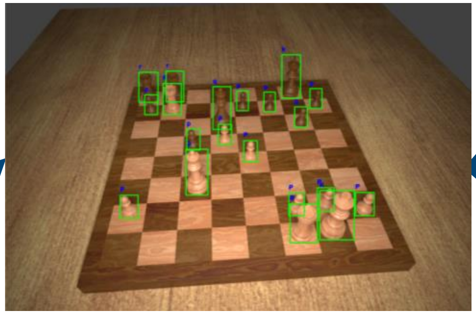
(Output) FEN Representation

```
rr4k1/pR2pp1p/
3q2p1/2pP4/4P3/
2Q5/P4PPP/5RK1
```

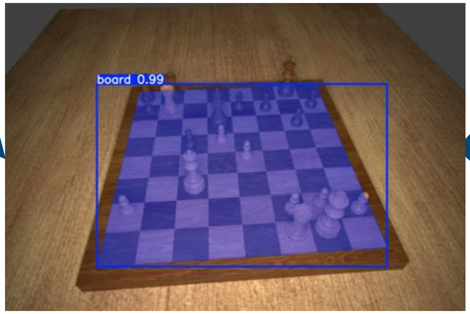
Defining the Tasks

(Input) Chess Board Image

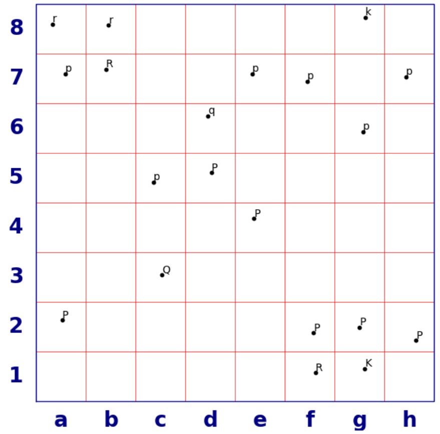
(1) Piece Detection



(2) Board Detection



(3) Computing Pieces' Squares



(Output) FEN Representation

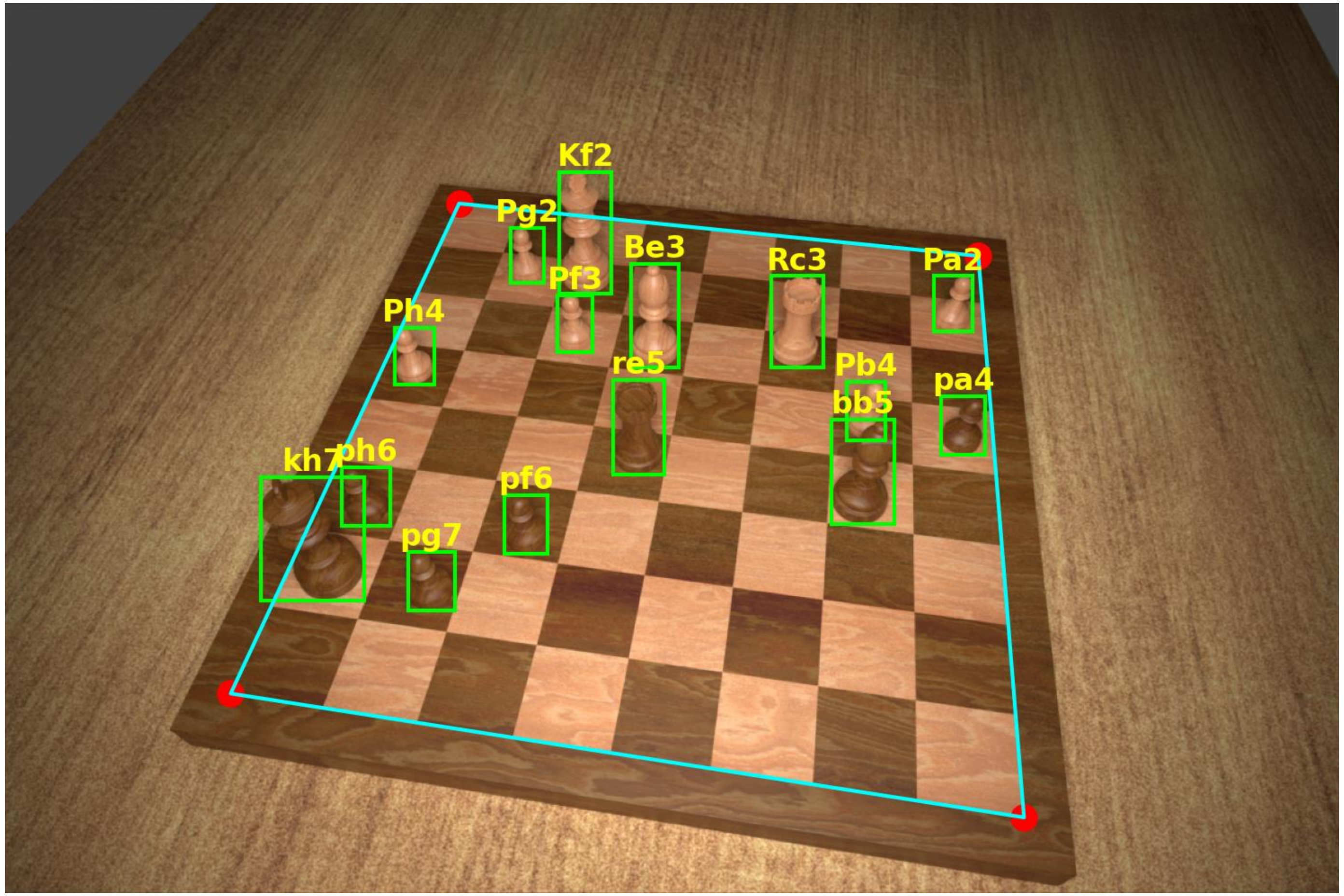
`rr4k1/pR2pp1p/3q2p1/2pP4/4P3/2Q5/P4PPP/5RK1`

The Dataset

4888 synthetic images, each with the following labels:

1. FEN representation
2. Chess board corners
3. Type, color, square and bounding box of each piece
4. Player who's turn it is
5. Camera angle and position
6. Lighting information

The board positions come from real games and include a total of 104893 pieces (on average 21/22 per image)



Computer Vision Models

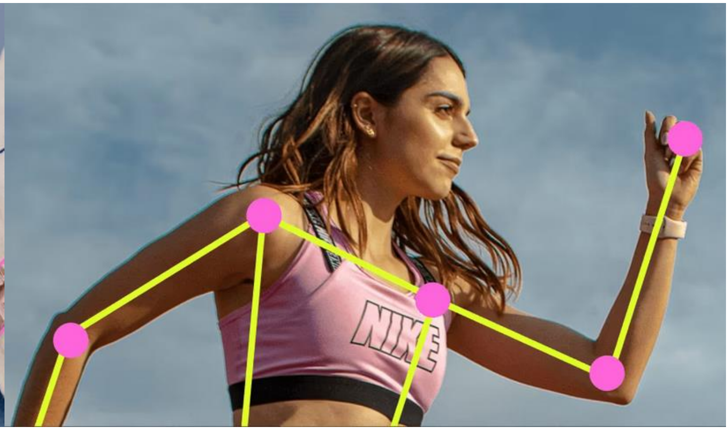
Chess Pieces

YOLO11

Chessboard orientation

YOLO11-seg

YOLO11-pose



Computer Vision Models

Model Sizes:

1. Nano
2. Small
3. Medium
4. Large

Starting Model:

1. Pretrained
2. Not Pretrained

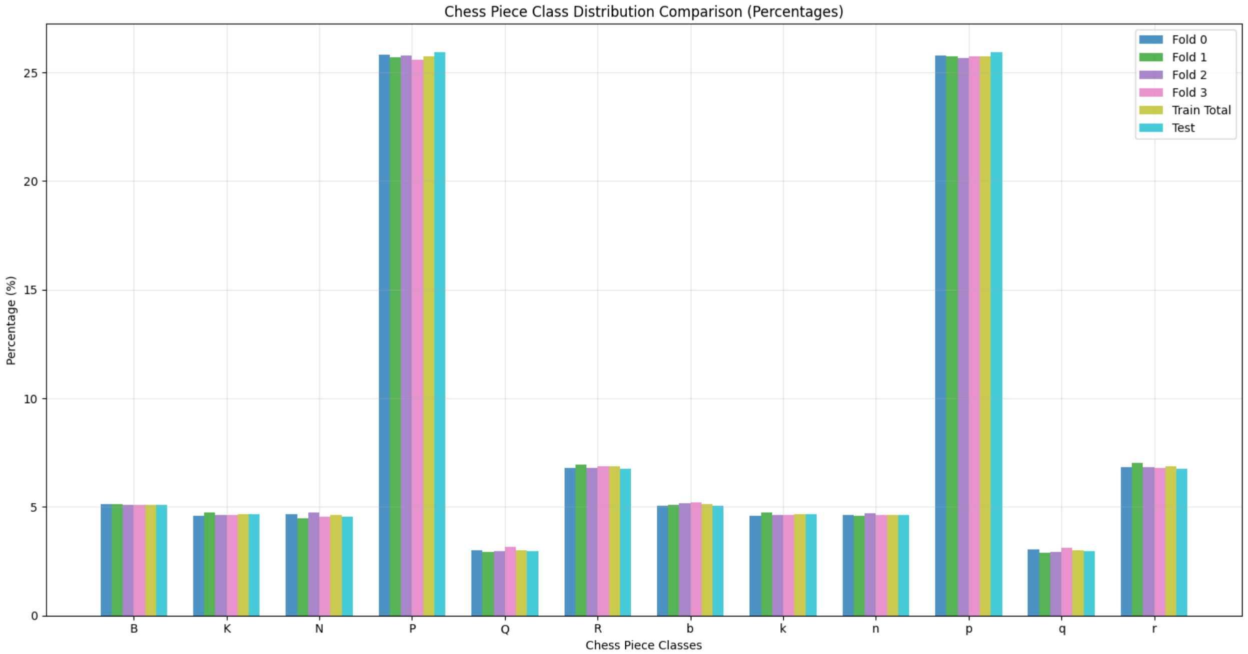
Maximum 1h training on NVIDIA GeForce GTX 1050
Best epoch (on validation) to avoid overfitting

Common metrics for comparison

Cross Validation

Dataset Partition:

1. Test set (1888 images, ~39%)
2. Training set (3000 images, ~61%)
   - 4 Fold
     1 validation (25%)
     3 train (75%)
   - Homogeneous class distribution
   - Average of relevant metrics

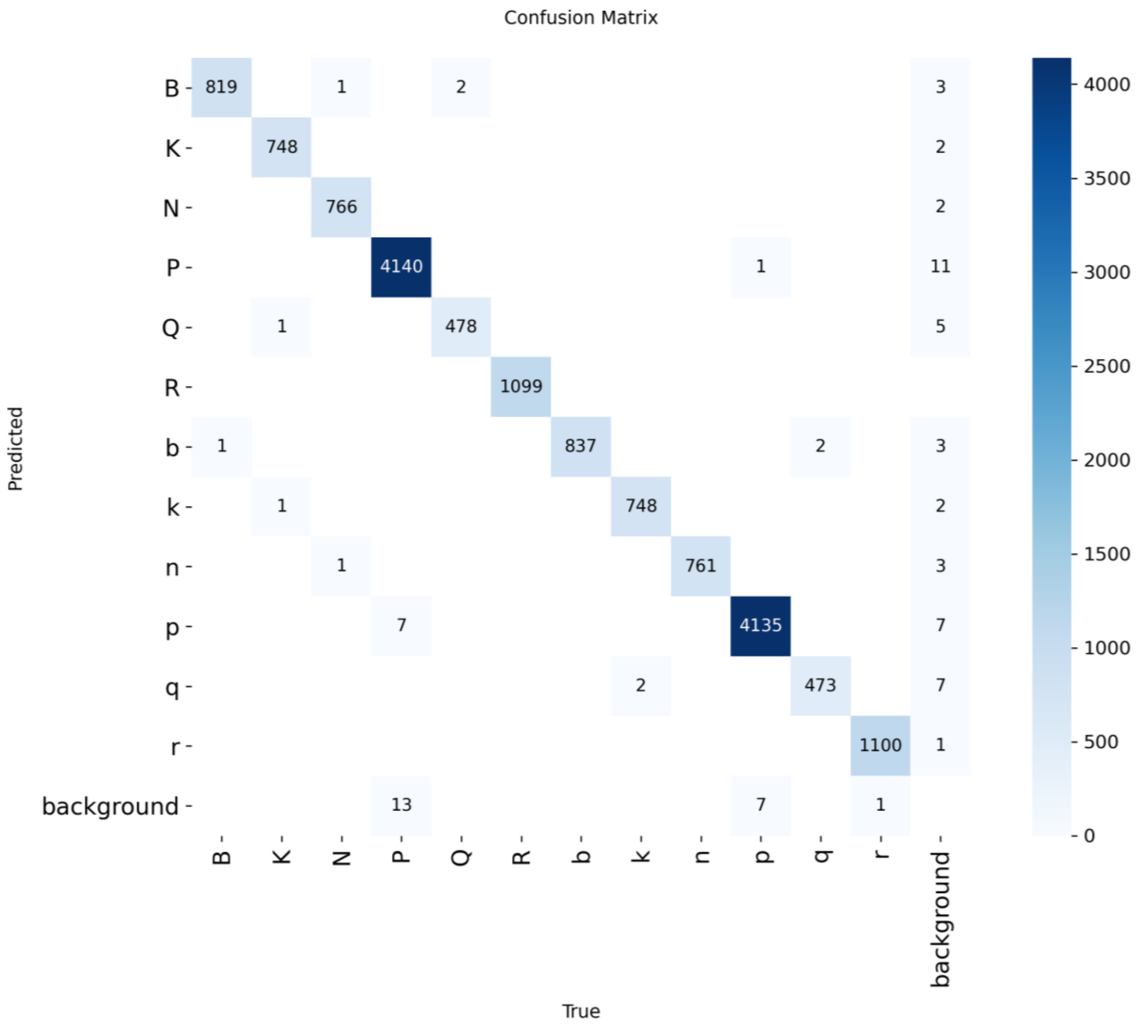


Piece Detection

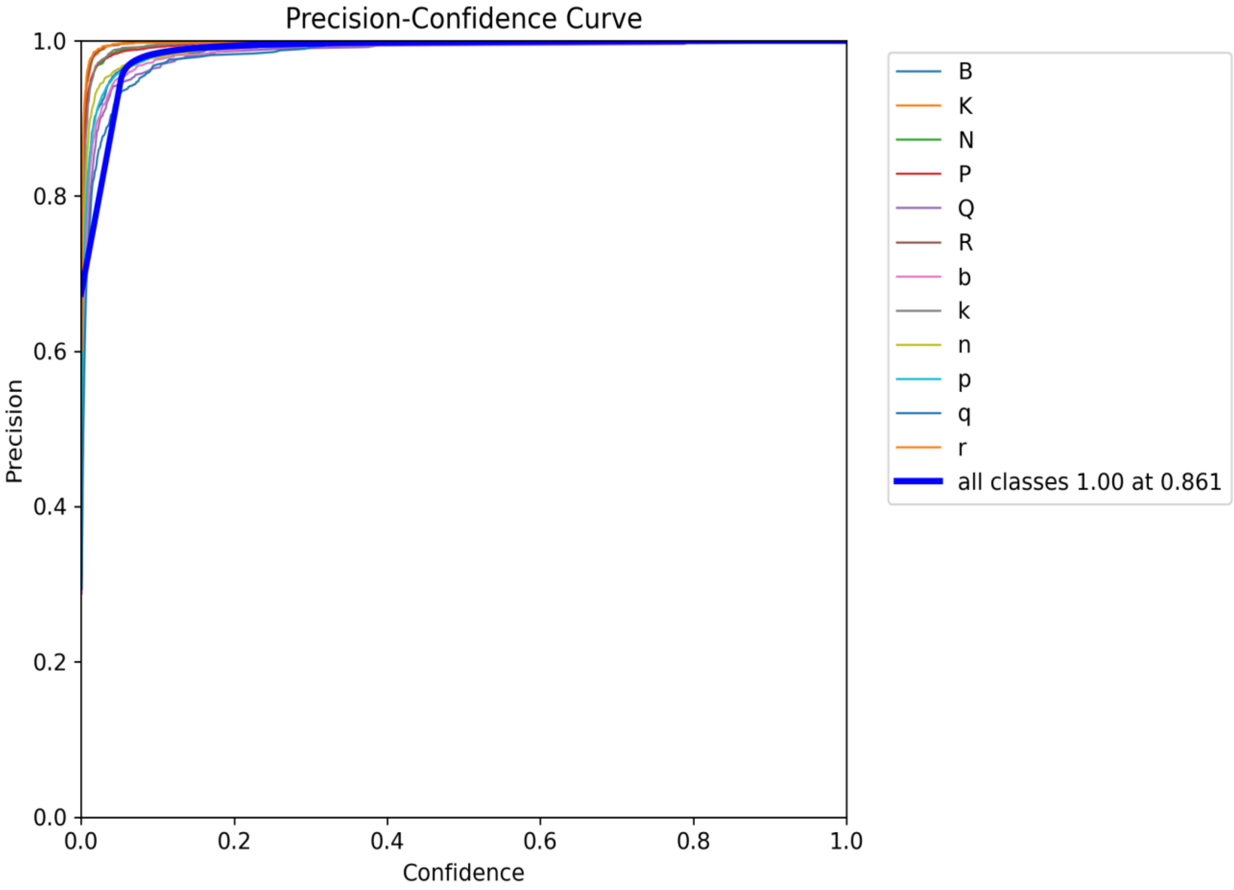
Model	Size	Pretrained	Precision	Recall	mAP@50-95
YOLO11	n	Yes	0.997 ± 0.0005	0.994 ± 0.0008	0.950 ± 0.0006
YOLO11	s	Yes	0.999 ± 0.0002	0.997 ± 0.0004	0.969 ± 0.0001
YOLO11	m	Yes	0.999 ± 0.0001	0.998 ± 0.0004	0.971 ± 0.0006
YOLO11	l	Yes	0.998 ± 0.0003	0.997 ± 0.0002	0.971 ± 0.001
YOLO11	n	No	0.902 ± 0.01	0.899 ± 0.006	0.793 ± 0.006
YOLO11	s	No	0.874 ± 0.02	0.875 ± 0.01	0.758 ± 0.01
YOLO11	m	No	0.700 ± 0.02	0.774 ± 0.01	0.586 ± 0.01
YOLO11	l	No	0.597 ± 0.02	0.720 ± 0.003	0.499 ± 0.004

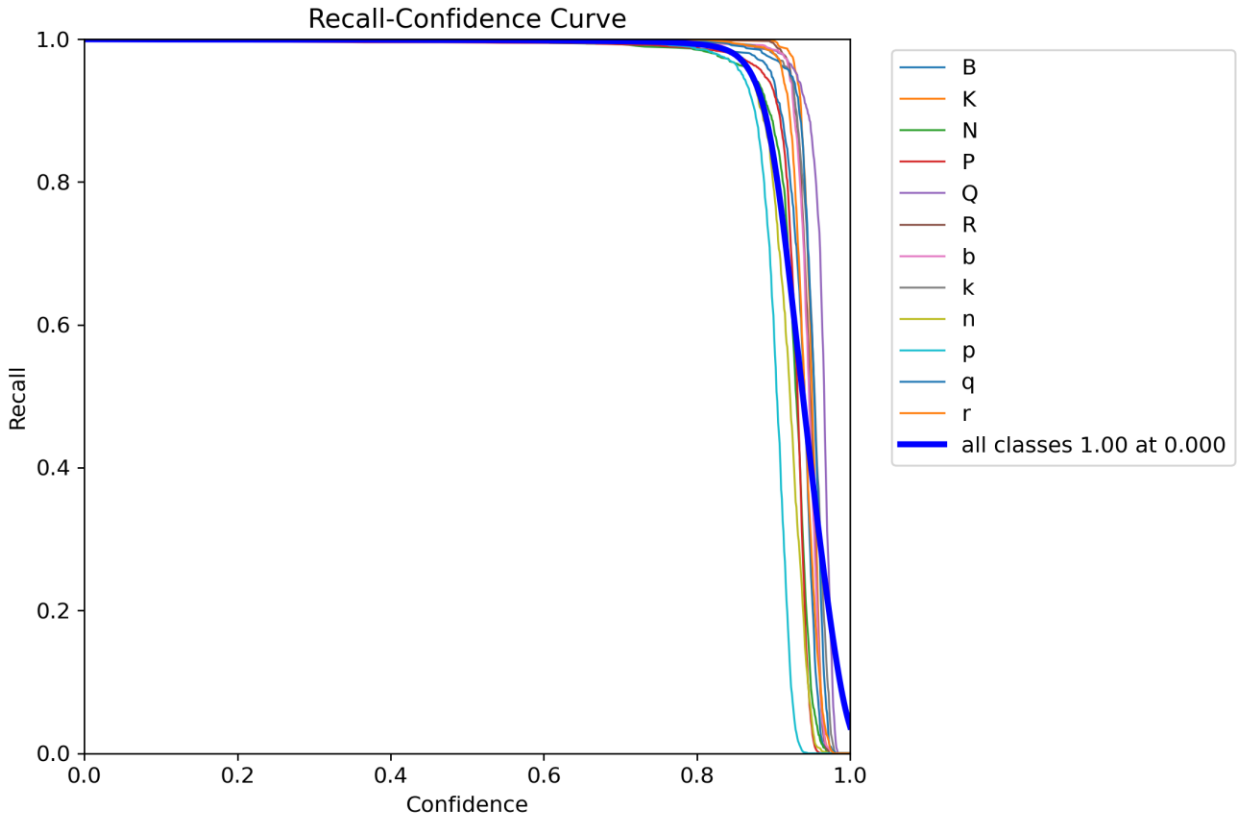
Selected model: YOLO11-m Pretrained

Piece Detection – Confusion Matrix



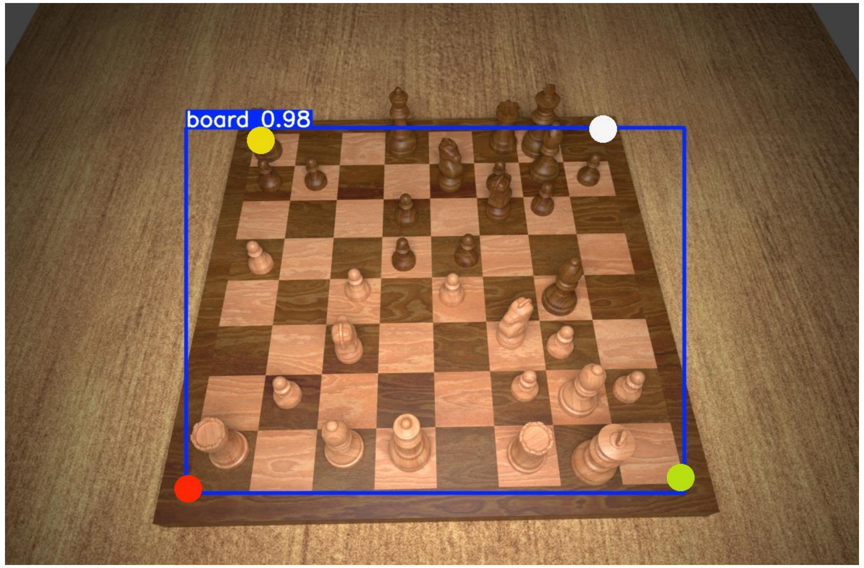
Piece Detection – Precision and Recall



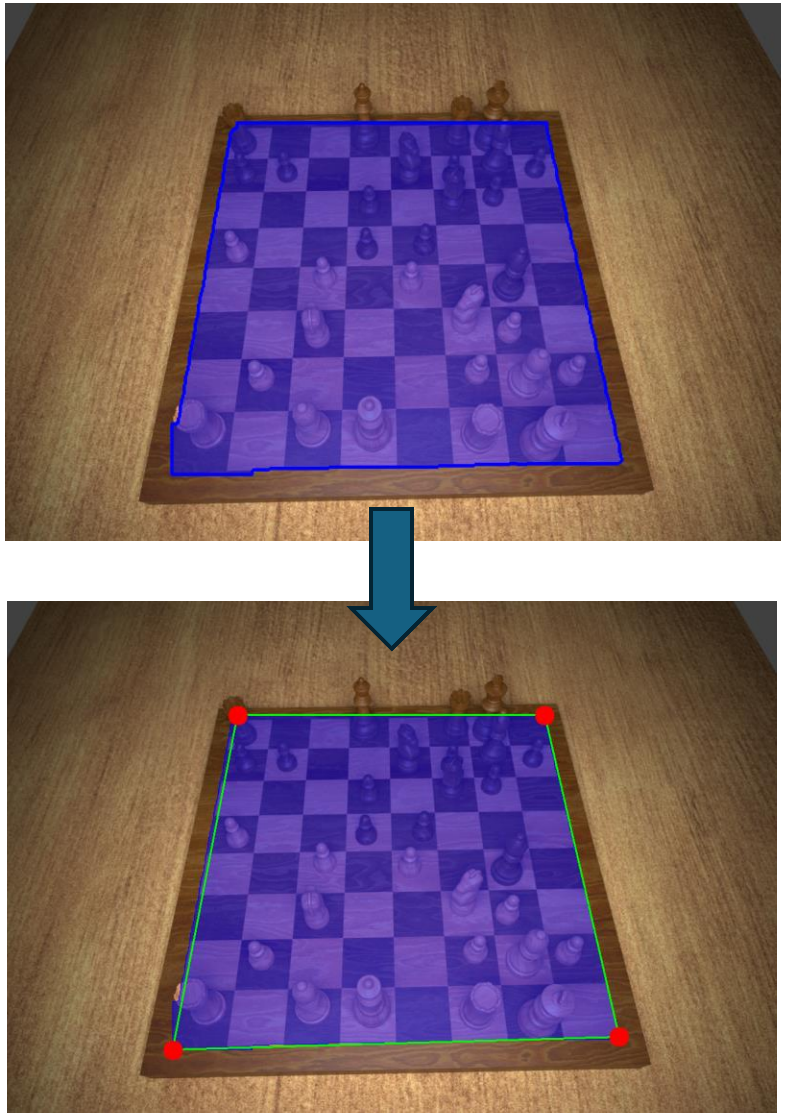


Board Detection

Pose



Segmentation



Board Detection

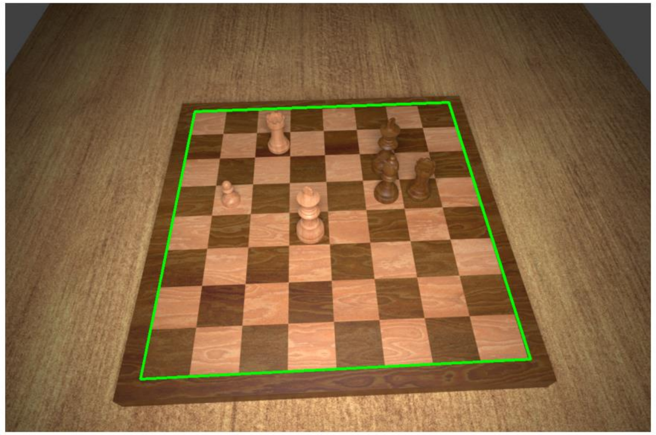
Model	Size	Pretrained	Pose		Segmentation	
			IoU	Transformed IoU	IoU	Transformed IoU
YOLO11	n	Yes	0.959 ± 0.004	0.957 ± 0.005	0.978 ± 0.0007	0.977 ± 0.0009
YOLO11	s	Yes	0.942 ± 0.006	0.938 ± 0.007	0.976 ± 0.0006	0.975 ± 0.001
YOLO11	m	Yes	0.875 ± 0.03	0.852 ± 0.02	0.974 ± 0.001	0.973 ± 0.0007
YOLO11	l	Yes	0.863 ± 0.02	0.858 ± 0.03	0.973 ± 0.0004	0.972 ± 0.0005
YOLO11	n	No	0.013 ± 0.008	0.018 ± 0.009	0.977 ± 0.0007	0.976 ± 0.0007
YOLO11	s	No	0.887 ± 0.009	0.891 ± 0.01	0.973 ± 0.001	0.972 ± 0.001
YOLO11	m	No	0.559 ± 0.4	0.561 ± 0.4	0.961 ± 0.007	0.964 ± 0.003
YOLO11	l	No	0.297 ± 0.3	0.293 ± 0.3	0.950 ± 0.01	0.952 ± 0.009

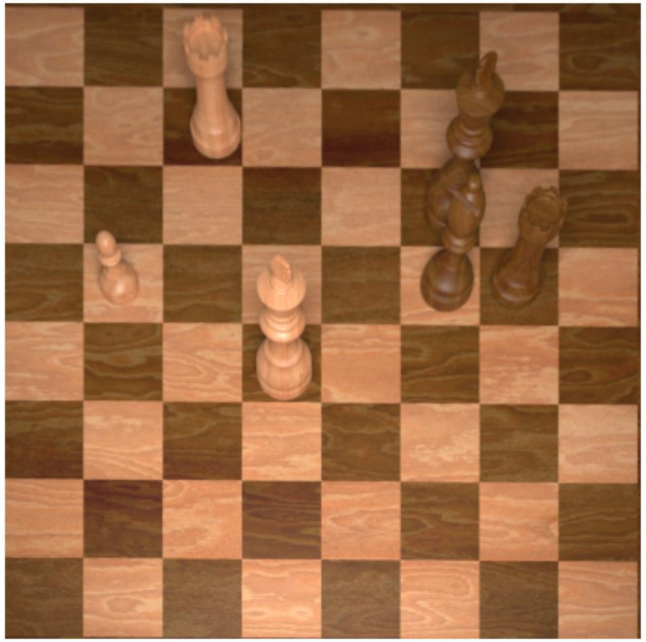
Selected model: YOLO11-n Segmentation Pretrained

Computing Pieces' Squares

We compute the pieces' squares projecting their location on a unit square:

1. Compute the projection matrix from image space to board space using the board's corners locations

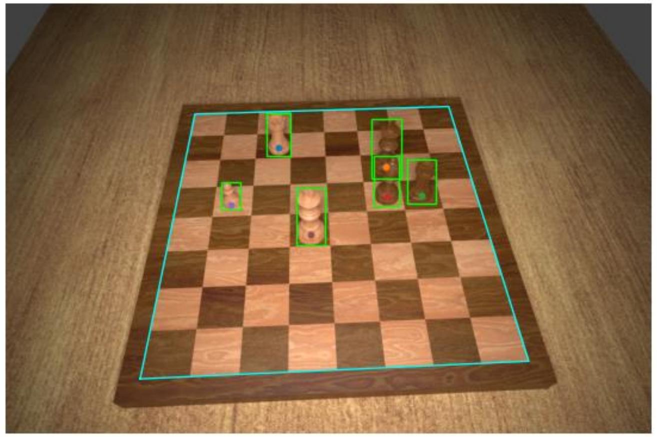


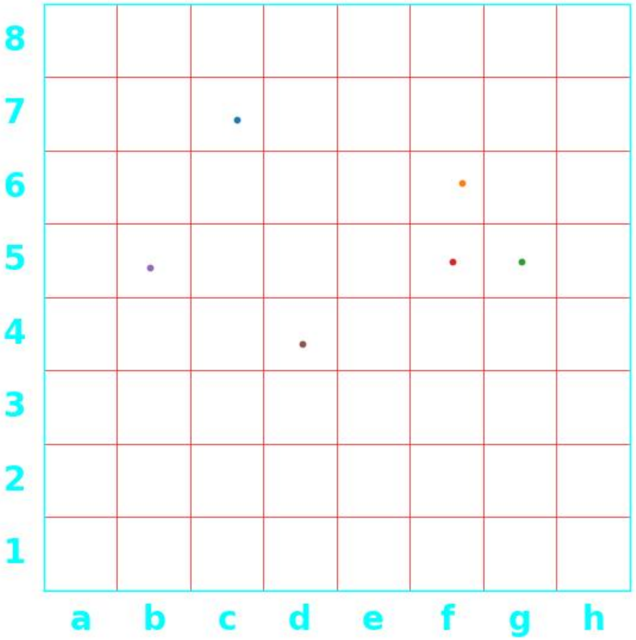


Computing Pieces' Squares

We compute the pieces' squares projecting their location on a unit square:

1. Compute the projection matrix from image space to board space using the board's corners locations
2. Apply the projecting transformation to all the pieces' locations
3. Convert the result in chess square notation





End-to-End Results

92.69 %

Full board correctness

117.7 ms

Inference on i7-7700K CPU 4.20GHz

Piece	Precision		Recall	
	White	Black	White	Black
Bishop	99.14 %	99.52 %	99.33 %	99.57 %
King	99.36 %	99.42 %	99.36 %	99.42 %
Knight	99.24 %	99.73 %	98.97 %	99.57 %
Pawn	99.49 %	99.44 %	99.04 %	99.18 %
Queen	99.10 %	99.34 %	99.42 %	99.51 %
Rook	99.43 %	99.75 %	99.43 %	99.75 %
All	99.39 %	99.51 %	99.17 %	99.37 %
	99.45 %		**99.27 %**	

Future Work

Ways to explore for possible improvements:

- Better algorithm to determine which point of a piece's boundig box to use as location for the projection (using piece type and perspective information)
- Better board corner derivation algorithm
- How to leverage the structure of legal chess positions to improve the robustness of the system and provide early error recognition and correction
- More thorough study of generalization capabilities and of ways to expand the dataset to include different chess set styles

Thank You
for Listening