yolo12s Hyperparameter Tuning Report

Generated: 2025-12-01 02:26:00

1. Optimization Overview

Property	Value
Model	yolo12s
Dataset	bdd100k_yolo_tuning
Total Trials	20
Completed Trials	20
Failed Trials	0
Best Trial	15
Best mAP@0.5	0.5002
Optimization Duration	7:12:17.512343

2. Optimization Configuration

Parameter	Value
Total Trials	20
Epochs per Trial	6
Batch Size	96
Startup Trials (TPE)	4
Device	cuda
Number of Classes	10
Train Images	16391
Val Images	10000

2.5 Executive Summary & Key Findings

Metric	Value
■ Best Performance	Trial #15: mAP@0.5 = 0.5002
■ Performance Range	0.4161 to 0.5002 (20.2% improvement)
■ Mean Performance	0.4725 across 20 trials
■ Best Optimizer	Adam (mean: 0.4842)
■■ Optimal Image Size	768px (8.17% better)
■■ Optimization Time	7:12:17.512343
■ Success Rate	20/20 trials (100.0%)

Key Insights:
• The optimization process successfully explored 20 trials, achieving a 20.2% performance improvement from worst to best.
• **Adam** optimizer demonstrated superior performance with mean mAP@0.5 of 0.4842.
• Image size of **768px** provided optimal accuracy-efficiency tradeoff.
• High consistency achieved: mean performance (0.4725) close to best (0.5002), indicating robust hyperparameter space.

3. Best Hyperparameters

Parameter	Value	Description
imgsz	768	
optimizer	Adam	Optimization algorithm
lr0	0.000122	Initial learning rate
momentum	0.888900	SGD momentum / Adam beta1
weight_decay	0.000034	Weight decay (L2 penalty)
warmup_epochs	2	Warmup epochs
warmup_momentum	0.775337	Warmup momentum
warmup_bias_lr	0.073696	
mosaic	0.751058	Mosaic augmentation
mixup	0.068131	Mixup augmentation

4. Top 20 Trials Performance

#	mAP@0.5	ImgSz	Opt	lr0	mom	mixup	mosaic
1	0.5002	768	Adam	0.0001	0.889	0.07	0.75
2	0.4988	768	Adam	0.0001	0.851	0.15	0.57
3	0.4972	768	Adam	0.0001	0.860	0.09	0.85
4	0.4964	768	Adam	0.0001	0.906	0.12	0.69
5	0.4952	768	Adam	0.0002	0.858	0.14	0.55
6	0.4942	768	Adam	0.0003	0.857	0.19	0.64
7	0.4937	768	Adam	0.0002	0.859	0.10	0.50
8	0.4918	768	Adam	0.0003	0.866	0.16	0.61
9	0.4869	768	Adam	0.0004	0.918	0.06	0.70
10	0.4862	768	Adam	0.0003	0.863	0.17	0.67
11	0.4829	768	Adam	0.0005	0.909	0.09	0.79
12	0.4796	768	Adam	0.0005	0.915	0.20	0.57
13	0.4703	768	Adam	0.0008	0.864	0.08	0.58
14	0.4544	640	Adam	0.0003	0.930	0.16	0.98
15	0.4514	640	Adam	0.0001	0.875	0.14	0.57
16	0.4506	640	Adam	0.0002	0.913	0.08	0.53
17	0.4496	640	Adam	0.0001	0.881	0.15	0.56
18	0.4348	768	SGD	0.0002	0.857	0.17	0.98
19	0.4203	640	Adam	0.0005	0.885	0.16	0.73
20	0.4161	768	SGD	0.0001	0.892	0.02	0.50

4.1 Detailed Hyperparameters - Top 5 Trials

Rank 1: Trial 15 (mAP@0.5: 0.5002)
imgsz=768, lr0=0.000122, mixup=0.068131, momentum=0.888900, mosaic=0.751058, optimizer=Adam, warmup_bias_lr=0.073696, warmup_epochs=2, warmup_momentum=0.775337, weight_decay=0.000034

Rank 2: Trial 11 (mAP@0.5: 0.4988)
imgsz=768, lr0=0.000101, mixup=0.153552, momentum=0.851408, mosaic=0.569202, optimizer=Adam, warmup_bias_lr=0.086765, warmup_epochs=3, warmup_momentum=0.826914, weight_decay=0.000353

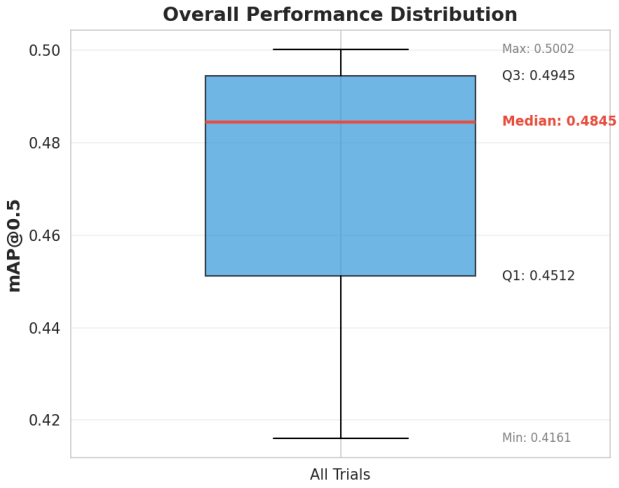
Rank 3: Trial 14 (mAP@0.5: 0.4972)
imgsz=768, lr0=0.000103, mixup=0.094014, momentum=0.859534, mosaic=0.845037, optimizer=Adam, warmup_bias_lr=0.089373, warmup_epochs=2, warmup_momentum=0.827685, weight_decay=0.000216

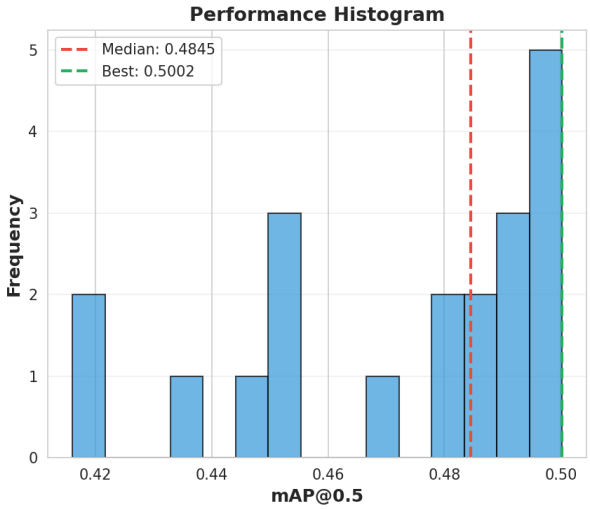
Rank 4: Trial 19 (mAP@0.5: 0.4964)
imgsz=768, lr0=0.000112, mixup=0.115972, momentum=0.906379, mosaic=0.687213, optimizer=Adam, warmup_bias_lr=0.057120, warmup_epochs=2, warmup_momentum=0.789644, weight_decay=0.000125

Rank 5: Trial 2 (mAP@0.5: 0.4952)
imgsz=768, lr0=0.000195, mixup=0.136847, momentum=0.857806, mosaic=0.548836, optimizer=AdamW, warmup_bias_lr=0.030461, warmup_epochs=3, warmup_momentum=0.863779, weight_decay=0.000790

5. Optimization Visualizations & Analysis

5.0 Performance Distribution Analysis



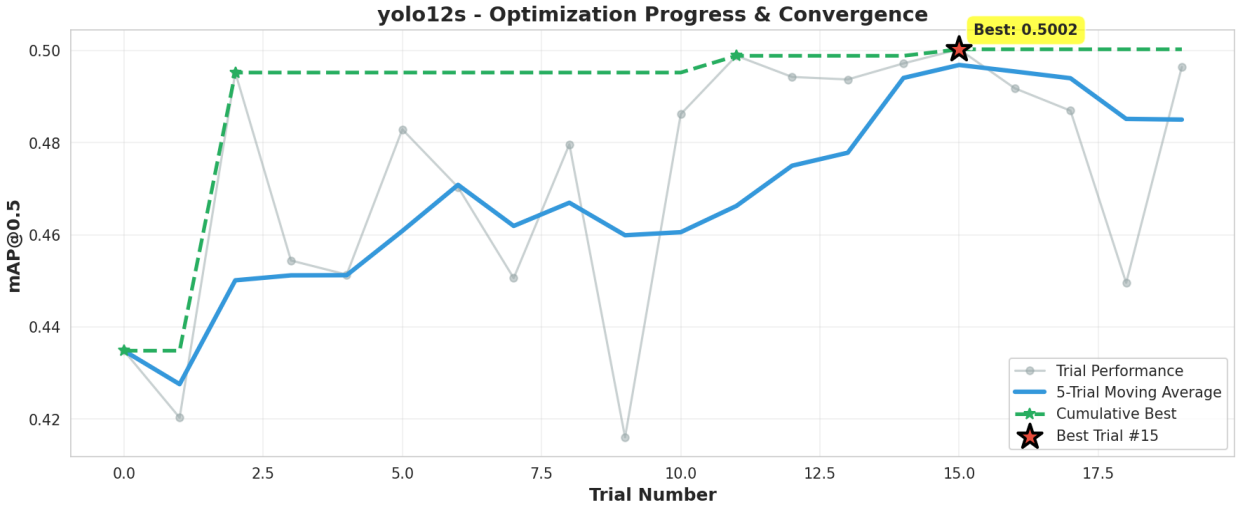


Statistic	Value
Mean	0.4725
Median	0.4845
Std Dev	0.0273
IQR (Q3-Q1)	0.0433
Range	0.0842

5.1 Parameter Correlation Analysis

Correlation Insights:
• Strongest positive correlation: **mixup** (0.082) - Higher values tend to improve performance.
• Strongest negative correlation: **momentum** (-0.215) - Higher values tend to decrease performance.
• Green cells indicate positive correlation, red cells indicate negative correlation.

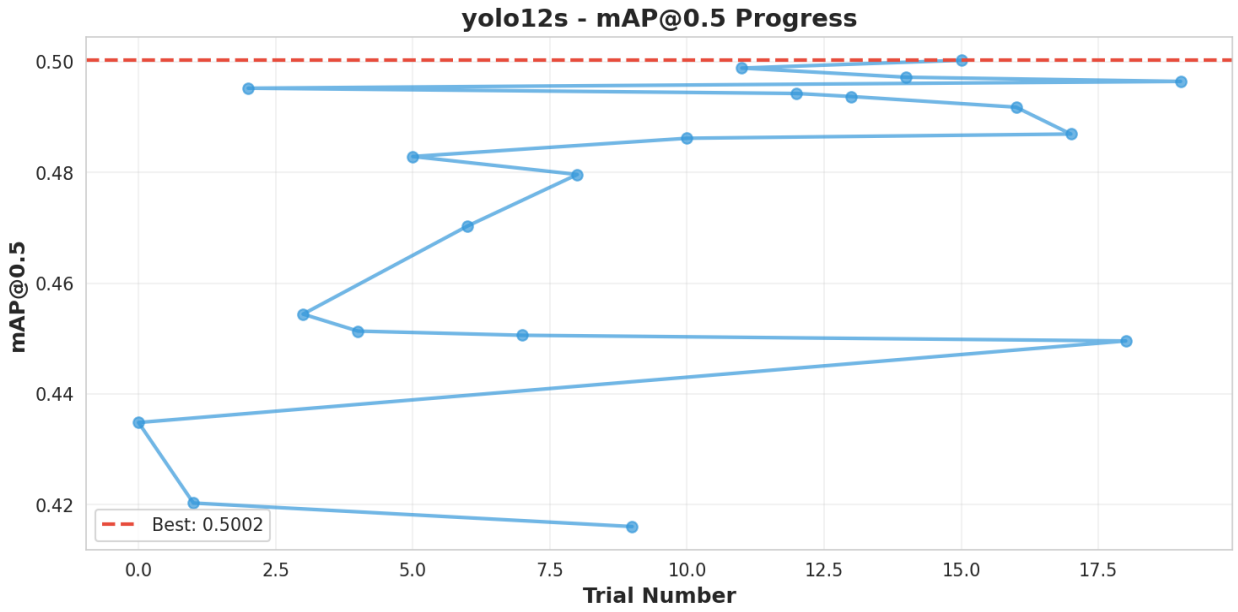
5.2 Optimization Timeline & Convergence



Convergence Analysis:

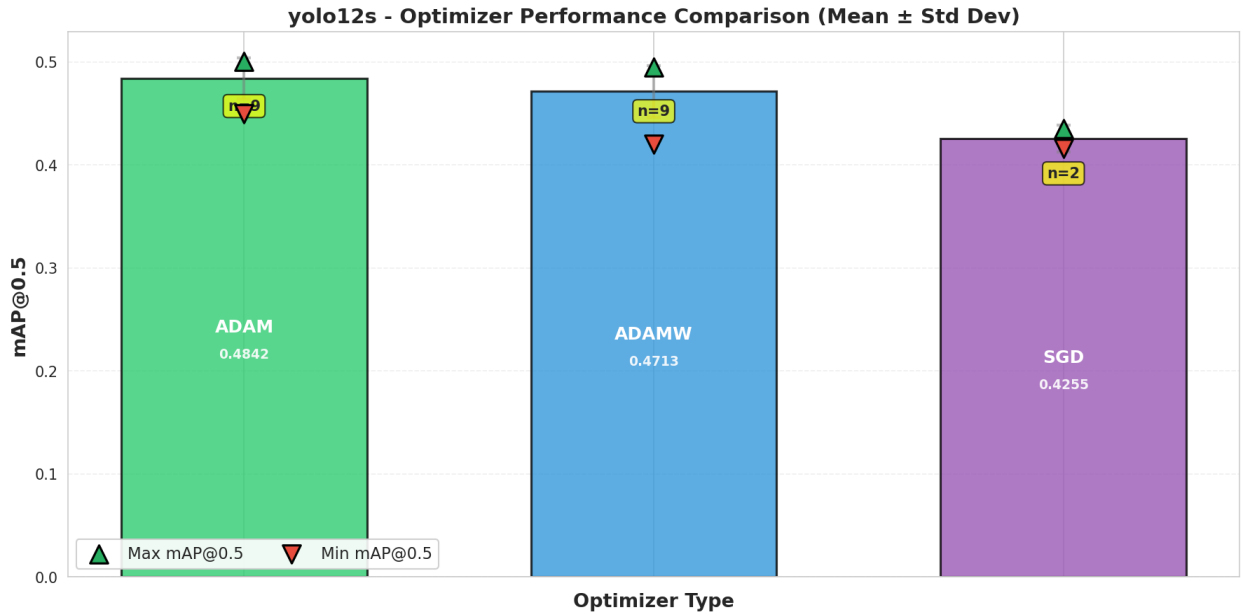
• Best solution found at trial **#15** (75.0% through optimization).
• Moving average shows late discovery pattern.
• Cumulative best curve indicates moderate exploration of hyperparameter space.

5.3 mAP@0.5 Progress Over Trials



5.4 Learning Rate Impact on Performance

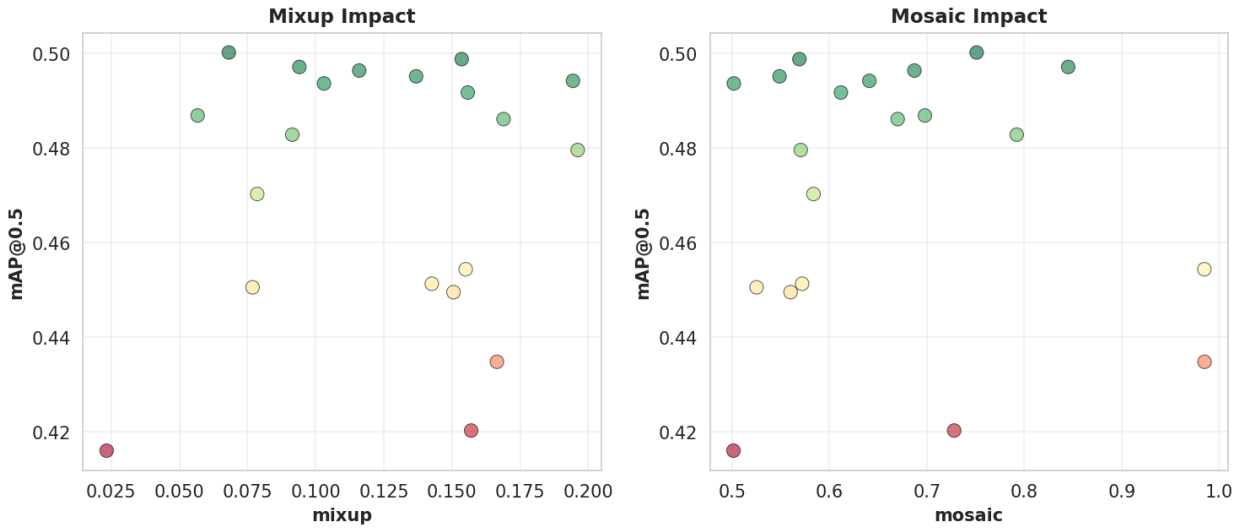
5.5 Optimizer Performance Comparison



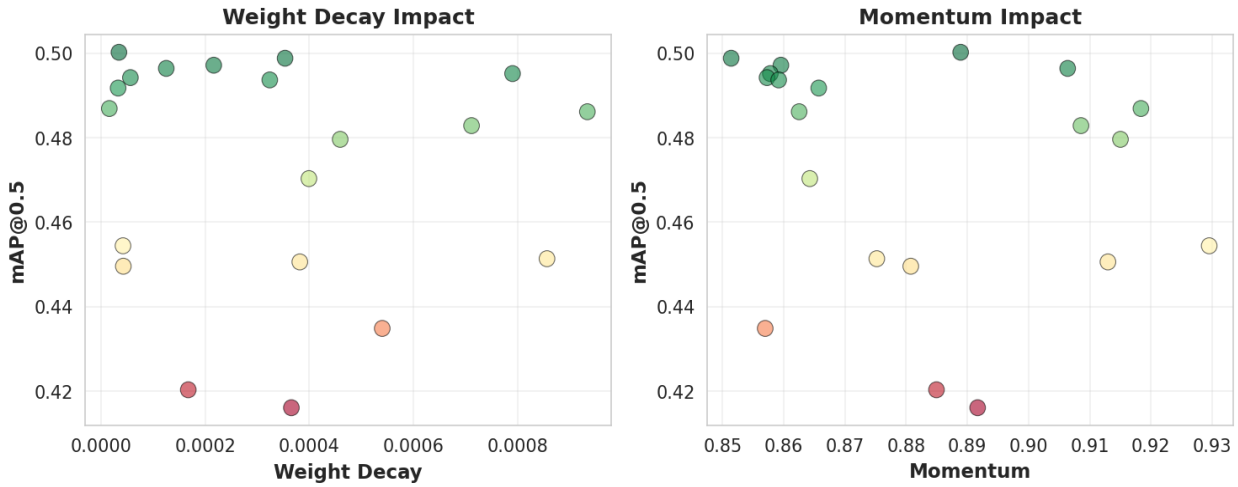
Optimizer	Mean	Max	Min	Std Dev	Trials
ADAM	0.4842	0.5002	0.4496	0.0200	9
ADAMW	0.4713	0.4952	0.4203	0.0252	9
SGD	0.4255	0.4348	0.4161	0.0133	2

Analysis: ADAM achieved the highest mean performance (0.4842) across 9 trials. The error bars show the standard deviation, indicating performance consistency.

5.6 Augmentation Parameters Impact



5.7 Regularization Parameters Impact



5.8 Image Size Impact on Performance

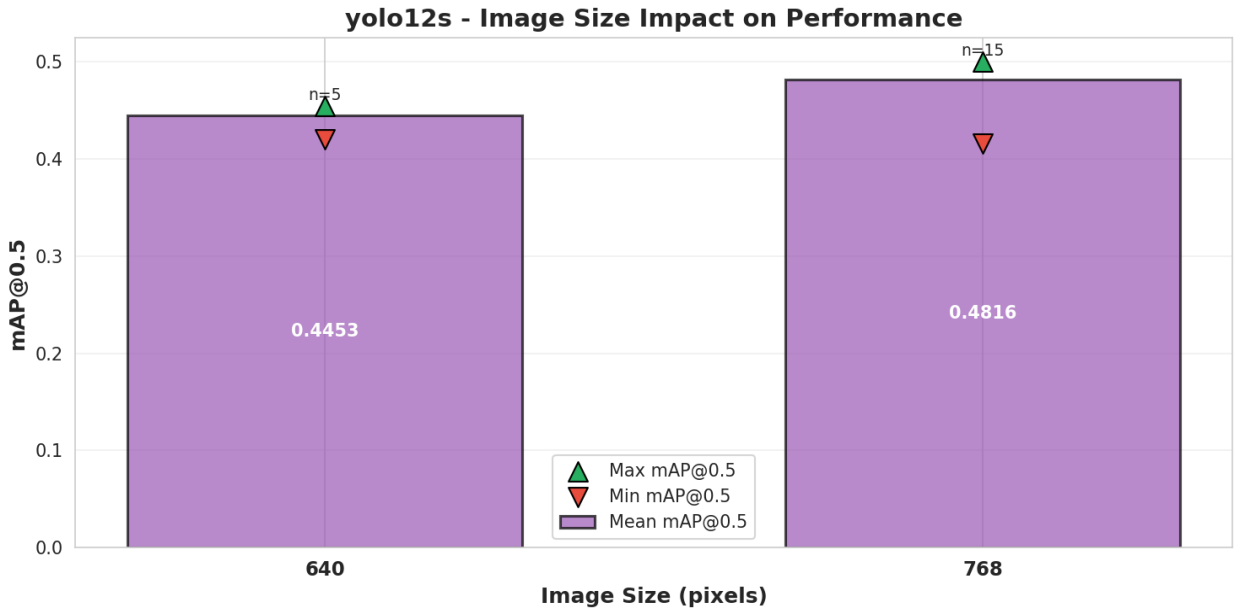


Image Size	Mean mAP@0.5	Max mAP@0.5	Min mAP@0.5	Trials
640	0.4453	0.4544	0.4203	5
768	0.4816	0.5002	0.4161	15

5.9 Key Insights & Production Recommendations

■ Optimal Configuration for Production Deployment:

1. Image Processing:
• Use **768px** input resolution for optimal accuracy
• Expected performance: **mAP@0.5 = 0.5002**
• Tradeoff: Higher resolution improves accuracy but increases inference time

2. Optimizer Configuration:
• Algorithm: **Adam**
• Learning rate (lr0): **0.000122**
• Momentum: **0.8889**
• Weight decay: **0.000034**

3. Training Warmup:
• Warmup epochs: **2**
• Warmup momentum: **0.7753**
• Warmup bias lr: **0.073696**

4. Data Augmentation:
• Mosaic augmentation: **0.7511** (strong augmentation for robustness)
• Mixup augmentation: **0.0681** (light augmentation)
• Recommendation: Use these exact values for similar datasets

5. Performance Metrics:
• Best trial found at **#15** out of 20 trials
• Performance improvement: **20.2%** over worst trial
• Consistency: Mean mAP@0.5 = 0.4725 (Std = 0.0273)

6. Deployment Recommendations:
• **Adam** optimizer demonstrated best performance (mean: 0.4842)
• **Adam** outperformed SGD by 13.8%
• For maximum accuracy, use 768px images
• For faster inference with slight accuracy trade-off, consider 640px (mAP: 0.4453)

7. Next Steps:
• Train full model with these hyperparameters
• Monitor validation metrics for overfitting
• Consider ensemble methods for further improvement

■ Confidence Level:
• Based on 20 successful trials
• Optimization converged steadily (best at 75.0% through search)
• Standard deviation (0.0273) indicates moderate consistency

Metric	Best Trial	Mean Performance	Worst Trial
mAP@0.5	0.5002	0.4725	0.4161
Trial #	#15	-	#9
Learning Rate	0.000122	0.000271	0.000132
Momentum	0.8889	0.8823	0.8917

6. All Trials Summary

Metric	Value
Completed Trials	20
Best mAP@0.5	0.5002
Worst mAP@0.5	0.4161
Mean mAP@0.5	0.4725
Std Dev mAP@0.5	0.0273
Median mAP@0.5	0.4845