Image Signal Processing Optimization for Object Detection

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EVP

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nextchip

NEXTCHIP Overview

World-class ISP In-house Core

- Developing & optimizing vision core;
  Image signal processing technology for 27 years
- Tuning know-how with various MP models
  with global OEMs and Tiers
- Tuning capability for human vision & machine mision
- Open architecture with various image sensors,
  CFAs (color filter arrays)

ASIC Design Technology

- Automotive process foundry experience;
  14nm/28nm/55nm/60nm/95nm
  Samsung/Global Foundries/USJC/TSMC

Automotive Reliability

- ISO26262; Functional safety
- Cyber security
- CMMI Lv.-3
- A-Spice process
- AEC-Q100 Gr.2 lineup

Image Signal Processing Optimization for Object Detection

Chapter 1: What is the Difference? Human Vision vs. Machine Vision

Chapter 2: The Image Tuning Challenges for Human Vision

Chapter 3: The Image Tuning Challenges for Machine Vision

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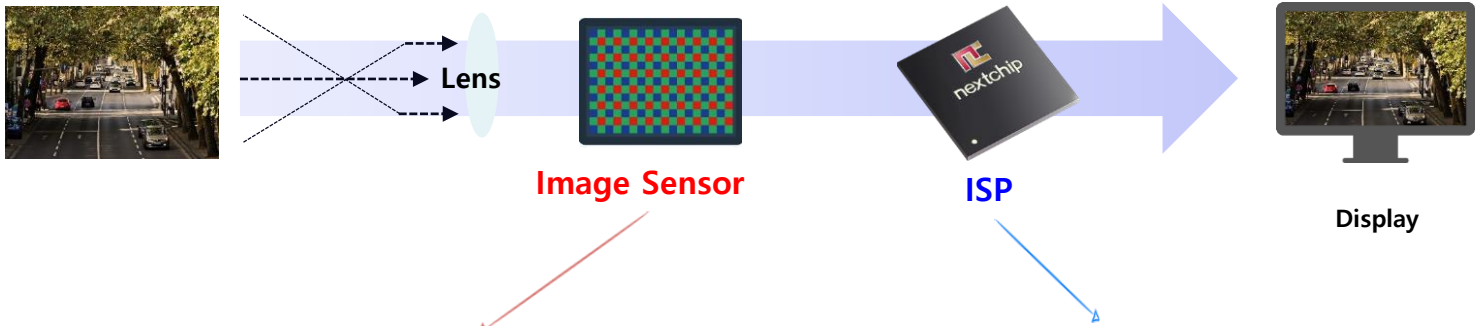
Human Vision vs. Machine Vision

- **We asked this question to ChatGPT… It gave this image as an answer!**

Do you feel the same way?

Image Tuning Needed for Both Types of Vision

- What is image tuning? Why is it needed?



The key point of image sensor

➔ Delivery of Robust "raw (bayer) data"

① Sensitivity (Pixel technology)

② Color (CFA-color filter array)

The key point of ISP

➔ Processing "image signal data"

① Reproduction signal to vision

② Color/less noise

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Image Tuning Challenges for Human Vision

What is the challenge?

Make the image as similar as possible to one seen through a human eye

What is the key factor to tune for human vision?

- Color reproduction
- Lower noise level
- Brightness/edge/HDR (high dynamic range), etc.

Tuning under various environment, e.g., day & night

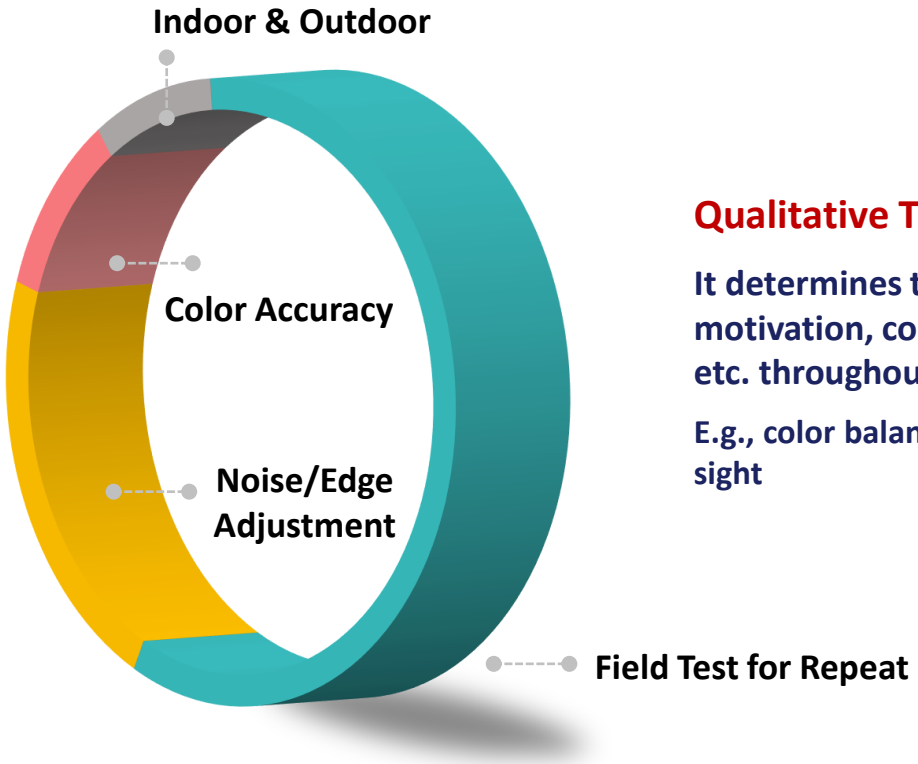
Image Tuning Challenges for Human Vision

How to do?

Quantitative TEST

It presents you with numerical value.

E.g., Δ-E, HDR dB, AE (auto exposure) speed, etc.



Qualitative TEST

It determines the user's motivation, comments, feeling, etc. throughout the test process.

E.g., color balance and bright in a sight

Image Tuning Challenges for Human Vision

How to do?

Day

① Tuning

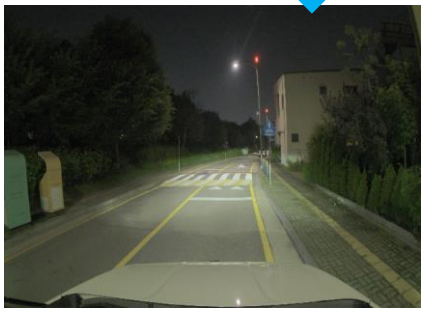
Day Result

② Test

Night

③ Tuning

④ Repeat Test



Night Result

Image Tuning Challenges for Human Vision

DAY

- **Problem**
  - Generally dark
  - Too strong color
  - Too strong edge level

Image Tuning Challenges for Human Vision

DAY

- **Tuning#1**
  - **Brightness**
  - **HDR & Contrast**
  - **GCE**

(global contrast enhancement)

Image Tuning Challenges for Human Vision

DAY

- **Tuning#2**
  - Color (hue, saturation)
  - Color suppression

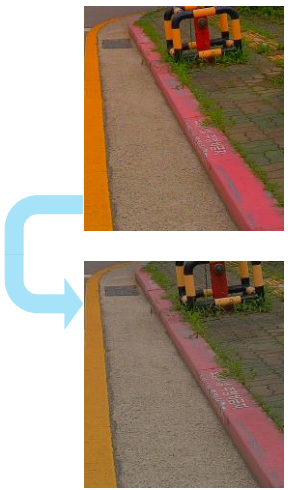
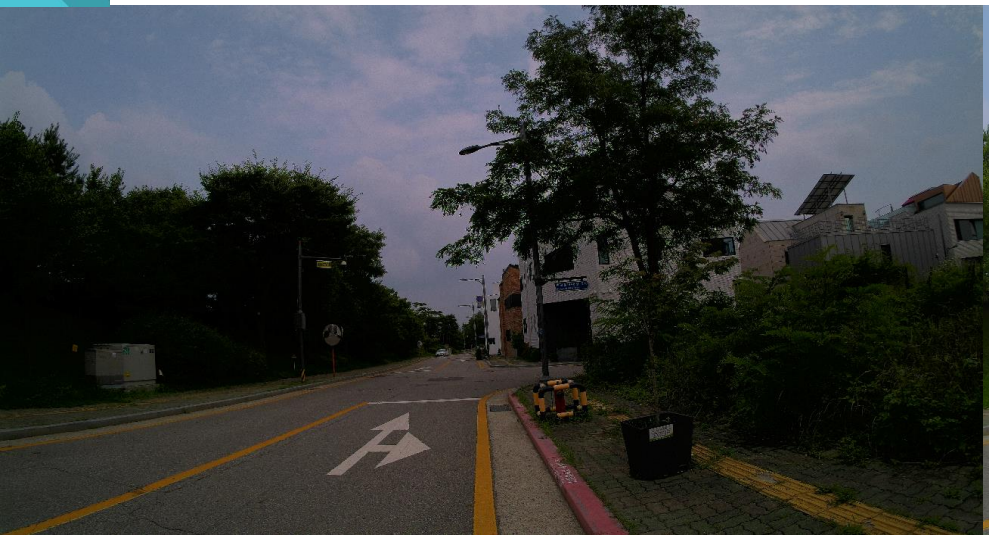


Image Tuning Challenges for Human Vision

DAY

▶ Problem



▶ Final tuned image

Image Tuning Challenges for Human Vision

NIGHT

- **Problem**
  - Generally dark
  - Too strong color
  - Too strong edge level

Image Tuning Challenges for Human Vision

NIGHT

- **Tuning#1**
  - **Brightness**
  - **HDR & Contrast**
  - **GCE**

(global contrast enhancement)

Image Tuning Challenges for Human Vision

NIGHT

▶ **Tuning#2**

- Color (hue, saturation)
- Color suppress

Image Tuning Challenges for Human Vision

NIGHT

▶ Problem

▶ Final tuned image

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Image Tuning Challenges for Machine Vision

What is the challenge?

- Higher detection rate is needed

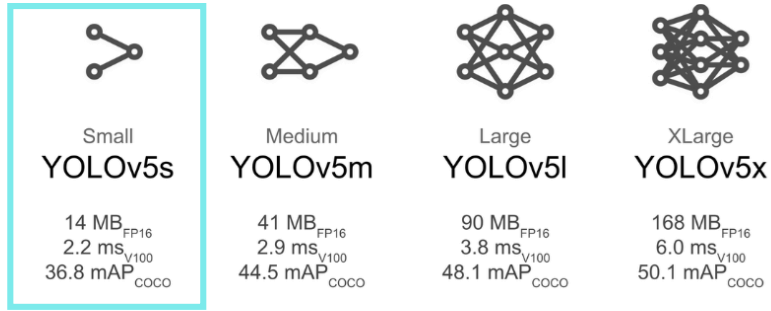
Methods to increase detection rate such as:

- Retraining
- Changing training method
- Changing field of view and resolution
- Image tuning, etc.

Measure Factors for Test

Detection network

- YOLOv5s



Datasets

- Location : Pangyo, Korea
- Scene : Sunny, daytime & nighttime, rearview fisheye 190°
- Training image resolution : 640x360 / training images : 12,732

Test Dataset & Tuning

Test Dataset

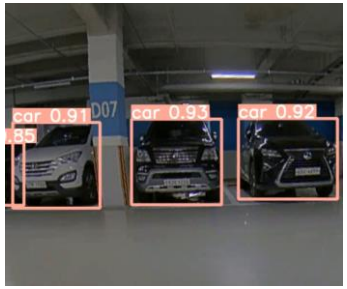
- Quantitative experiments: Stationary object + Ground Truth
- Qualitative experiments: Driving scene

ISP Tuning

- Brightness level: Auto exposure (AE)
- Edge sharpness level: Edge enhancement (EDGE)
- Noise level: Noise reduction (NR)

Quantitative Experiments – Metric

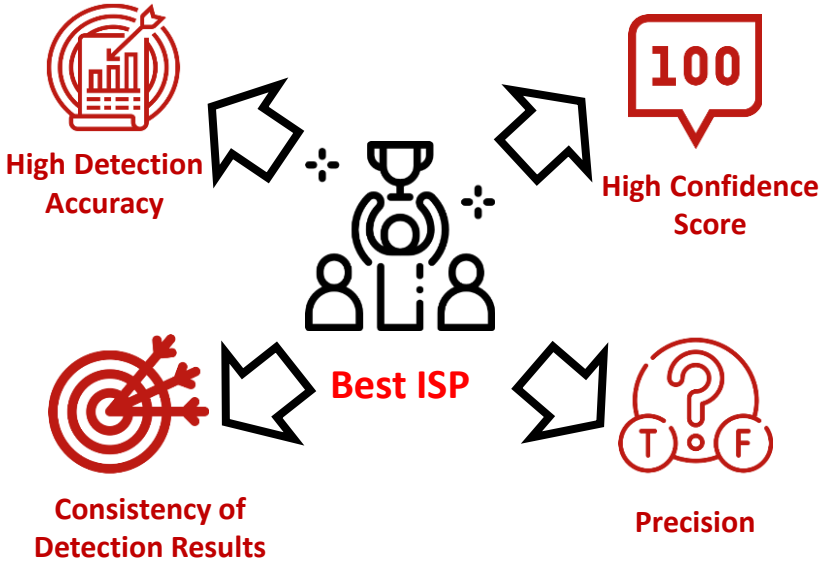
Metrics of best ISP for object detection



Detection Rate

Frame(t-1)

Frame(t)



Object Score

False Positive

Quantitative Experiments – ISP Tuning & Test Dataset

Test dataset

- 4 different ISP settings for the same scene
- About 3200 frames for each tuning point

ISP tuning

- Brightness level: Auto exposure (AE)
- Edge sharpness level: Edge enhancement (EDGE)
- Noise level: Noise reduction (NR)

T1

Viewing Optimization Tuning

T2

All ISP OFF except color related

T3

AE Up, EDGE Up

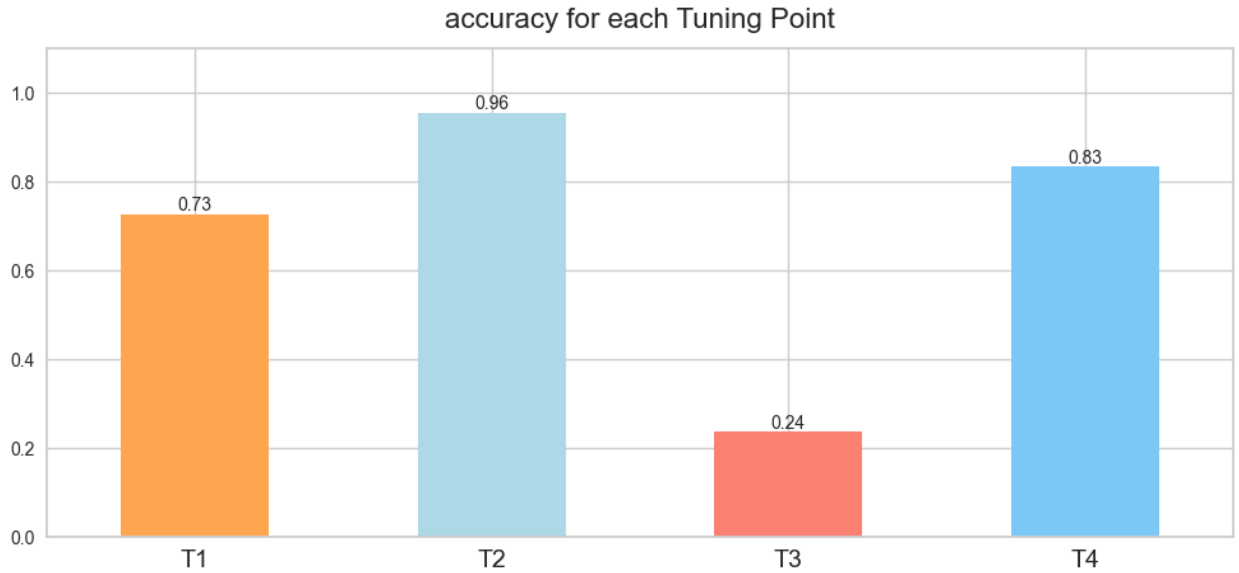
T4

AE Down, NR Up

Quantitative Experiments – Detection Accuracy

High detection accuracy

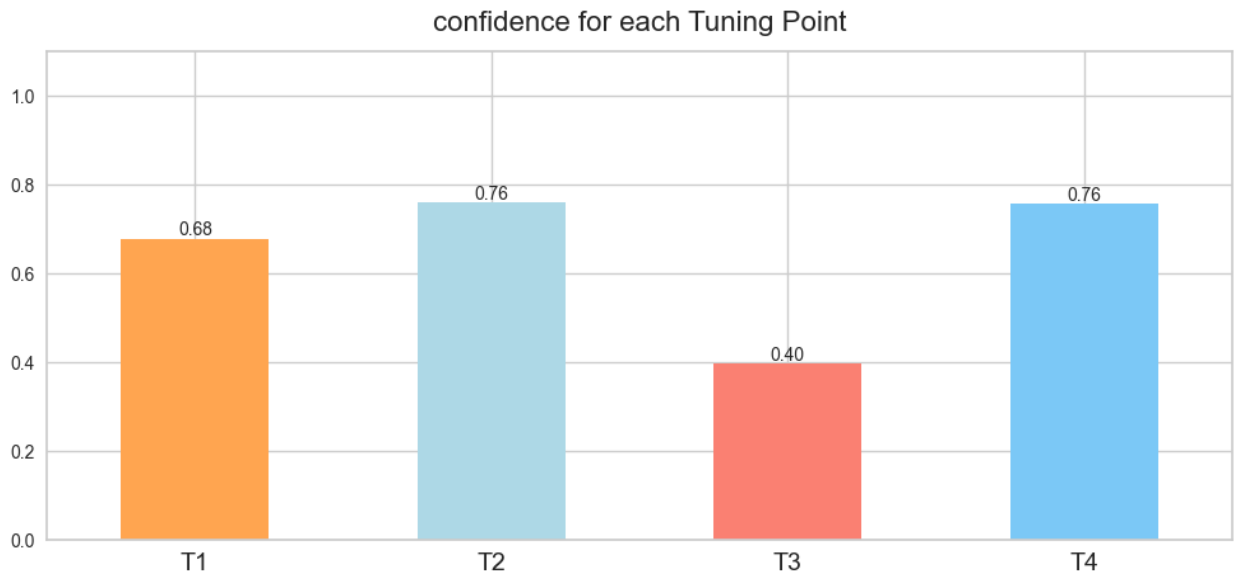
- An indicator of recognition accuracy for each tuning point



Quantitative Experiments – Confidence Score

High confidence score

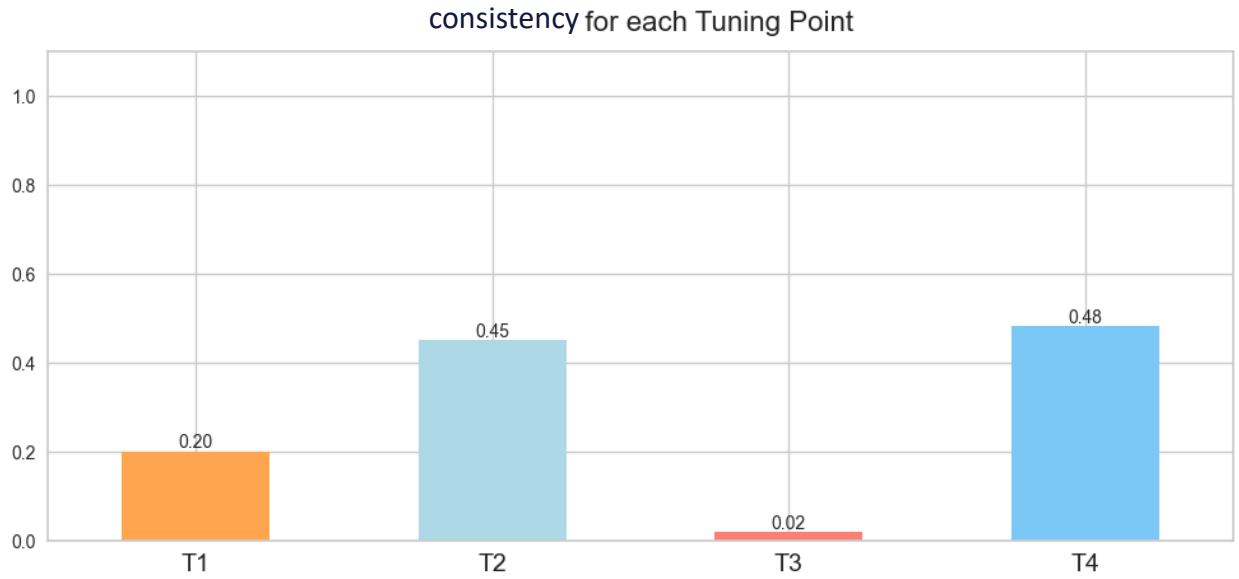
- A score which represents likelihood that the bounding box contains an object



Quantitative Experiments – Detection Consistency

High consistency score

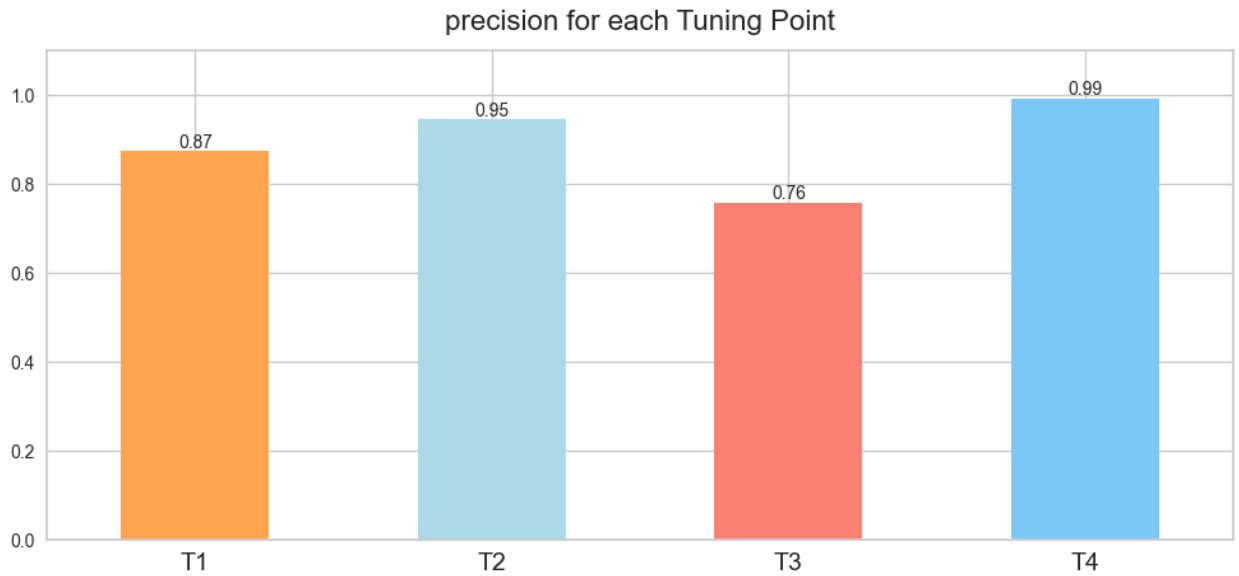
- **An indicator of whether the same object is consistently recognized**



Quantitative Experiments – Precision

Precision

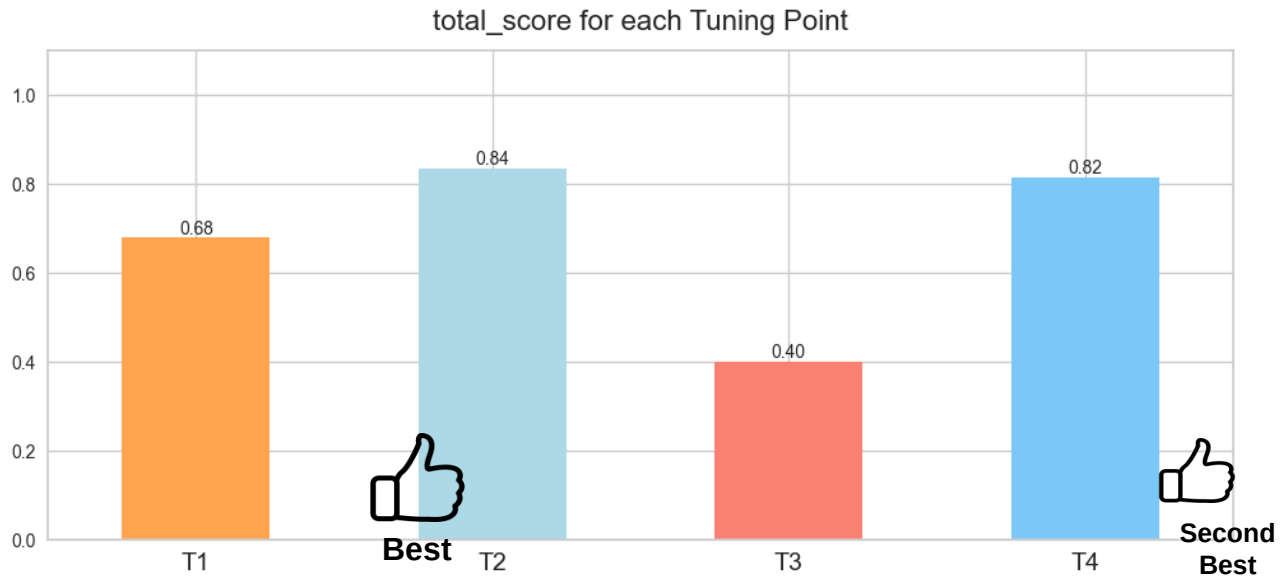
- An indicator of recognition precision



Quantitative Experiments – Result

Total evaluation results

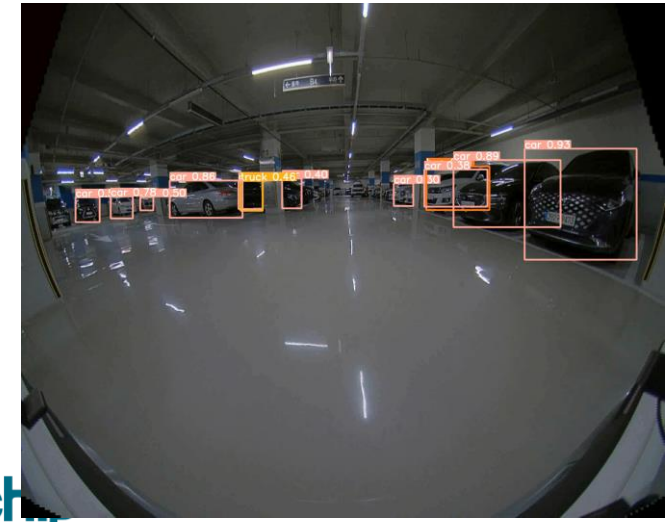
- For all metrics, the higher the better



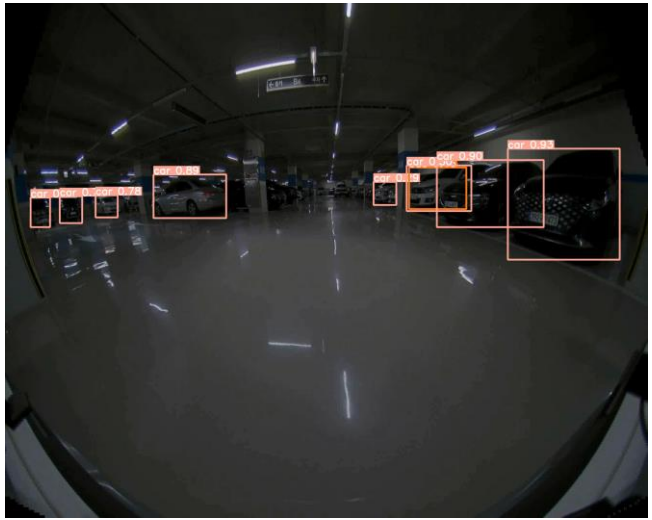
Quantitative Experiments - Conclusion

- EDGE has the greatest impact on detection performance
  - 1. Too many EDGE → Worse detection performance
  - 2. More EDGE → More false detections
- Darker image → Reduced false detection rate and accuracy
- Need to fine the best ISP setting value between T2 and T4

T2 Result



Best ISP Point



T4 Result

Qualitative Experiments – Evaluation Methods

- **Evaluation Methods**
  - Estimate the false detection rate
  - Counting false positives (FP) for period in which false detection occurs in all tuning points

T1 : Original Setting

T5 : Edge Sharpness Off + Bright Up

T6 : Edge Sharpness Off + Bright Up + NR Up

T7 : Edge Sharpness Off + Bright Down

T8 : Edge Sharpness Off + Bright Down + NR Up

Qualitative Experiments – Best ISP for Object Detection

- **Daytime test**
  - Additional 5 ISP settings for the same driving path

T1 : Original Setting

T5 : Edge Sharpness Off + Bright Up

T6 : Edge Sharpness Off + Bright Up + NR Up

T7 : Edge Sharpness Off + Bright Down

T8 : Edge Sharpness Off + Bright Down + NR Up

Qualitative Experiments – Best ISP for Object Detection

- **Daytime evaluation result**

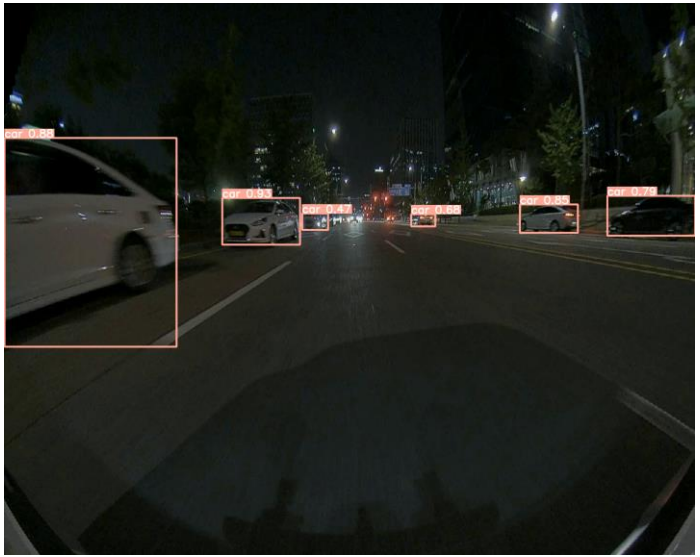
T8

: EDGE sharpness OFF + AE Down + NR Up

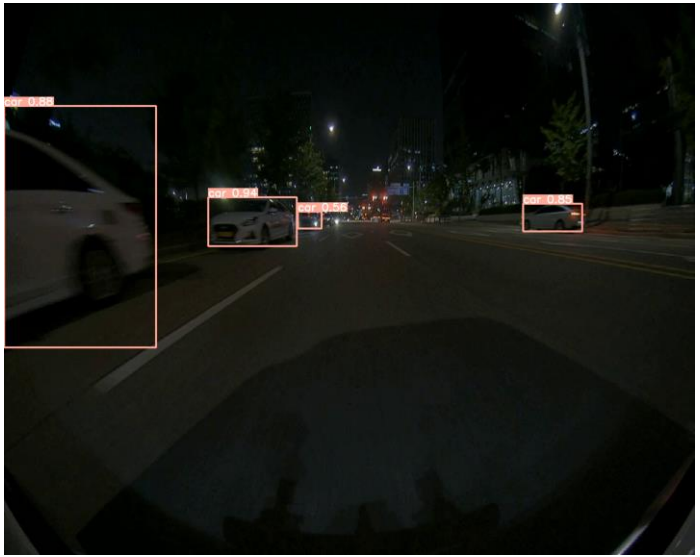
Qualitative Experiments – Best ISP for Object Detection

- **Nighttime test**
  - **2 ISP settings are applied for same driving path**

T1 : Viewing Optimization Tuning

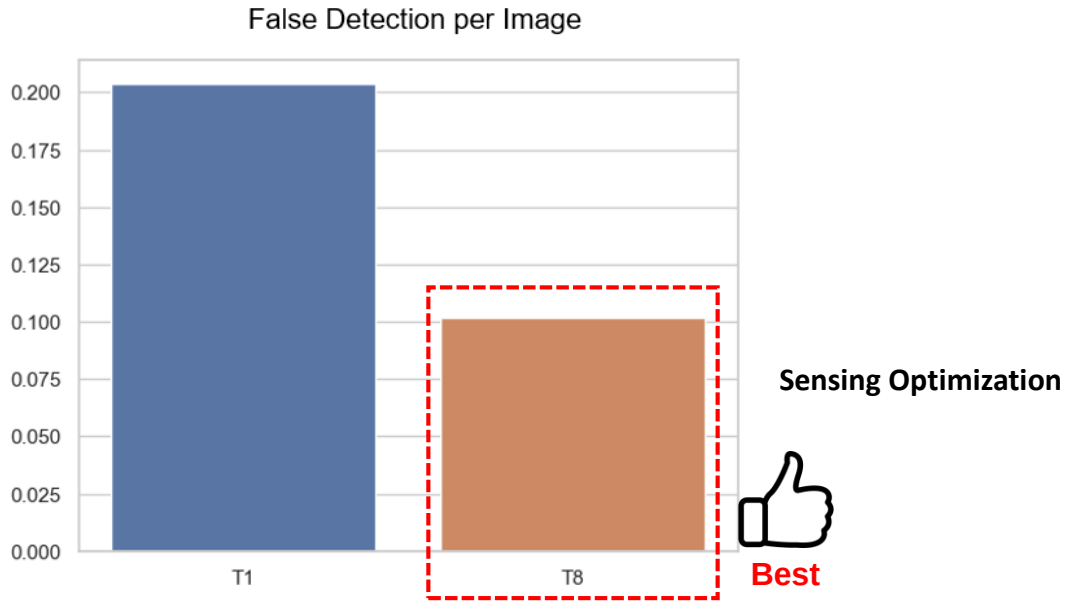


T8: Edge Sharpness Off + AE Down + NR Up



Qualitative Experiments – Best ISP for Object Detection

- **Nighttime evaluation result**



Quantitative Experiments – Conclusion

- Qualitatively, the detection rates are similar at all tuning points

- Datasets1 (Day time)

  1. When noise level is high, reduces false detection rate

  2. In daytime, brightness does not seem to have a significant effect on false detection

- Datasets2 (Night time)

  1. T8 (Sensing) false detection rate is 0.1 better than T1 (viewing tuning)

  2. At nighttime, when brightness level is low, reduced false detection rate

Future Works

The problem with current experiments

- Since the performance is evaluated only for specific points,

  there are some limitations to estimate the tendency value for each tuning factor.

Further experiments

- We keep working to analyze the trends while changing the AE (brightness), EDGE, and

  the noise level in optimal ISP tuning.

Resources

- ChatGPT https://chatgpt.com/n
- Test by Nextchip Internal Standard of Image Quantitative & Qualitative Test

2024 Embedded Vision Summit

- Booth#109
- Mr. Young-Jun Yoo
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