II International Scientific Symposium

Intelligent Solutions

Application of Computational Intelligence

ANALYSIS OF THE INFLUENCE OF PULSE WIDTH MODULATION OF ARTIFICIAL LIGHTING SOURCES ON THE HUMAN BODY USING ARTIFICIAL INTELLIGENCE METHODS

Lyudmyla Kirichenko, Artur Zhadan, Selivanova Alla

Sigma Software University

CEUR Workshop Proceedings http://ceur-ws.org ISSN 1613-0073

Introduction

Industrialization led to indoor workspaces.

Artificial lighting is ***crucial*** for workspaces.

Types of artificial lighting sources can include both ***lamps*** and ***displays***.

Main artificial lighting quality indicators is

brightness and ***pulsation coefficient (PWM)***.

Problem

Artificial lighting (for example, lamps or displays)
not always up to standards.
Poor lighting ***impacts health and productivity***
(for example, headache or eye strain).
Relatively expensive devices (for example, luxmeters)
are used to check workplaces for compliance with standards.

Objective of Research

Develop ***accessible*** pulsation detection method.

AI, specifically computer vision, offers a solution.

Embed AI model in smartphone apps for ***easy checks*.**

Scientific Novelty

AI methods applied for the ***first time***
in the field of Occupational safety and health (OSH).
A unique ***blend*** of methodologies
(AI methods with Math methods).

Impact of Research

Improve Occupational safety and health (OSH) workspace certification.

Prevent health issues caused by poor lighting.

Existing articles

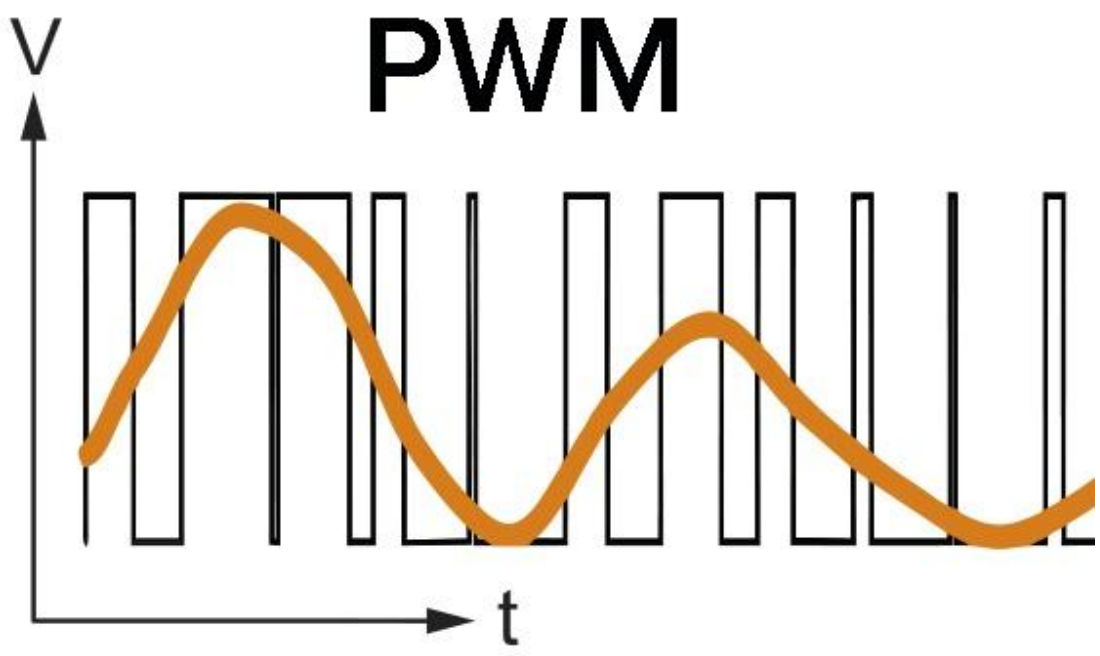
In order to understand this research methodology, it is necessary to consider such concepts from already existing scientific publications as:

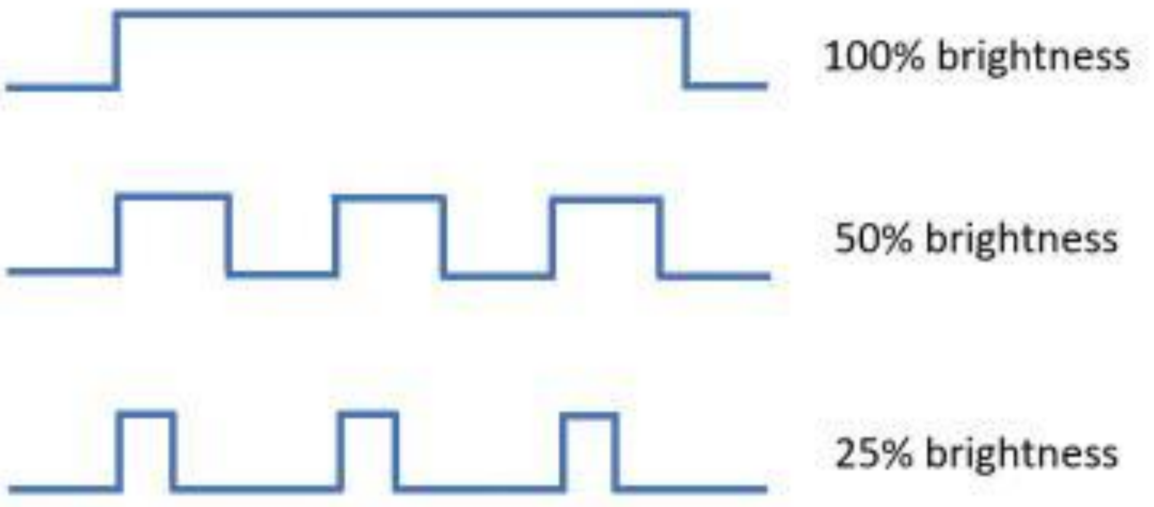
- ***Pulse width modulation (PWM)***
- ***Rolling shutter (RS)***

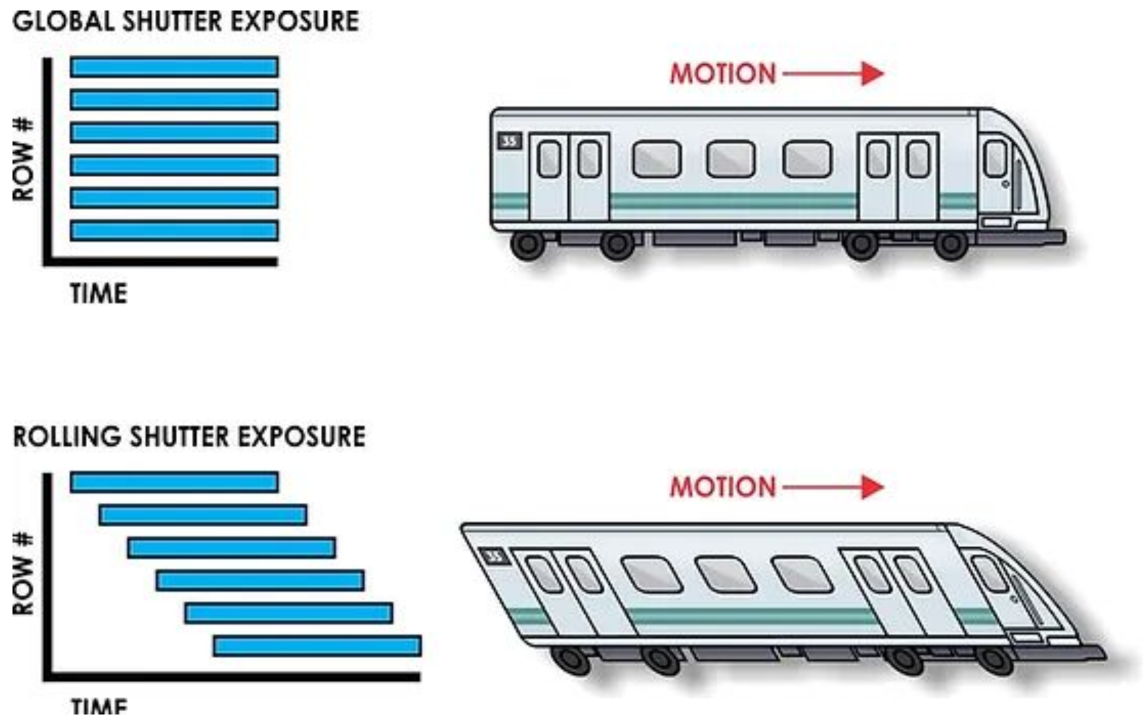
Pulse Width Modulation

Pulse Width Modulation (PWM) is a technique used to control the brightness of light sources, including displays like LED (Light Emitting Diode) screens. It works by rapidly turning the light source on and off at a high frequency. By varying the width of the on-time (duty cycle) relative to the off-time in each cycle, you can effectively control the average brightness perceived by the human eye.

DC (Direct Current) dimming is a technique used to control the brightness of light sources or displays by adjusting the voltage or current supplied to them continuously.







Rolling Shutter

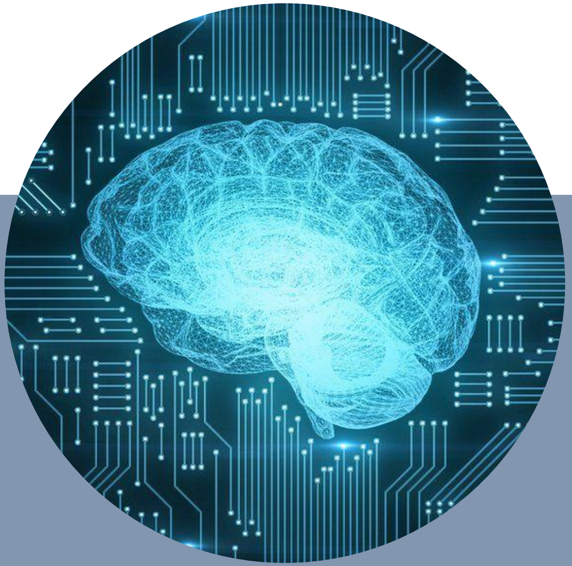
CMOS sensors can detect PWM flicker because they ***capture images row by row***. When the PWM frequency is similar to the sensor's capture rate, some rows may catch the light source at different brightness levels, causing flickering or uneven illumination in the image.

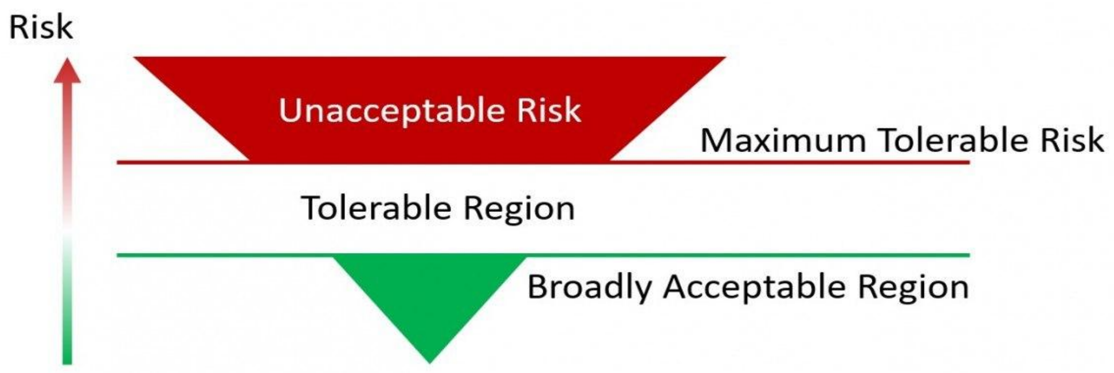
Connection between PWM and RS

CMOS sensors can detect PWM flicker because they capture images row by row. When the PWM frequency is similar to the sensor's capture rate, some rows may catch the light source at different brightness levels, causing flickering or uneven illumination in the image.

Methodology

1. Detection of pulse-width modulation (PWM) ***using artificial intelligence (AI) methods***
2. Detection of pulse-width modulation (PWM) ***using math methods*** as a helper method for improvement of general accuracy





AI Method

It was decided to establish a relationship between the width of the PWM strip and the level of risk to human health. Low-frequency PWM have wider bands than high-frequency ones.

The proposed method ***uses a qualitative*** assessment rather than a quantitative one.

Classes

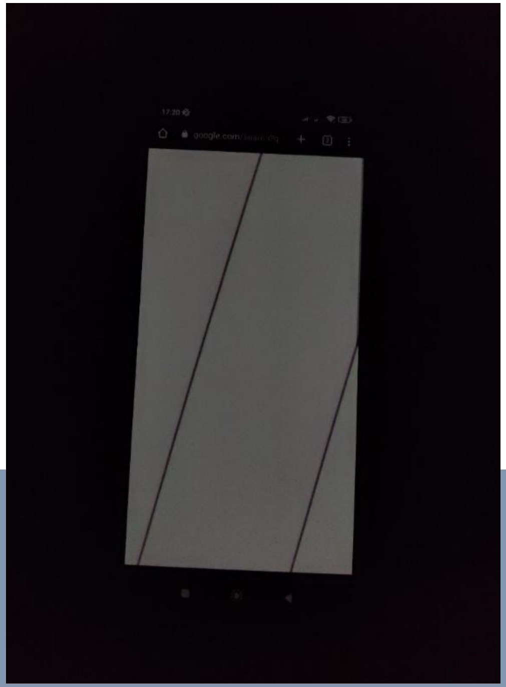
Camera Params:

Exposure – 1/11626

ISO – 5699

Display Param:

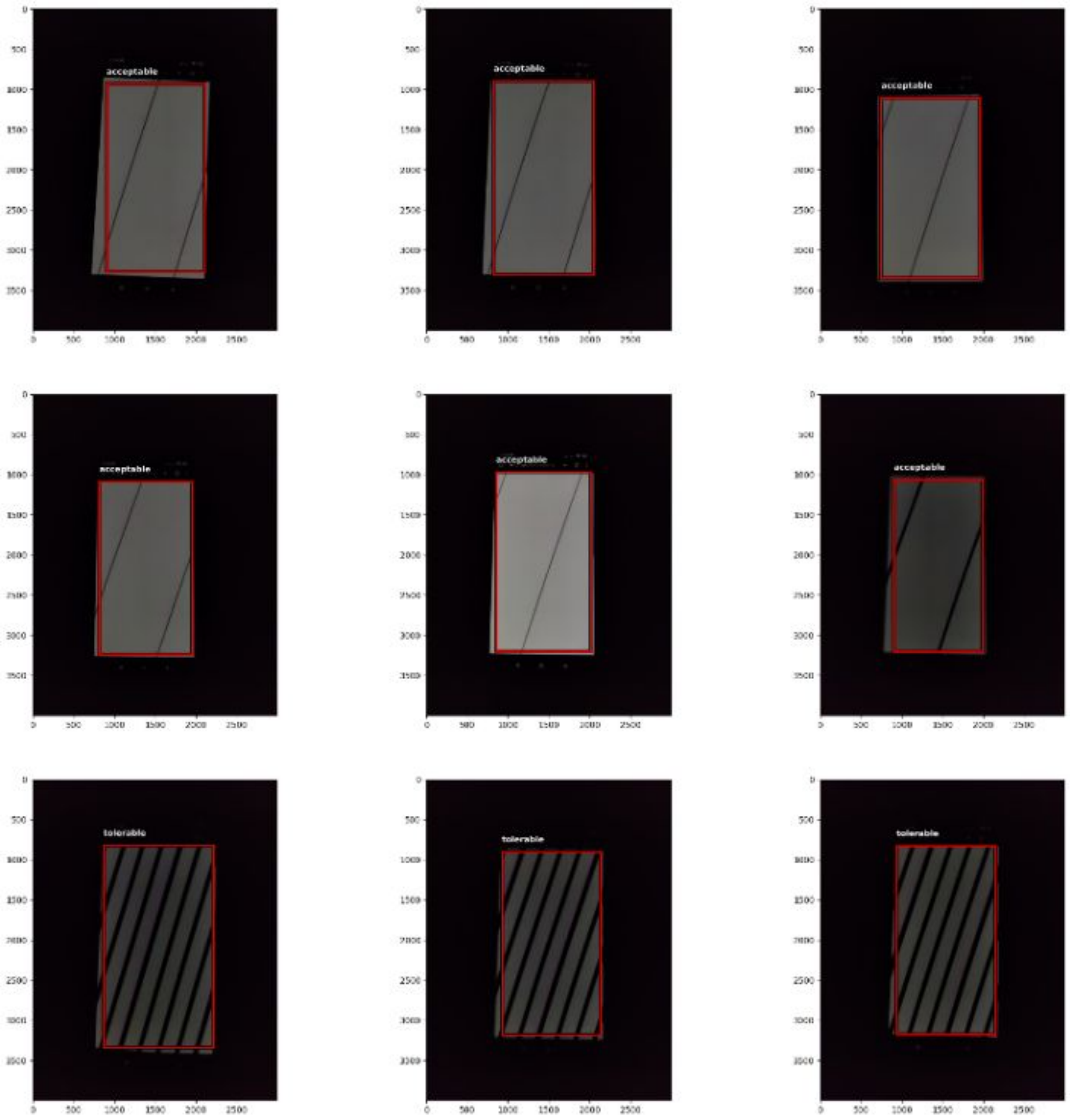
PWM freq – 480 Hz



Acceptable risk

Tolerable risk

Unacceptable risk

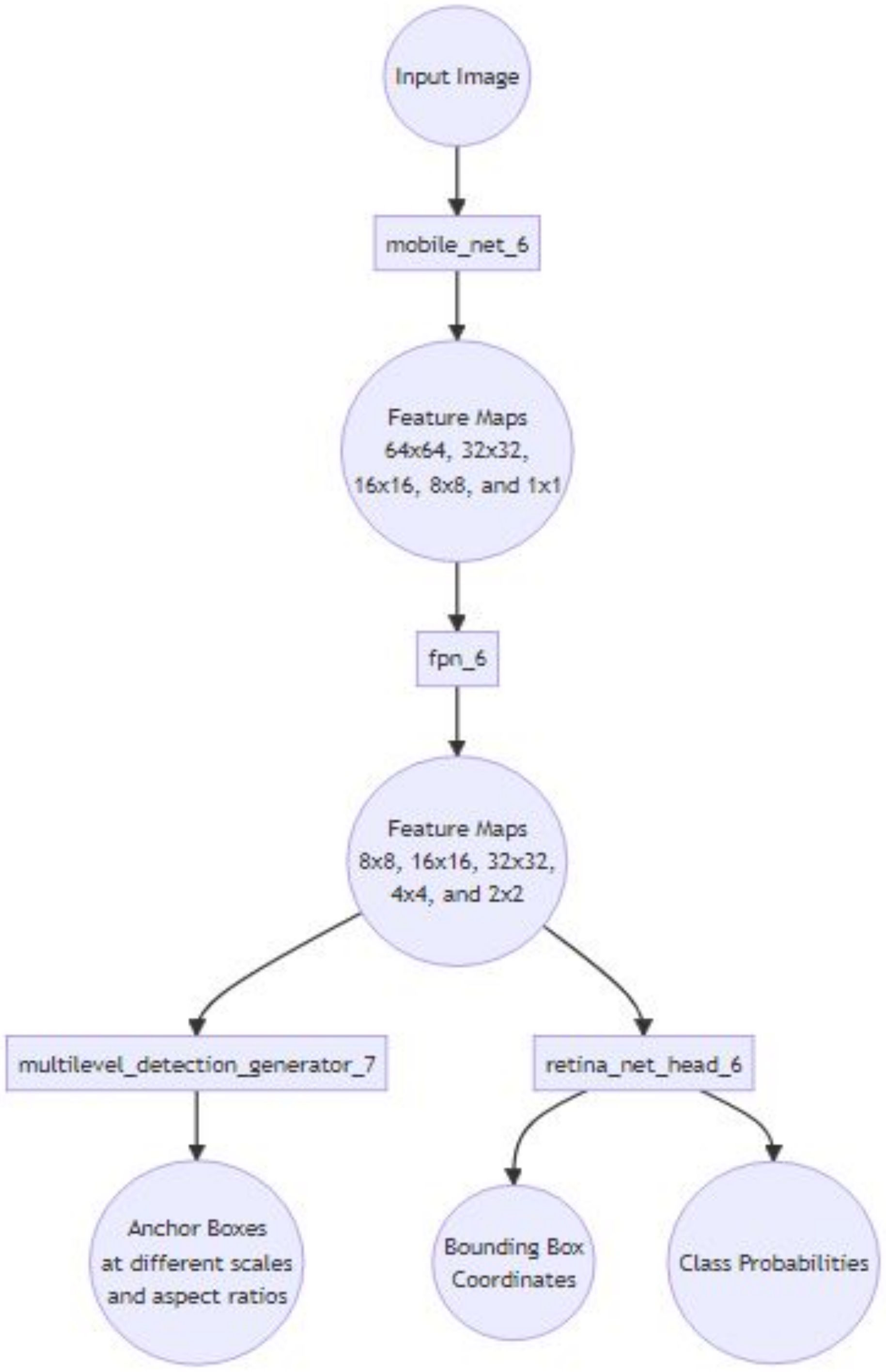


Dataset labeling

Model Architecture

This research uses a model RetinaNet model for object detection pulse-width modulation (PWM). RetinaNet is a model architecture that is commonly used for object detection tasks. It consists of two main components: a core network (pretrained on ImangeNet MobileNetV3) for extracting features from images, and a RetinaNet head for detecting objects based on these features.

The choice of these models is due to the fact that they are free, supported by large companies, have a balance of performance and accuracy. Thus, they are ideal for an our experimental setup.



Characteristics of the learning process

Training parameter	**Value**
Number of epochs	20
Learning rate	1
Batch size	4
Training dataset	70 images
Validation dataset	7 images

Metric	IoU	Area	Max Dets	Value
Average Precision	0.50:0.95	all	100	0.703
Average Precision	0.5	all	100	0.914
Average Precision	0.75	all	100	0.889
Average Precision	0.50:0.95	small	100	-1
Average Precision	0.50:0.95	medium	100	-1
Average Precision	0.50:0.95	large	100	0.704
Average Recall	0.50:0.95	all	1	0.746
Average Recall	0.50:0.95	all	10	0.754
Average Recall	0.50:0.95	all	100	0.754
Average Recall	0.50:0.95	small	100	-1
Average Recall	0.50:0.95	medium	100	-1
Average Recall	0.50:0.95	large	100	0.754

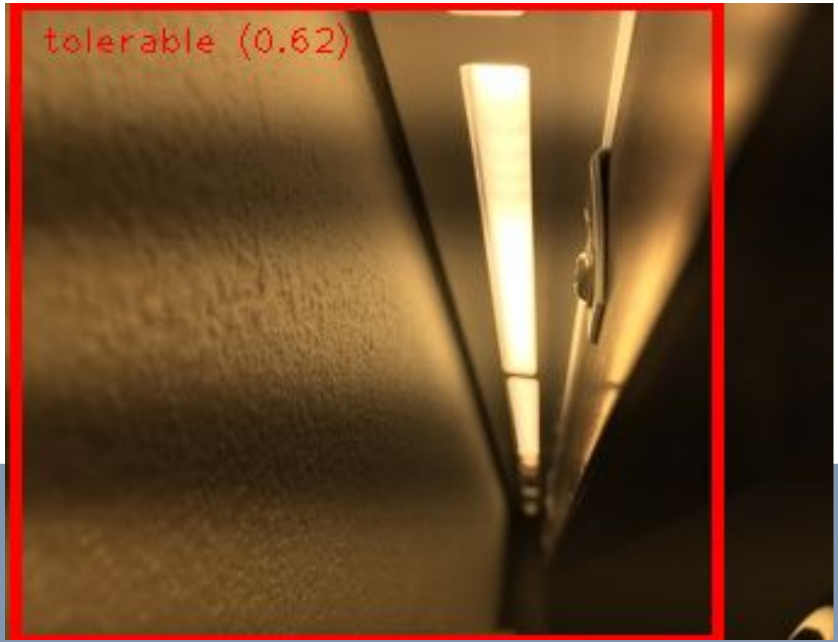
Training metrics results

The model training results show that the average accuracy (AP) at various IoU values ranges from 0.703 to 0.914. This means that the model accurately detects and classifies objects in the image. However, the average accuracy for small and medium objects cannot be calculated, which may indicate difficulties in detecting such objects.

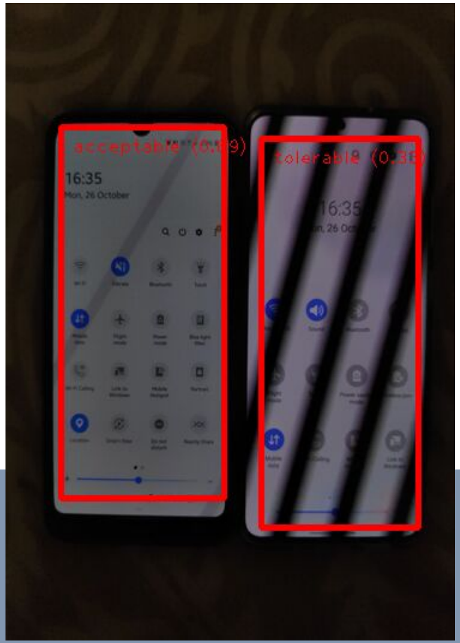
In terms of recall (AR), the model achieves a value between 0.746 and 0.754 for various IoUs and maximum detections. This means that the model is able to detect most of the objects, but some may be missed.

The total validation loss is [0.8219069242477417, 0.5985177159309387, 0.003196648322045803, 0.758350133895874], indicating that the model converges and trains well enough.

Detection results on images from internet



LED PWM with acceptable risk



Display PWM with acceptable and tolerable risk

Math method

Using the camera imposes some restrictions. The camera perfectly shows high-frequency ripples. For example, if the flicker frequency is extremely low, for example, about 30 hertz, then black bars may not form - the camera will track the flicker like a stroboscope.

This method consists in getting an image from the camera and then averaging the RGB colors from Camera or from physical built-in light sensor. This will give the brightness of the color. This information should be added to the array over some time, such as 1 second.

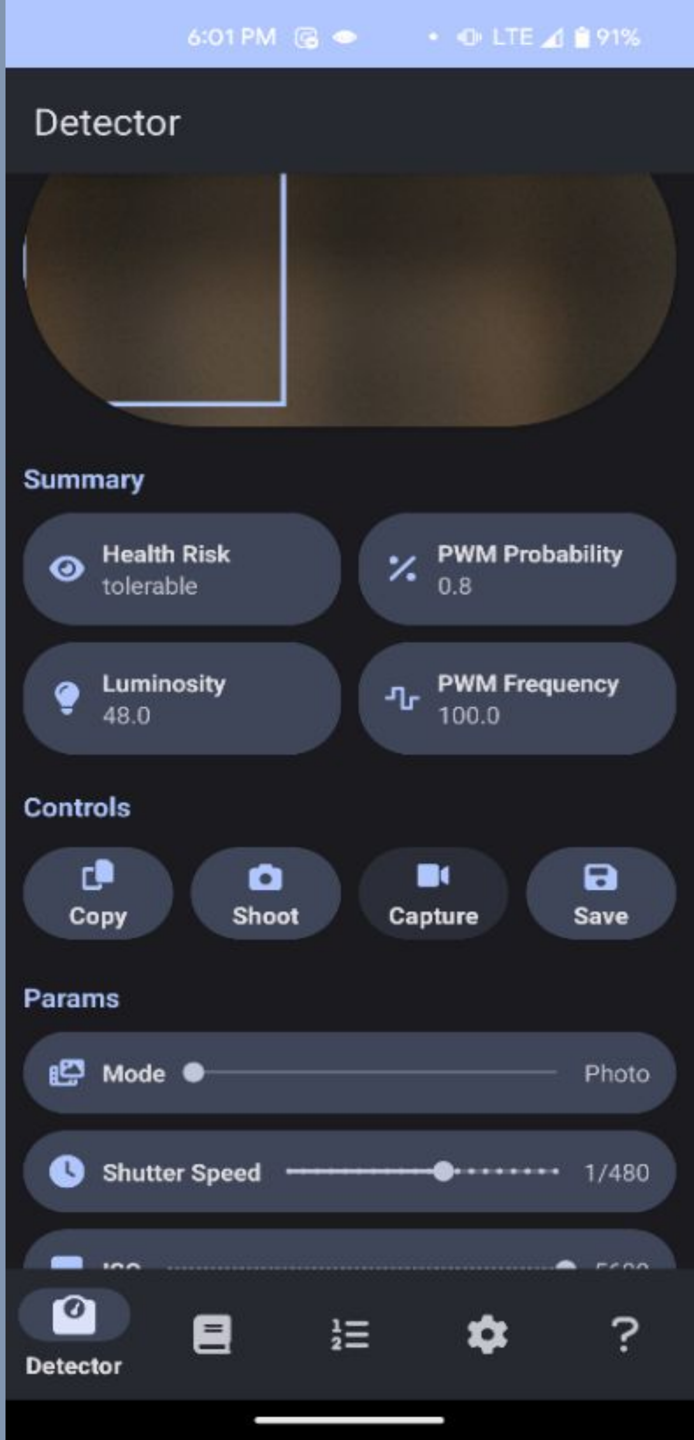
A formula to calculate the relative deviation of the mean (the sum of the values divided by the number of values) of the data set (x) from the maximum value (max) as a percentage.

$$P = \frac{100 * \left(\frac{\sum x}{n}\right)}{x_{max}}$$

where P – is the percentage of flickering, $\sum x$ – is the total sum of brightness, n – is the total number of average color values, E_max – is the max value of average color value brightness.

Real-time detection & practical results with Android native application

LED PWM detection with ***80% probability*** of tolerable risk and ***0.1 sec. speed*** of detection on mid-range smartphone with SOC Snapdragon 765G and CMOS Sony IMX 586.



Research results discussion

Analyzed AI-based detection of PWM in artificial light sources using MobileNetV3.

Moderate accuracy and speed achieved.

Ways to Improve

Expand ***dataset size***.

Use ***non-square masks for labeling***.

Adjust ***training parameters***.

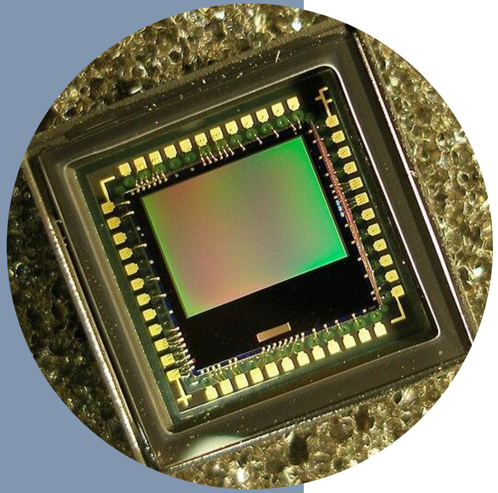
LIMITATION

Method Limitations

Relies on CMOS sensor's rolling shutter effect.

Not compatible with older CCD sensors.

Accuracy depends on ***object definition model quality***.



CMOS Sensor Variability

Different ***CMOS sensors impact result objectivity***.

Some limitations can be addressed ***by setting minimum system requirements***.

Detection ***possible even with a 1/1000 shutter speed for common artificial light sources***.

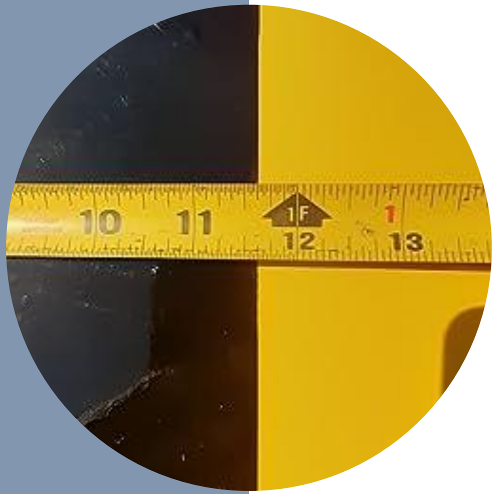
Research Summary

SUMMARY

Explored ***AI-based PWM detection in artificial light sources for human health protection***.

Demonstrated ***the effectiveness*** of the MobileNetV3-based image detection model.

Presented ***ways to enhance PWM detection***.



Future Work

Identified room for improving model speed and accuracy. Suggested exploring methods for calculating ***PWM stripe widths.***

SIGNIFICANCE

Significance of Research

This research advances ***occupational safety and health*** by providing ***alternative methods*** to ***assess workplaces*** and ***mitigate low-quality lighting effects***.

II International Scientific Symposium

Intelligent Solutions

Application of Computational Intelligence

Thank you for your attention!