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Street Lamp Detection

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Abstract

The concern on light pollution is rising. Scientific studies upon this problem introduce substantial consequences on the environment. Along with the invention and rapid escalation of electric lights systems multiple nighttime environments have been affected over ample portions of the surface of our Planet. Since one of the most prominent causes of light pollution is represented by street lamps, this paper is proposing a fast method of detecting street lamps in a scene image.

Although the problem and its effects upon biology and ecosystems, as well as the necessary actions that could be taken to reduce light toxicity are well known, little position has been taken towards it.

Street lamp detection is a small but fundamental act of commission, but despite its promising results, there are currently no works on this concern.

Subsequently, there appeared the need of creating a custom data-set for street lamps object detection and experimenting with the well-known preprocessing and image augmenting techniques. Combined with modern object detection models similar to the ones in the YOLO family, experimental results have yielded scores that verifies the effectiveness of the proposed method.

Keywords:
street lamps; object detection; YOLOv5; light pollution; custom data-set

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1. Introduction

The concern on light pollution is rising. Scientific studies [4] upon this problem introduce substantial consequences on the environment.

Ecological light pollution or ”photopollution” [6] is described by artificial light that alters the natural patterns of light and dark in ecosystems.

A wide variety of lighting devices contribute to night-time light pollution, including public street lighting, and light from advertising, architecture, domestic sources and vehicles. Of these, street lighting is a major concern [2] and the focus of the majority of attention, as it is often the most persistent, aggregated and intense source of lighting in urban areas. Street lighting alone uses about 114 TWh of energy globally [1].

Although street light pollution negative effect upon environment is well known, there is little research targeted to intelligent systems that can detect such incongruities.

Street lamp detection is an immediate approach and could be the basis of multiple subsequent works that could work together in observing the phenomenon of light pollution, of detecting its sources and limiting its spread. Besides street lamp detection, works such as color temperature of street lamps, intensity of street lamps, shielding and intensity of street lamps could be initiated.

Despite its promising benefits, there has been no research upon detecting street lamps or even light sources in scene images. However, there has been a lot of recent research upon detecting traffic lights. Using the data-sets provided by such research institutions, a new data-set containing night time images taken with a car camera has been created specifically for the task of street lamp detection. Each image has one or more street lamp annotation.

Further work upon the obtained data-set included image preprocessing and augmenting, to expand the data-set as well as to increase the variety of the images to increase the performance of the models that will be further trained on the data-set.

Since the objects of interest are street lamps lights, by definition the images could impose various lightning conditions. Weather conditions could also be representing a factor of change, at least from two perspective: first, the camera could suffer performance issues. Second, puddles could reflect light sources which the model could mistake for the real light source.

The object detection models that were used are part of the YOLO family, one of today's most promising single-stage object detectors, used to achieve both impressing speed and accuracy.

Experimental results using real scene images as well as car camera images including one or more street lamps verifies the effectiveness of the proposed method.

2. Concerns upon Light Pollution

This section describes the main negative effects of light pollution.

Light pollution can take several forms that can be identified as glare or undue brightness of a source of light;

- **over-illumination** lighting areas at such levels beyond so that human vision is no longer able to differentiate;
- **light clutter**. Represented by excessive grouping of sources of light;
- **light trespass** or unwanted direct lighting of an area;
- **skyglow**. Which is the increased night sky brightness, produced by electric light that is emitted and reflected upwards and being scattered by gas molecules, water and dust in the atmosphere.

Nocturnal environment changes caused by the expansion of transportation networks, human populations and resource extraction activities is been known to be a global issue with implications for human health and ecosystem integrity 1. Light presents diverse threats to species and ecosystems and important patters are emerging in the literature useful for resource management 2.

2.0.1. Negative Effects

The negative effects of light pollution target multiple spheres of ecology and human activity.

Plants suffer from artificial light pollution as darkness is representing a factor in some of their physiological processes.

Light pollution also affects animals [4]:

- turtles are bewildered at the moment of hatching;
- migrating birds bewildered while migrating and searching for food;
- fireflies mating is perturbed;

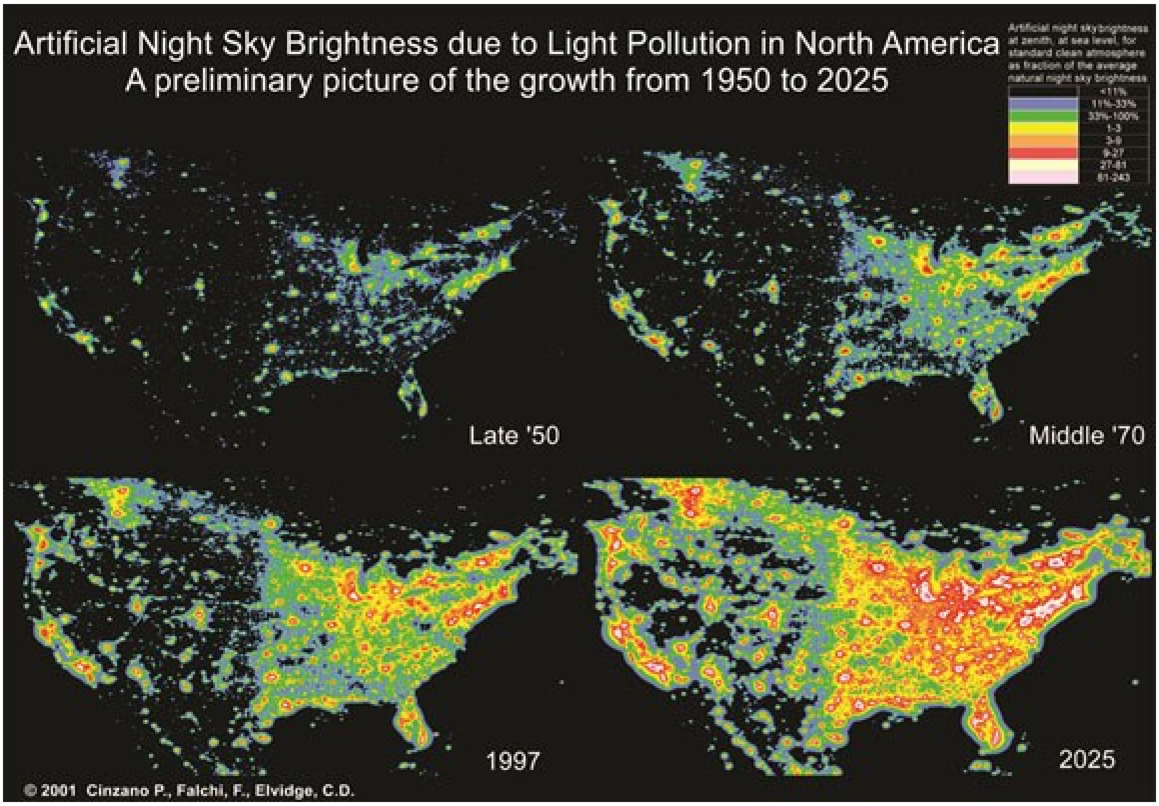


Fig. 1. Simulation of light pollution growth in the United States [www.nps.gov/articles]

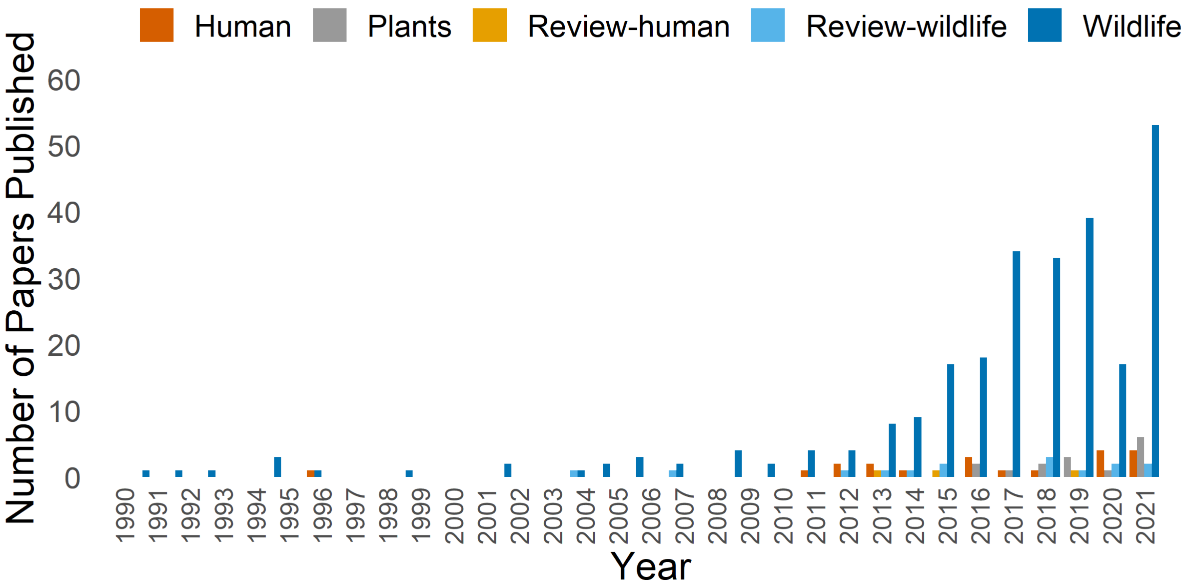


Fig. 2. Peer-reviewed studies published each year (1978-2021) on artificial light effects [www.nps.gov/articles]

Fig. 3. Bortle Scale

- amphibians mating rituals are denaturated;
- increases vulnerability in front of the predators.

Humans are also affected by light pollution:

- the secretion of melatonin, the substance that helps keeping a normal circadian rhythm (day / night cycle) is disrupted;
- Reduced melatonin [5] secretion may cause several diseases such as diabetes, obesity, cancer and insomnia
- at a sensorial level light pollutiaon may cause temporal blindness, irreversible destruction of the retina (eye tissue) or it may increase road accidents.

There are also negative effects over astronomical activities. A diagram representing Bortle scale can be seen in figure 3.

3. Street Lamps as Light Pollution Source

This sections discusses the contribution of street lamps to the light pollution problem.
The Street Lamps are responsible for over 80 percent of the light pollution, as can be seen in diagram 4.
According to [2], there are five management options to reduce night-time light pollution:

- **natural unlit areas** spread could be to be the most effective option for reducing the ecological effects of lighting.
- **decreasing lightning duration** will reduce energy costs and carbon emissions.

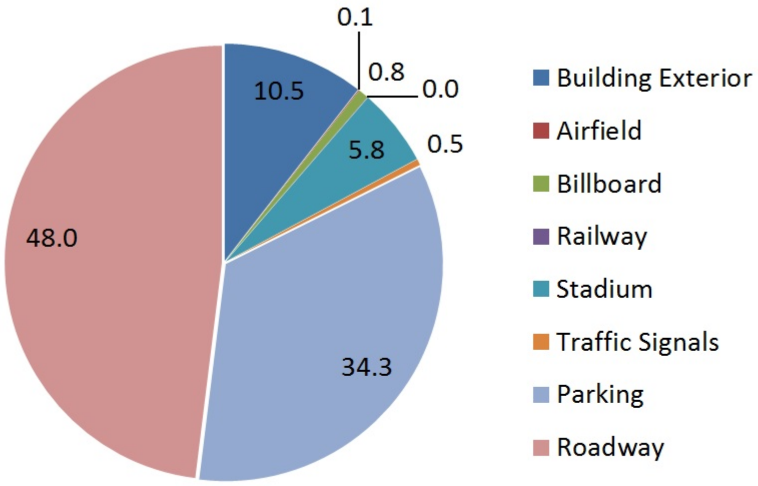


Fig. 4. Light Pollution Sources [allthingslighting.org]

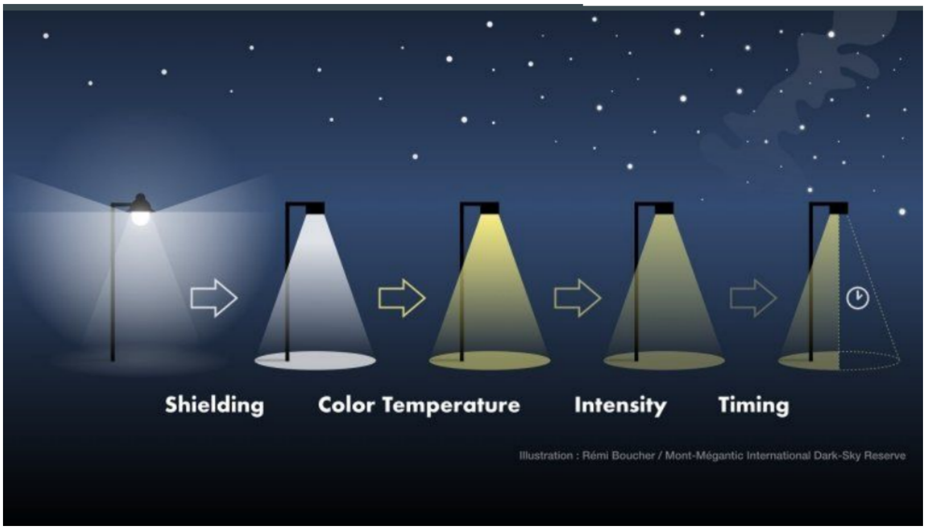


Fig. 5. Options to Current Illumination Systems

- **reducing trespass of lighting** can help with heterogeneity being maintain even in otherwise well-lit areas, such that mobile animals have dark refuges that they can exploit.
- **decreasing intensity of lighting** means reduced energy consumption; it can also mean skyglow limiting.

The management options are illustrated in diagram 5.

4. Proposed Solution

The proposed solution is the development of a fast object detection model that can be trained to identify street lamps in scene images.

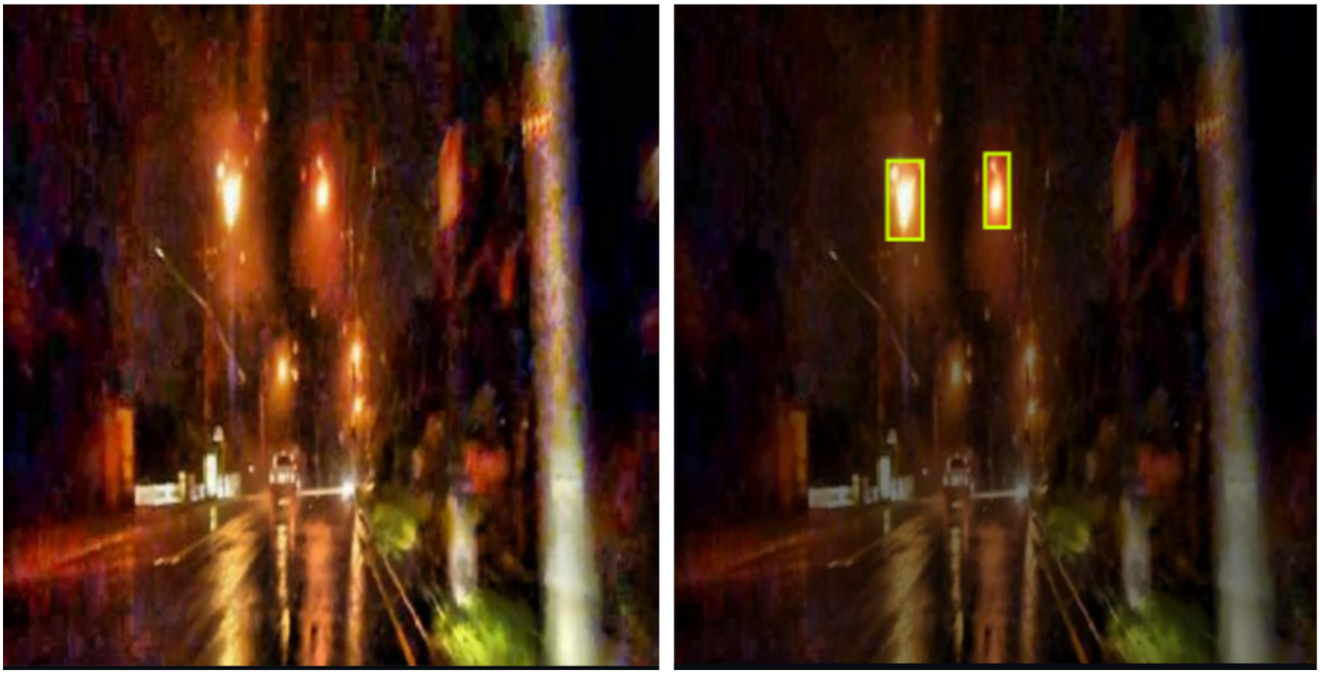


Fig. 6. Custom Data-set Image before and after Annotation

The implications of this research are that it can represent a basis for other works that can help fighting light pollution through street lamp, such as detecting ill-used street lamps, unnatural color temperature street lamps, unnecessary intense street lamps, etc.

Since there are no research works on this topic, there are no specific data-sets for street lamps or light sources detection. This implies the need of creating a custom data-set that can be used to train an object detection model.

4.1. Creating the Data Set

The custom data-set was created by annotating existing data-sets accordingly. For example, Oxford's RobotCar data-set contains images taken by a car camera during night time. This images illustrates a road scenery that contain street lamps. The images have an advantage that are well-structured in terms availability and size. Further, the images had to be annotated to obtain the ground truth data-set used in training. This process is simplified by using annotation software such as LabelMe. An example of image before and after annotation can be seen in the diagram 6.

Further, to enrich the data-set, pre-training image preprocessing and augmenting techniques were used. The effect aimed at expanding the data-set instances and varying the images such that the model could yield best performances.

4.2. Training and Experimenting

Roboflow is a framework for building computer vision models. It has a free tier and provides services such as annotation, image preprocessing and augmentation and even training.

After uploading the custom data-set, Roboflow allows customers to experiment with image preprocessing and augmenting.

The preprocessing step includes an Auto-Adjust contrast step which is used to enhance an image with low contrast. Roboflow allows for using Auto-Adjust contrast with Adaptive Equalization, using Contrast Limited Adaptive Histogram Equalization (CLAHE), an algorithm used to enhance local contrast. It uses histograms computed over different tile regions of the image. The results are that it provides enhancement for Local details, even in regions that are darker or lighter than most of the image. This is important for Street Lamps since the area around the light source is a lot more bright then in the rest of the image.

In the Augmentation step there were generated 3 images per training sample, each containing a random level of augmentation from each augmentation technique selected. This resulted in a data-set of 771 images, out of which 678 were used for training, 65 for validation and 31 for testing.

Some of the used augmentation techniques are described below:

- **Horizontal Flip**. This step produces more sample images. Since the street lamps are usually in the upper part of the image, a Vertical Flip is excluded because it may not inform the model not to label the reflection of the street lamps.
- Rotation between -15° and +15°. This step is similar in motivation with the step above. Again, an exaggeration in rotation could allow the model to mistake reflection for the real light source.
- **Grayscale** applied to 35 percent of the images. Since the color temperature may vary in light sources, applying grayscale augmentation to some images could be a way to communicate this feature of light sources to the model. However, applying grayscale could also instruct the model to label traffic lights as light bulb, since one of the main differences between a street lamp light source and a traffic light is the color.
- **Hue** between -30° and +30°. Hue can come as a complement to grayscale. Hue randomly alters the color channels of an input image, causing a model to consider alternative color schemes for objects and scenes in input images. From the same consideration as in using grayscale, Hue is considered only in limited value.
- **Exposure** can be used to increase the generalizability of the training model's performance by increasing the diversity of learning examples.
- **Cut-out**. Cutout simulates occlusion by adding black boxes to images. The motivation is that it could help the model do better at detecting objects that are occluded (hidden behind other objects).

A training batch can be seen at 7 and A training augmented batch in diagram 8.

Experimenting with different preprocessing and augmenting techniques has yielded 3 different results.

First experiment used vertical as well as horizontal flip as an augmentation process. This step was motivated by the annotation heatmap where can be observed that the majority of the objects of interest are located in the upper half of the images. The annotation map of the dataset can be seen in digaram 9. However, the model was mistaken reflections for the real street lamps, although it had a good performance. Another issue of the first experiment was that it was unable to recognize white source lights. This is a direct consequence of the fact that the images from RobotCar data-set contain only street lamps with yellow light.

The second experiment was defined by an exaggeration in the augmenting process. This resulted in a model that performed worse than the one in the first experiment. Besides the original augmentation steps, it has been also added Shear: ±15° Horizontal, ±15° Vertical, Saturation: Between -30% and +30%, Brightness: Between -45% and +45%, Noise: Up to 5% of pixels. A preprocessing step was also added, resizing images by fitting in black edges. The results of the second experiment had lead to the third experiment with the following changes:

- using grayscale augmenting to deal with white light problem.
- Eliminate some steps from augmentation since the current model is an exaggeration. The elimination should result in having only one augmentation step for each concept: variation and color sensitivity.
- Go back to Fit with stretch as it can be useful for the model to recognize different shapes of light bulbs and helps eliminate useless portions in an image that are introduced with black frame

The third experiment produced the best results and it also dealt with the white light problem of the first two experiments.

The Training model used in all experiments was YOLOv5. YOLO [3] is an acronym for 'You only look once'. It is an object detection algorithm that works by dividing images into a grid system. Each cell in the grid is responsible for detecting objects within itself. YOLO is one of the most famous object detection algorithms due to its speed and accuracy.

4.3. Results

The following subsection analyzes the three experiments in terms of their performance.

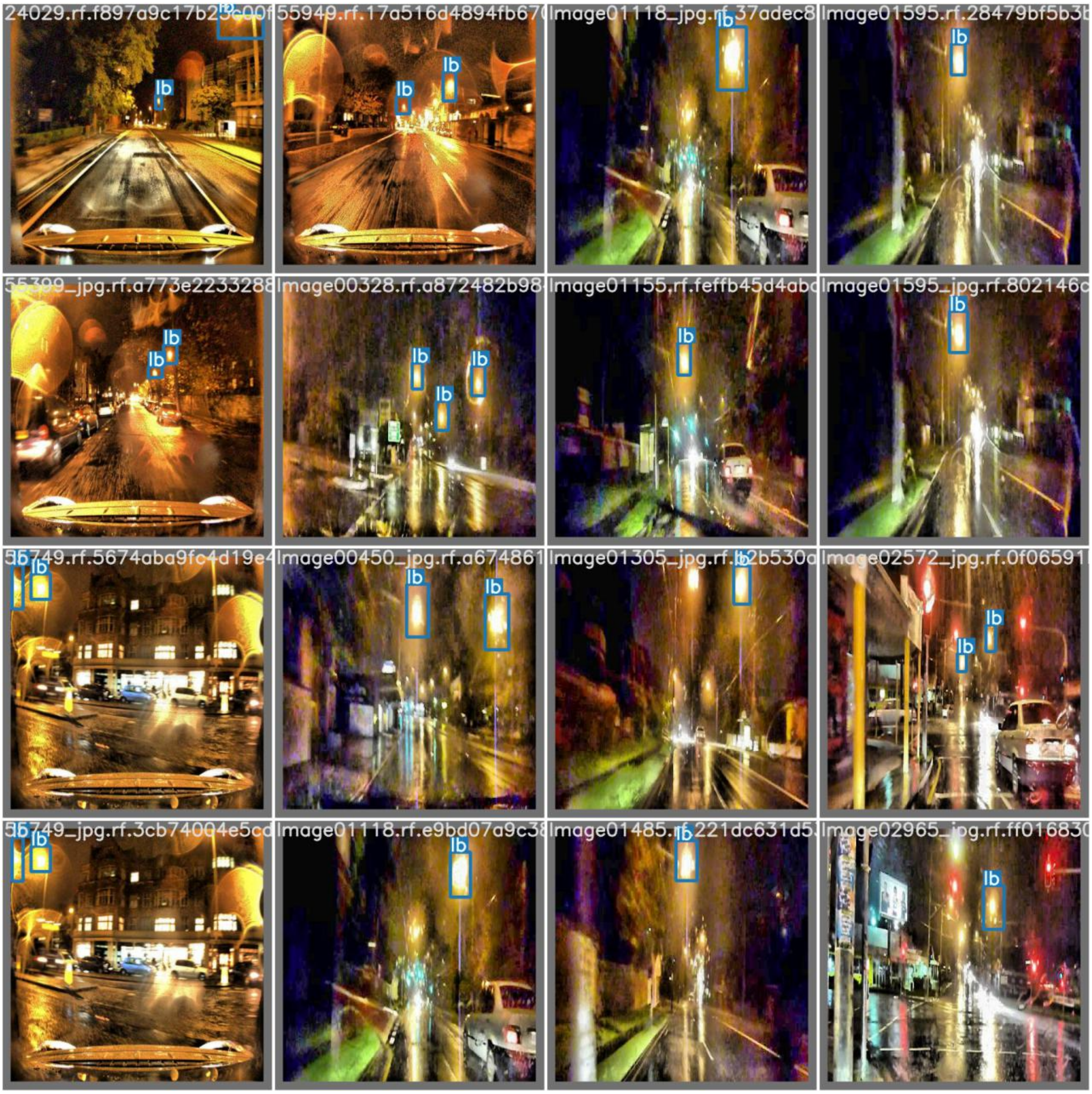


Fig. 7. Training Batch

As can be seen in the figure 10 The best performing model was the one in Experiment 2, while the worst performing was the one in Experiment 1.

The metrics for Experiment 2 (Best Performing) can be seen in detail in figure 11.

A comparison between the experiments on unseen data can be seen in figures 12 and 13.

5. Discussion

The paper discusses about the importance of light pollution and how it can be tackled by means of computer vision.

The detection of street lamps can bee seen as a starting point for other works that can be used together to analyse and even defer the impact of light pollution on our Planet.

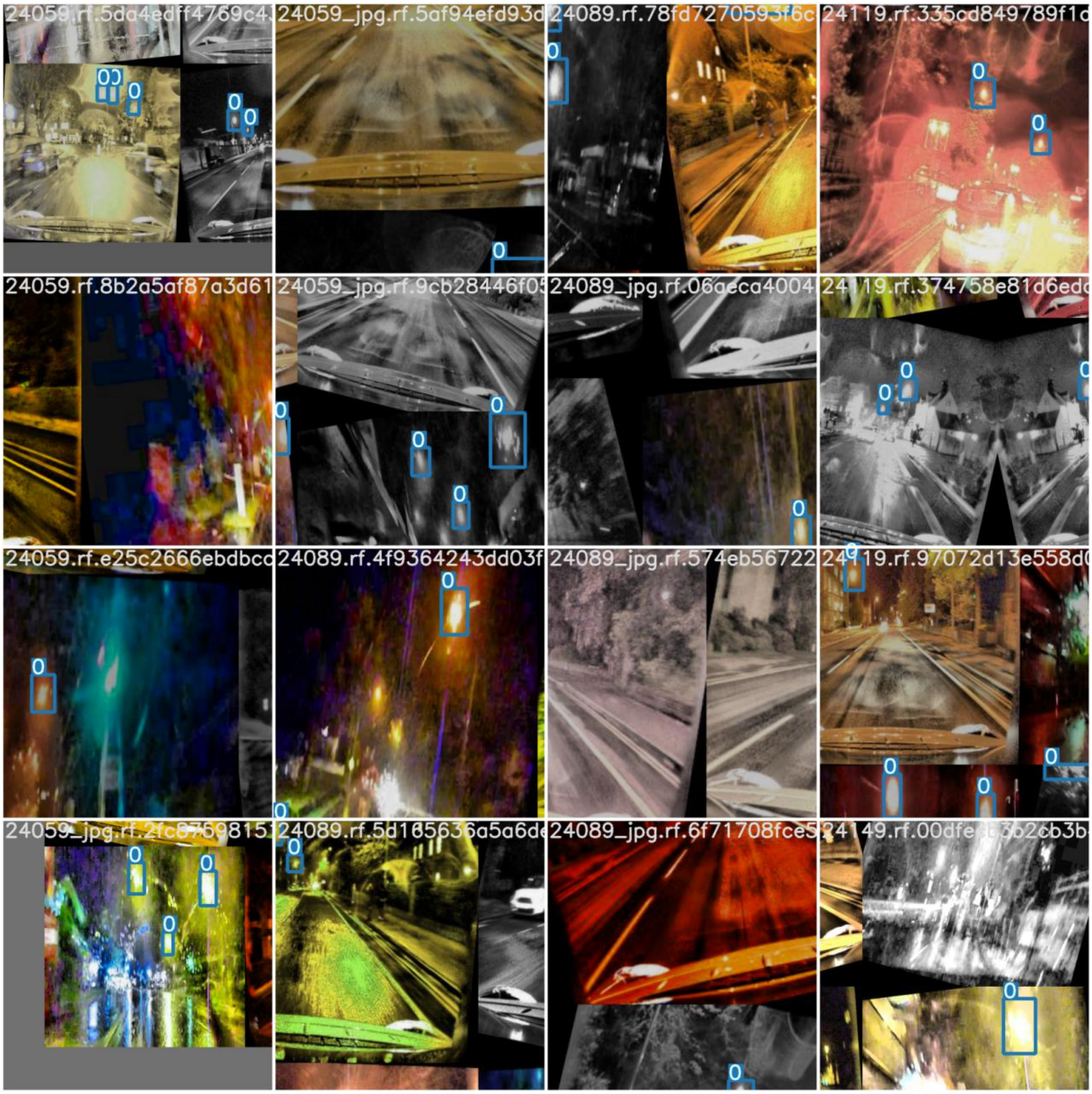


Fig. 8. Training Augmented Batch

The paper also shows the simplicity of creating computer vision models that are performing well and at high speed with modern day frameworks, even on custom data-sets.

The paper talks about the importance of augmentation and image processing in directing or helping the model to see the features we want to accentuate, and also how they can be leveraged to increase the size of a small data-set. Although excessive augmentation can have a negative impact on the model's performance, finding the best combination of augmentation and preprocessing techniques can increase the model's mAp up to almost 20%, the precission with up to 16% and the recall with up to 10%, as can be seen in 10.

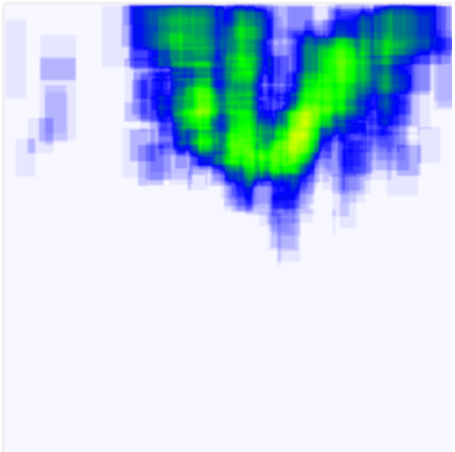


Fig. 9. Annotation Heat-map

Model	mAP	Precission	Recall
First Try	0.87	0.86	0.83
Experiment 1	0.71	0.70	0.77
Experiment 2	0.90	0.84	0.87

Fig. 10. Performance Analysis

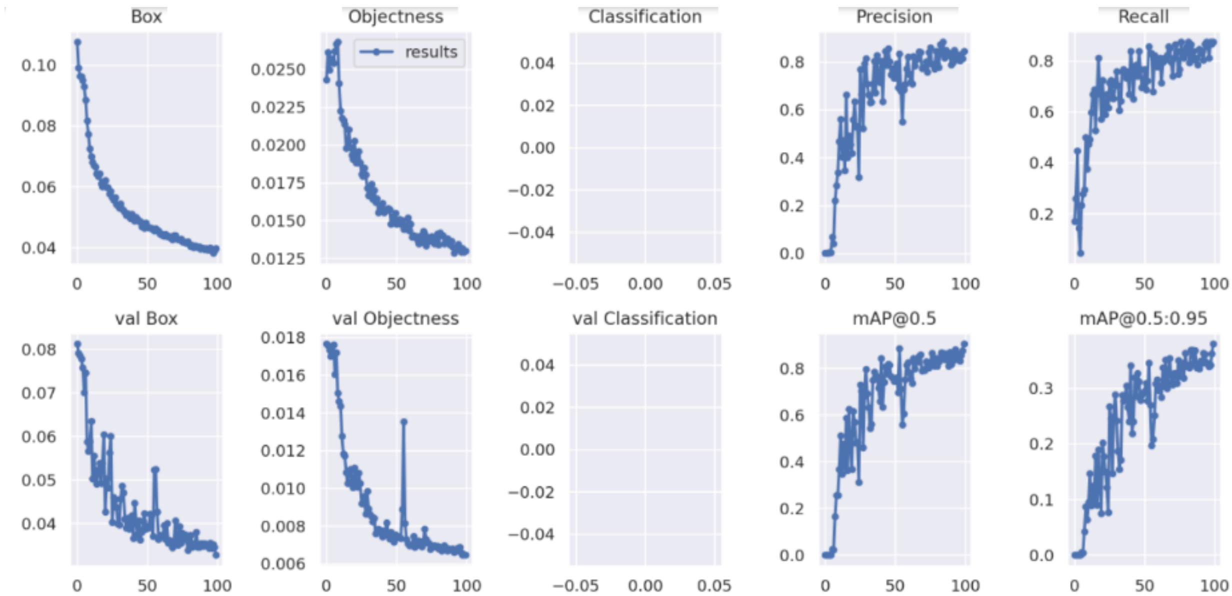
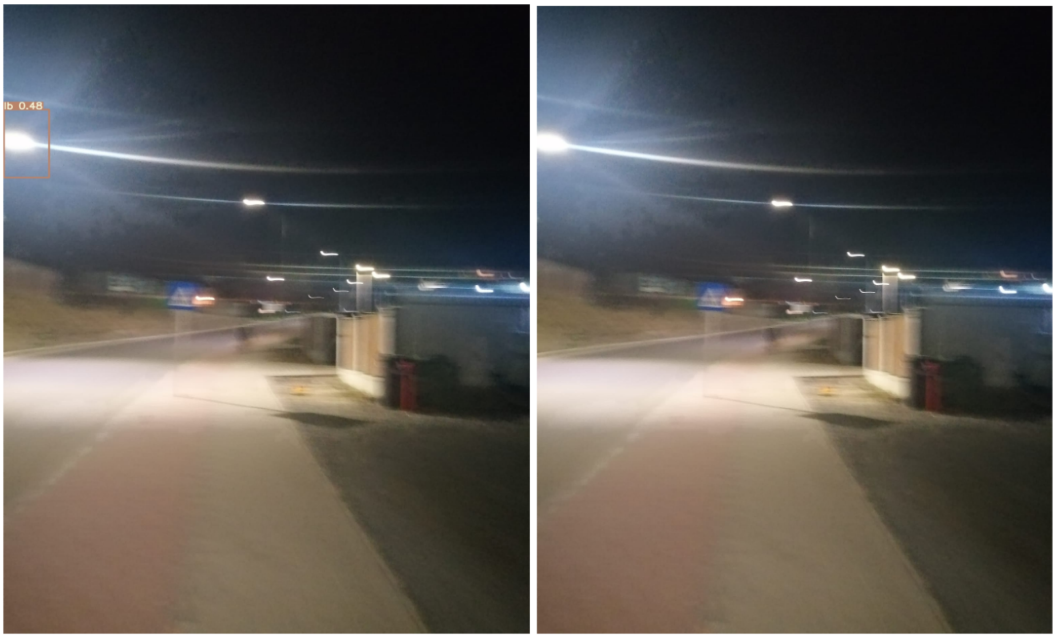


Fig. 11. Metrics for Best Performing Experiment



Experiment 2 correct with 0.48% Experiment 1 & First Try

Fig. 12. Comparison On Unseen Data

Experiment 2 correct with 0.53% and 0.61% Experiment 1 & First Try

Fig. 13. Comparison On Unseen Data

6. Conclusions and future work

In this paper, it was proposed a model for detecting street lamps from scene image with high accuracy and in reasonable time.

The simplicity of training models, even with custom data-sets, has become more and more simple with the use of modern frameworks, allowing students and non-experts in Computer Vision to work on real world problems.

The detection of Street Lamp is just the beginning of related future works that could be used in address light pollution impact over society and ecology. Combined with the Street Lamp detection model, other systems for detecting unfavourable street lamps color temperature, or light intensity could be used to detect ill-designed street lamps that could emit toxicity by means of light pollution.

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