A Self-Adaptive Traffic Light Control System Based on YOLO

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***Abstract*— Traffic congestion is becoming a serious problem with the large number of cars in the roads. Vehicles queue length waiting to be processed at the intersection is rising sharply with the increase of the traffic flow, and the traditional traffic lights cannot efficiently schedule it. A real-time traffic light control algorithm based on the traffic flow is proposed in this paper. In fact, we use computer vision and machine learning to have the characteristics of the competing traffic flows at the signalized road intersection. This is done by a state-of-the-art, real-time object detection based on a deep Convolutional Neural Networks called You Only Look Once (YOLO). Then traffic signal phases are optimized according to collected data, mainly queue length and waiting time per vehicle, to enable as much as more vehicles to pass safely with minimum waiting time. YOLO can be implemented on embedded controller using Transfer Learning technique, which makes it possible to perform Deep Neural Network on limited hardware resources.**

Keywords*— *Traffic light Control, waiting time, object detection, YOLO, Transfer Learning

I. Introduction

Traffic congestion is a major problem in many cities, and the fixed-cycle controllers are not resolving the high waiting time in the intersection. We see often a policeman managing the movements instead of the traffic light. He see roads status and decides the allowed duration of each direction. This human achievement encourages us to create a smart Traffic light control taking into account the real time traffic condition and smartly manage the intersection. To implement such a system, we need two main parts: eyes to watch the real-time road condition and a brain to process it. Cameras can be used to record traffic status and Machine learning adds intelligence to the system. In this paper, we benefit from the evolution of computer vision techniques to detect object thanks to deep learning and exactly based on YOLO [1], a new Real-Time Object Detection model. Then, green duration is optimized for more passing cars and minimum delay. The reminder of this paper is organized as follows. The literature review is presented in Section 2. More details on YOLO model are described in Section 3. Section 4 shows the proposed system and the designed algorithm. Section 5 describes the implementation techniques, discussed in Section 6. Finally, the paper is concluded in Section 7.

II. Related Work

To solve congestion problem, many transportation researchers and industrials as detailed in [2] and [3], have worked on traffic light Optimization.

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Three important adaptive traffic control systems are described below.

Split Cycle Offset Optimization Technique (SCOOT): uses on street detectors embedded in the road. In fact, when vehicles pass the sensor, SCOOT receives the real-time traffic data and uses them to construct the traffic flow models to estimate queue length when the light is red. Its objective is to minimize the sum of the average queue in a given area [4]. It takes decisions before the phase changes (real-time adaptive algorithm). It effects on offsets, cycle length, and phase length.

RHODES is a Real-time Hierarchical Optimizing Distributed Effective System developed by a research team at the University of Arizona [5]. The Fig. 4 gives us a simplified view about it is architecture:

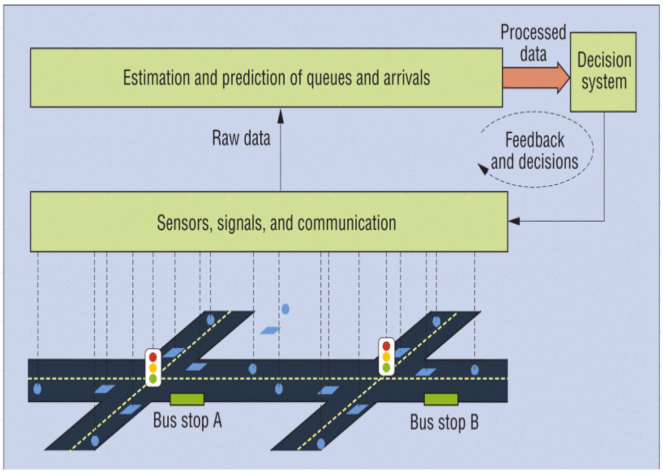

Fig. 1. A simplified diagram of RHODES operation [5]

InSync : The InSync adaptive traffic control system is developed by Rhythm Engineering [6]. It is composed by an IP video camera and a processor. InSync counts the number of vehicles and the delay in order experienced to optimize the phasing. InSync has two major aspects of operations: it automatically adjusts local signal timings and it coordinates signals along roadway arterials according to real-time traffic demand.

Adaptive traffic control systems are created to resolve fixed-time traffic light limitations. Each of them has its characteristics that make it interesting to compare. Indicators like average waiting time is a good KPI to evaluate the performance of those algorithms.

III. Object Detection With YOLO

YOLO is a state-of-the-art, real-time object detection system. It is a fully convolutional network applying a single neural network to the full image. It divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities. Only Look Once makes YOLO very fast, more than 100x faster than Fast R-CNN. (see Fig. 2)

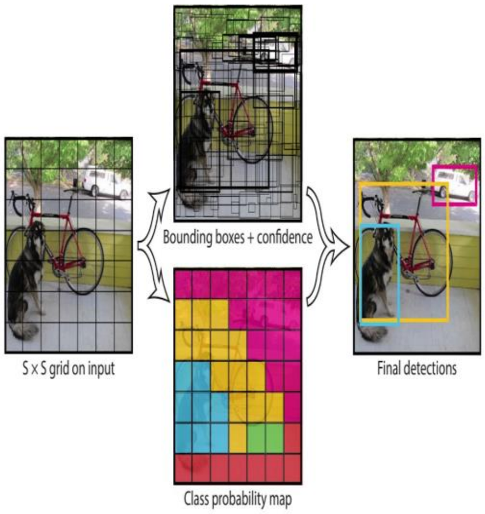

Fig. 2. Object detection approach with YOLO

In 2018, a new version of YOLO is released [7]. YOLO v3 uses a variant of Darknet, with 53 layers network trained on Imagenet. For detection, 53 more layers are stacked onto it, giving us a 106 layer fully convolutional underlying architecture. Find in Fig. 3, YOLO v3 architecture with detections at three different scales.

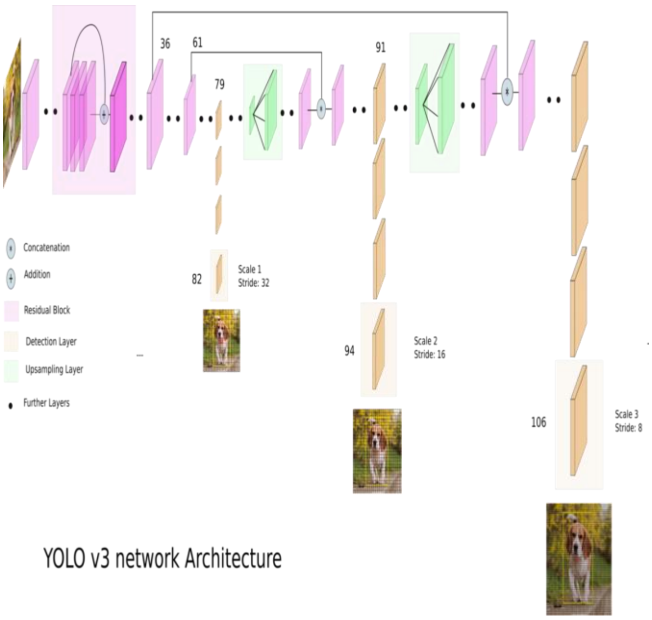

Fig. 3. Object detection approach with YOLO v3 network architecture

YOLOv3 uses a convolutional layer, using 1 x 1 convolutions. It means that the size of the prediction map is exactly the size of the feature map before it. Then in this prediction map, every cell can predict a fixed number of bounding boxes. In YOLO v3 trained on COCO, there is 3 bounding boxes for every cell and 80 classes. YOLO v3 uses 9 anchor boxes, three for each scale.

IV. System and Algorithm Design

A. System Architecture

As shown in Fig. 4, Our System is based on computer vision to have a real time status of the traffic at the intersection. The embedded Controller is then processing the frames using YOLO as a deep Convolutional Neural Networks. In fact, in each lane, a Camera is installed and YOLO is detecting and tracking objects: For each new vehicle, the model is launching a timer to record its waiting time until it leaves the intersection. The controller can then compute vehicles per lane and their waiting time.

Based on this real time information, the system will optimize the green light timer of the next phase to enable maximum number of vehicles to pass safely with minimum waiting time.

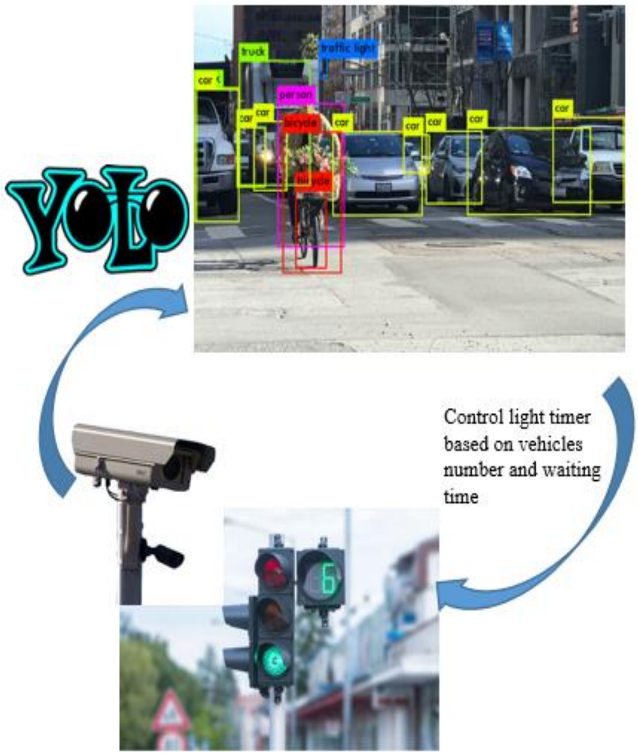

Fig. 4. System Overview of the self-Adaptive Traffic Light Control

B. Adaptive Traffic Light Algorithm

1) Requirements:

The National Electrical Manufacturers Association (NEMA) has defined the safe movements to avoid conflict when crossing the intersection. It is known as NEMA Phasing Diagram as shown in Fig. 5. A cycle is defined as the total time to complete one sequence of signalization for all movements at an intersection. In a Cycle, a phase is a timing unit that controls movements by specifying traffic light color for each lane. A sequence of phases that must time sequentially is called a ring.

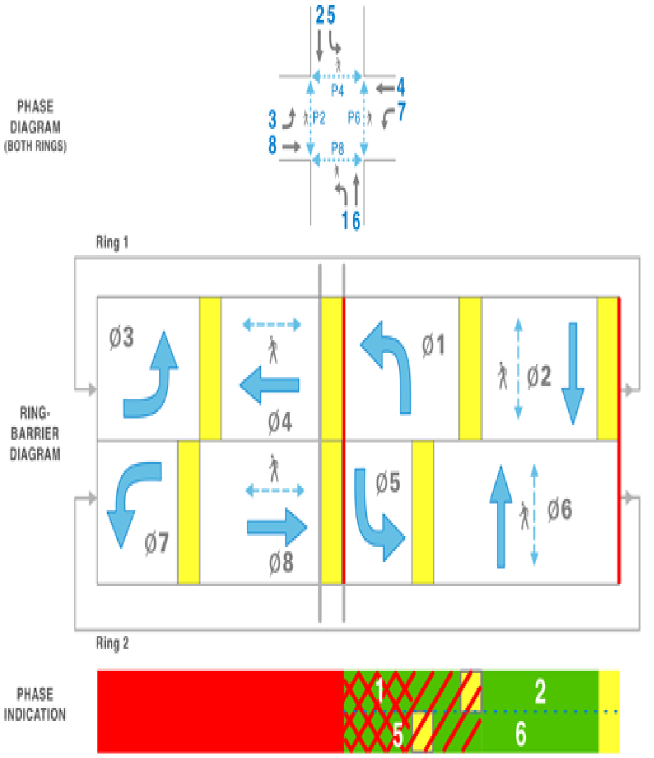

Fig. 5. Phase and ring-and-barrier diagrams of intersection of two one-way streets [8]

Since conflicting traffic flows are possible at intersections, several safety requirements must be realized by a traffic light system. First, each signal plan must ensure that conflicting traffic flows cannot proceed at the same time; this is guaranteed by using NEMA Phasing Diagram. In addition, a Yellow and Red Clearance time must be respected before switching from one phase to another to allow vehicles just entering to the intersection to exit before the switch to green for the other side. For Safety reason and legal constraint, a fixed phase sequence shall be respected and a timer is shown on each road to specify to the driver the remaining time to switch the phase.

Finally, to avoid infinite waiting time, the controller shall respect two configurable durations, the maximum and the minimum duration of the green light for each phase (GT_MAX and GT_MIN).

2) Algorithm Design:

A new Adaptive traffic light Control algorithm is designed respecting safety requirements and using deep learning. YOLO v3 makes possible a real time detection and vehicle tracking with duration before leaving the intersection. In fact, when light is switching to yellow, the controller get from YOLO model how many vehicles per lane and their waiting time. Based on maximum and average waiting time for each lane and the queue length, the duration of the next phase is calculated to minimize the waiting time. Our system give the priority to people that have waited the most, without breaking the cycle order. See below the description of this algorithm in Fig. 6.

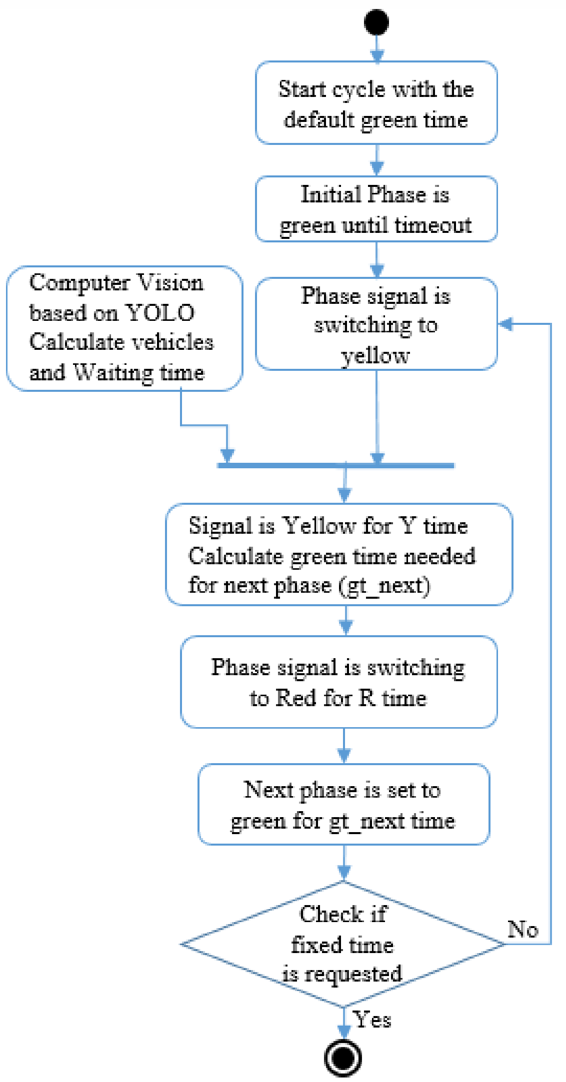

Fig. 6. Activity Diagram for the proposed traffic light Algorithm

V. SYSTEM IMPLEMENTATION

A. Transfer Learning

Transfer learning [9] is a technique allowing the reuses knowledge of the source domain to solve a new task of another domain. Because application constraints in term of data and computation, Transfer Learning becomes more applicable in Deep Learning. It uses the early and middle layers and only re-train the latter layers.

B. Pytorch

PyTorch is an open source machine-learning library for Python, based on Torch [10]. It is used for AI applications and many research fields. It was developed by Facebook and Uber. PyTorch Tensor computation and deep neural networks built on a tape-based autograd system. PyTorch's key features are dynamic computation graphs and imperative programming. Running YOLO on Pytorch confirms the good accuracy and its detection speed. (See Fig. 7)

Fig. 7. YOLO detection result running on Pytorch

C. *Results and Discussion*

YOLO gave us the possibility to replace the policeman in traffic control optimization, thanks to it is accuracy and real time efficiency. A hardware implementation shall be done to have a real evaluation of the solution.

Our System shall not be limited to the camera. More sensors shall be used to complete the weakness of the camera like poor results in bad weather. Sensor fusion technique will be used for sensors like, radar, magnetometers…

We can connect intersection to prevent lane status thanks to data from infrastructure. Our Intelligent Transport System can use also vehicle networking technology to collect data and to prevent traffic congestion [11].

VI. Conclusion and Future Work

The goal of this work is to improve intelligent transport systems by developing a Self-adaptive algorithm to control road traffic based on deep Learning. This new system facilitates the movement of cars in intersections, resulting in reducing congestion, less CO_2 emissions, etc. To do this, we began with a comparative search in the field of traffic light monitoring. Then we used YOLO, a fully convolutional network, to give real-time traffic status to the embedded controller. Finally, we have designed a new algorithm taking this real-time data from YOLO and optimizing phases in order to reduce cars waiting time.

To put in value this work, an implementation on hardware is ongoing. We have implemented YOLO on Pytorch and used the transfer learning technique to run it on limited hardware resources like embedded card. Then experiments will be done to confirm theoretical analysis and the reduction of waiting time.

As a future work, we will include pedestrians as input into the Adaptive Traffic Light Control to minimize their waiting time. Another axis is to add sensors fusion to the controller and not limit to camera, which will give more adaptability and robustness to our system face different weather state.

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