Urban Traffic Simulation Using SUMO
Open Source Tools

Muhammad Zaky, Davindra G. Airulla, Endra Joelianto, Member IEEE, and Herman Y. Sutarto

Abstract—This paper considers SUMO usage to simulate traffic within two intersections in Surabaya. It also revolves the method used to acquire arrival flow, the type of sensor being used to retrieve flow data, some justifications made to resemble the simulation with the actual condition, some parameters being used, as well as how to connect SUMO to MATLAB through TraCI. The parameters used in the simulation are critical since it becomes the threshold on whether the simulation is fairly representative with the real conditions. Several parameters used in the simulation through SUMO are vehicle speed, acceleration, deceleration, gap between vehicles, as well as the size of each type of vehicle. Simulation results confirm the capability of SUMO to simulate the behaviour of the two intersections.

Index Terms—TraCI, Induction Loop Sensor, Queue Length, Arrival Flow, SUMO

I. INTRODUCTION

Transportation systems have happened to be more complex and often congested [1]-[6]. At present, there is no exact model of traffic flow due to its high complexity, chaotic behaviours and unique characteristics to local conditions. Traffic prediction is usually carried out by using simulations. Simulation and modelling have acquired recognition as an effective approach for quantifying traffic operations and also become a standard approach to understand complex traffic network processes. There are many simulation packages exist and vary in the software architecture paradigms and the models that represent traffic processes [7].

SUMO or "Simulation of Urban MOBility" is an open source, highly portable, microscopic and continuous road traffic simulation package designed to handle large road networks [7]-[11]. SUMO allows modelling of intermodal traffic systems including road vehicles, public transport and pedestrians [13]. There are many papers that already discussed about how to simulate urban traffic using SUMO [6][12][13].

To validate whether a simulation already representative for the real condition, there bound to be parameters needed in order to figure out so. In this traffic light system control, the needed parameters are velocity of vehicles, acceleration, deceleration, arrival flow, as well as queue length. However, truth to be told, there will always be boundaries to make the simulation really representative of the real situation due to complexity of factors taken into account. In this traffic simulation, the type of vehicles acquired from the data is unavailable thus it will be difficult to incorporate it into SUMO. Some justifications, however, have been performed with as much as factual and data driven as possible.

To perform a proper simulation is difficult and also time consuming. Several ways that need to be identified in order to be successfull in simulating a traffic situation in Soetomo and Musi intersections in city of Surabaya, Indonesia as a study case are the way to acquire the traffic flow (arrival flow) data, phase signal/ cycle information and also geometry data of the network. In this Surabaya’s case (data courtesy of the PUSIATAN Bandung), the data obtained from the sensors of the SCATS (the Sydney Coordinated Adaptive Traffic System) system include measurements of the traffic flow as well as the period of each cycle of each intersection from the SCATS traffic control system and also some geometric data in that area.

In this paper, it is described how to produce the visual map into the simulator (SUMO) including every configuration justification used in the SUMO, constraints being evaluated. It is also considered the way to communicate between the simulator (SUMO) and controller (MATLAB) by using TraCI [14].

II. SUMO CONFIGURATION

Before going further about traffic simulation, we need to understand first about the schematic of the step as explained by Fig. 1.

A. Study Area Overview

In this paper, simulation on two urban traffic intersections will be discussed, which are intersection Diponegoro-Soetomo and
Diponegoro-Musi as can be seen in Fig. 2 and Fig. 3. Both intersections which are pretty packed up in Surabaya only adrift 200 meters which cause the vehicle traffic queue on both intersections becomes something crucial.

On these intersections, SCATS has got data of actual arrival flow for every 15 mins for one whole day and one whole month in October 2015. Besides that, the detail of cycle time, green light duration, and red light duration, also included in the data. Further, these both parameters will be the determinant whether the simulation already similar with the real condition.

Soetomo and Musi intersections are regarded as intersections with two phase systems, which means both have two different conditions each, which are green light phase and red light phase for every arm in every direction [15].

In Soetomo intersection, each arm has three lanes, which marked by number of 1-12 in Fig. 4. In the picture, it is also explained the direction for every lanes, in which vehicles forbid to turn right on every arm. There is also the number of vehicles which enters for each arm in every 15 minutes in one whole day, therefore it makes route input into SUMO gets easier.

To acquire arrival flow data, the sensor used is camera sensor which uses image processing technology to detect vehicles [16] shown in Fig. 5. These sensors placed at 5-9 meters high with angle of 30-90 degrees depending on the need.
Meanwhile, the traffic light system used is one with constant cycle time and green-red time period. In this system, there is no yellow light condition, therefore in one cycle there will always only two conditions, which are red or green light period. At Soetomo intersection, the total time for one whole cycle is 145 seconds and the duration of green-red light consecutively are 73 and 72 seconds for the north-south arm, as can be seen on active plan A part for the green light duration of north-south arm and B for the green light duration of east-west arm.

C. Importing Map

To do the simulation in SUMO based on geometry and street topology which resemble the real condition, the map could be acquired by importing one from openstreetmap.org. This process could be done by accessing openstreetmap site, and then look up the required location and then click export. After the file has been exported into osm file, that file then converted into network file and polygon by using python programming to be runned in SUMO [17].

After map importing was done, crosscheck between the acquired data and the real condition could be done, one of which are the direction and the number of vehicles of each lane for every arm.

D. Configuring Traffic System

After the map has been successfully imported and matched with the real condition, traffic condition adaptation needs to be done. Some of the things that needs to be adapted are traffic light conditions and the vehicle routes.

Timer for every traffic light on both intersections on every arm reconciliated with the data from PUSJATAN in the net.xml file. While for the vehicle route, after the data required disaggregated on each intersection (Musi & Soetomo), route designing in SUMO would be done. In this route designing process, several important values could be inputed, which are the type vehicle, the size, probability of every kind of vehicle occurs, acceleration, velocity, minimum gap between vehicles, lane for a certain route, the duration for a certain vehicle to pass through a certain route, position when started and ended the route, as well as the number of vehicles in a certain route.

E. Queue length estimation

To estimate the queue length in a certain arm, the formula that can be used is [1], [18].

\[
Q(K+1) = Q(K) + (N_{entry}(K) - N_{exit}(K))
\]

Notes:

- \(Q(K+1)\) = The number of vehicles queueing in one cycle of a traffic light (vehicles)
- \(Q(K)\) = Initial condition of total vehicle number (vehicles)
- \(N_{entry}(K)\) = Total number of vehicles entering a road
- \(N_{exit}(K)\) = Total number of vehicles exiting a road

Queue length calculation needs a sensor data that placed upon the end and the origin of a road arm, therefore it could count the number of vehicles passing through the sensor in a certain period. From that point forward, by using the equation (1), the queue length in a cycle could be estimated. In order to ease that, an incremental file needed to help the sensor read the number of vehicles in each cycle on both intersections [19] [20].

This queue length (cycle-by-cycle) can be obtained based on the sensor then write it down in the new .xml file. On the next step, SUMO will be connected with MATLAB to enable automatic value reading by the system and to be able to process further the traffic light control system.

F. Connecting Matlab-SUMO via TraCI

There is an API (Application Programming Interface) developed in MATLAB environment that allows the communication between MATLAB workspace and the urban traffic simulator SUMO. One of the API that can be downloaded freely is TraCI4Matlab. This TraCI4Matlab implemented the TraCI (Traffic Control Interface) application in level protocol, which is built on top of the TCP/IP stack, so the application developed in MATLAB workspace, which is
the client, can access and modify the simulation environment provided by the server (SUMO). TraCIMatlab allows controlling SUMO objects such as vehicles, traffic lights, junctions, enabling applications like traffic lights predictive control and dynamic route assignment, among others [20].

In the configuration file of SUMO, the only thing need to be added is traci server in order to detect the port and connect to MATLAB. Furthermore, additional file at MATLAB needed for controlling including to acquire induction loop sensor data and to alter the traffic light to adaptive.

III. SIMULATION

After data for one whole day inputted, SUMO has been configured and connected with MATLAB, the simulation then runned correspond with the real condition. In the result of the simulation, there are several overflow in several arms therefore the arrival flow data emitted by SUMO became less representative to the real condition. This phenomenon by several factors, firstly, the number of vehicle acquired from SCATS didn't identified previously whether it was personal car, motorcycle, bus, or truck, meanwhile inside the SUMO the type of vehicle generated configurated as default, which was in the size of average personal car. This thing regarded as pretty critical since the size of each types differ and will affect the area or capacity of road used in total. Besides that, parameters such as acceleration, velocity, deceleration, and gap between vehicles is less than representative of the real situation.

To solve these problems, the type of vehicle passing divided into two general category, which are personal vehicle (van size) and motorcycle. According to Kantor Kepolisian Republik Indonesia data, back in 2013 the comparison between personal vehicle and motorcycle number were 1:8.5 with motorcycle growth number is the largest every year. Due to that, an adjustment made to distribute the type of vehicle into 1:9 between personal car (van size) and motorcycle. In addition, the size and gap between vehicle also customized with the plentiest kind of four tires vehicle and two tires vehicle in Indonesia (Avanza and Supra according to detik.com) with 4.2 meters length for the four tires vehicle and 2 meters length for the two tires vehicle, meanwhile for the gap are 1 and 0.3 meter consecutively for four and two tires kind of vehicle. In terms of parameter such as velocity, acceleration, and deceleration by referring to the data from MKJI (Manual Kapasitas Jalan Indonesia) [21], the velocity should be between (20-60)km/hour for a certain arteri road, while acceleration and deceleration is not more than 1.5 m/s².

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Velocity</td>
<td>60 km/hour</td>
</tr>
<tr>
<td>Maximum Acceleration</td>
<td>1.5 m/s²</td>
</tr>
<tr>
<td>Maximum Deceleration</td>
<td>1.5 m/s²</td>
</tr>
<tr>
<td>Length for two tires vehicle</td>
<td>2 m</td>
</tr>
<tr>
<td>Length for four tires vehicle</td>
<td>4.2 m</td>
</tr>
<tr>
<td>Comparison of two tires and four tires vehicle</td>
<td>1:9</td>
</tr>
<tr>
<td>Gap for two tires vehicle</td>
<td>0.3 m</td>
</tr>
<tr>
<td>Gap for four tires vehicle</td>
<td>1 m</td>
</tr>
</tbody>
</table>

After some adjustment was done, the acquired result of flow match with the data from SCATS, means that SUMO is already representative with the real condition. Fig 9, Fig 10, and Table 2 below are the graph plot of arrival flow and relative error from the simulation result after identification on both intersections was done.
Fig. 10. Arrival flow in Musi Intersection

After justification made, relative error for every 15 mins for one whole day is shown in Table 2.

<table>
<thead>
<tr>
<th>Intersection</th>
<th>South</th>
<th>East</th>
<th>North</th>
<th>West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soetomo</td>
<td>3.08</td>
<td>2.89</td>
<td>5.84</td>
<td>5.29</td>
</tr>
<tr>
<td>Musi</td>
<td>1.65</td>
<td>2.05</td>
<td>3.73</td>
<td>4.13</td>
</tr>
</tbody>
</table>

### IV. CONCLUSION

Traffic Simulation was simulated accurately on SUMO. There were some parameters that have to be considered in order to synchronize with actual condition such as Vehicle velocity, acceleration, de-acceleration, length of vehicle, vehicle type probability and vehicle gap.

To control the traffic light, it was added induction loop sensors in SUMO and connecting SUMO to MATLAB is required. After SUMO was connected with MATLAB, a traffic control system is possible to be implemented in the simulation environment.

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### REFERENCES


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