A SUMO Based Simulation Framework for Intelligent Traffic Management System

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***Abstract*—Continuous increments in world population demands transportation with essential vehicle facilities and directly effect on road traffic volume or congestion, mostly in metropolitan cities, and thus it needs significant investigation, analysis, and maintenance. In these regards, an Intelligent Traffic Management System (ITMS) with a Deep-Neuro-Fuzzy model was proposed and implemented. Dijkstra algorithm is used to select optimum path from source to destination on the basis of calculated road segment weights from Deep-Neuro-Fuzzy framework. However, Deep-Neuro-Fuzzy framework needs some comprehensive analysis, other means some simulation or emulation, and etc, to proof the efficiency and workability of the model. In this paper, we are going to explore the Deep-Neuro-Fuzzy model in pragmatic style with an open-source traffic simulation model (SUMO) and helps to explore traffic-related issues including route choice, simulate traffic light or vehicular communication, etc in our ITMS. In addition, a new GUI is developed to control the simulation input attributes and presents the feedbacks into the traffic flow in SUMO environment. Results highlight that the proposed SUMO model can realistically simulate ITMS based on the road segment weights from Deep-Neuro-Fuzzy model. Different built-in routing algorithms are also used to proof the workability of this model.**

***Index Terms*—ITMS, SUMO, traffic simulation, dijkstra, deep-neuro-fuzzy model, road segment weight**

I. Background Analysis

Vehicles are one of the major needs for transportation in day to day life. Due to the increment of vehicle numbers, the situation turns out to be a challenging issue to route from a source to a destination in time. The subject becomes more concerning due to the bad road circumstances including road construction, road accident and other environmental causes like rainfall, temperature, wind, etc. Integrating IoT based intelligent traffic management system can help to supply information related to vehicles, traffics, road statuses, and environmental situations, and make constructive decisions for optimum, timely, and safely routings. Thus, a new software-based real-time bi-directional Traffic Management System (TMS) with Artificial Neural Network (ANN) was proposed and implemented in [1]-[4]. However, decision classes were made by instinct method and thus the ITMS suffers for optimal data clustering strategies. Nawrin *et al*. [5] applied hierarchical and partition k-means clustering algorithms on the ITMS data sets. However, calculating road weight from each cluster was a chaos overlapping scenario. Therefore, building the interoperability between classifications and clustering algorithms was necessary and inspired us to rethink the solution for traffic management problem based on hybridization of clustering and classification approaches. Thus, we implemented a novel Deep-Neuro-Fuzzy classification [6] to solve the weight overlapping burdens, to remove the data outliers, and to avoid the overfitting problems. Input data were collected by IoT based sensors [7].

At present, the ITMS solves the decision problem, calculates dynamic road weights from continuous environmental, road and vehicle-related decision attributes in different time domains- for every hour in everyday in a year, and takes analytical decision on optimal route planning. Deep-Neuro-Fuzzy [6] model is responsible for generating road weights with 98.63% accuracy. However, the complete ITMS is not yet been implemented in a real testbed with real traffic scenarios. Simulation or emulation-based implementation can explore an opportunity to expose the model and proof the hypothesis. On these regards, Sumo Urban Mobility Simulation (SUMO) open-source tool is used to simulate the ITMS.SUMO [8]-[10] is a simulation framework that is used for microscopic and continuous road traffic simulation package designed to handle large road networks. It uses to develop different applications including online traffic monitoring system [11], traffic light games [12], etc.

A Graphical User Interface (GUI) is developed to control the simulation. This GUI accesses the value of the attribute and takes input from the user. User can set random values to the decision attributes or our IoT tool collects attributes values directly from the environment and vehicles. Deep-Neuro-Fuzzy framework [6] is used to classify those values and to formulate a weight for a mapped road segment. Thereafter, three (3) different algorithms including CHWrapper, A*, and Dijkstra are used to trace the optimum route. The result section

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highlights the simulated time for all the algorithms and concludes their performances.

II. Proposed Simulation Model

Realization of the traffic density at a particular intersection for a given time can also help in reducing traffic congestion at that point. This data can be analyzed to determine several factors like green light length, traffic at the particular time. Our ITMS model has the capability to crawl data intelligently from online web domains, to collect locations/area/road segments base high-resolution information from IoT sensors for real time TMS decision, and to circulate them to the running vehicles. However, the full model workability is not tested in real/ simulation platform. Sumo Urban Mobility Simulator is used for road vehicles and traffic light simulation. It uses the concept of adaptive traffic light control algorithm and manipulates both the sequence and length of traffic lights in accordance with the detected traffic [13]. The algorithm uses real-time data like the waiting time of vehicles, volume of traffic in each lane, and etc. Finding the best and the shortest path to destination can be used as a tool to minimize the traffic along a path. The traffic along the road can be sent to the incoming vehicle proving them the idea about the road traffic network and thus they can take an alternative path to the destination [13].

Sumo Urban Mobility Simulator is used for road vehicles simulation. SUMO uses three (3) built-in algorithms including Dijkstra, A*, and CHWrapper to find out the best routing (shortest path) in the simulation environment. We apply all of them in our road map and compare their performances. C-means clustering and Deep-Neuro-fuzzy classification [6] tool is used to generate road weights of a particular location. Python code is used to generate a weight file and connect with GUI developed by C#. Two (2) different potential state changes are considered in our implementation-natural occurrences (humidity, rainfall, peak hour, temperature, and wind) and artificial occurrences (road accident, road construction, and road status). Both types of attributes are accessible simultaneously to generate a significant road weight. The speed value is calculated from the weight value (proportional to weight value)

A. Setup Sumo Simulation

A certain part of Dhaka city map is downloaded from the internet (openstreetmap.org) as .osm format. At first, ITMS simulation is implemented in a prototype map (“Fig. 1”) selected from the real map (“Fig. 2”). Thereafter, the whole simulation is implemented on the real map of Dhaka city. SUMO needs to convert the map files to XML format for generating optimum route and traffic system. DOS command script “start-command-line.bat” and “netconvert” command are used to convert the map.osm files to map.net.xml files. Additional necessary elements including road name, traffic light timing, etc. are added using SUMO Neteditor. The route for vehicles is written in map.rou.xml file. “Fig. 3” shows the flowchart of the full simulation. For vehicle simulation, the simulator needs to configure the configuration file on “map.sumocfg” [14]. The configuration follows the following format:

```
<configuration>
<input>
<net-filevalue="map.net.xml"/>
<route-filesvalue="map.rou.xml"/>
<gui-settings-filevalue="gui-
                    settings.cfg"/>
</input>
</configuration>
```

The environmental interface of SUMO can be changed in “gui-setting.cfg” file and it looks like the following:

```
<viewsettings>
<delayvalue="300"/>
<schemename="real world"/>
</viewsettings>
```

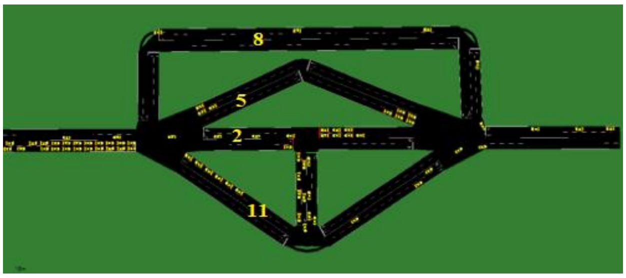

Figure 1. Prototype Map (Sample Map).

Figure 2. Map of Gulshan, Dhaka (Real Map).

TABLE I. Range of Attributes

Attributes	Range	Value Named As
Humidity	32-95	
Peak Hour	8-129	
Rainfall	0-30	
Temperature	13-34	
Wind	0-15	
Road Status	0,1	normal
Road Construction	0,1,2	low, medium, high
Road Accident	0,1	no, yes

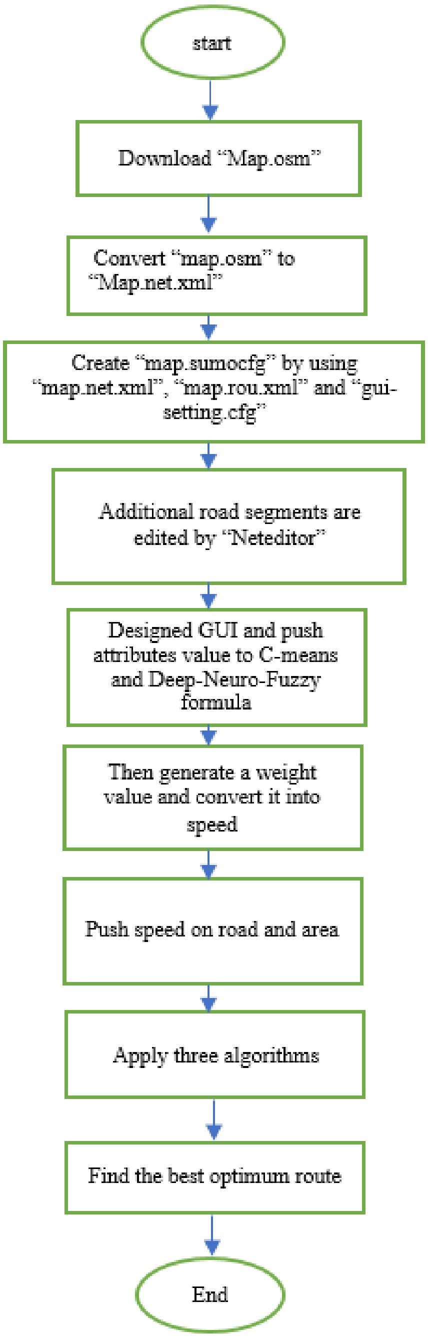

Figure 3. Flow chart of full simulation process.

B. Formulation of Road Weights

Deep-Neuro-Fuzzy is a hybridization model of fuzzy C-mean clustering, fuzzification system and deep neural networks. The compact module solves the road weight measurements problems in ITMS [1]-[3]. C-mean was used to provide two outputs including optimum clusters in each weather features data set and optimum clusters in the combined data set using DI [15] and SC [16] validation technique. The number of clusters in combined data sets reflects to the optimum number of road weight classes. Thereafter, applying the triangular membership function and specific fuzzy inference rules on the cluster numbers those are generated by C-mean clustering algorithms on each ITMS feathers. Implications of the fuzzy rules are aggregated to generate fuzzy output set (which is the specific road weight of number from optimum clusters in the combined data set). A supervised Deep Neural Network is trained to formulate the road weight (road weight cluster number) using the implications from the fuzzy rules. The Deep-Neuro-Fuzzy provides a complete package for generating dynamic road weight from given input data sets. However, this model is sufferings for lack of proof of its work ability and proper user interface (UI) to collect or show I/O data. We develop our own GUI in C# to make the simulation process interactive and user-friendly. This GUI helps to enhance the testing process by changing different weights to the system. Weight calculation depends on eight (8) different attributes including humidity, peak hour, rainfall, temperature, wind, road status, road construction, and road accident. All of these attributes are combined with different ranges as presented in Table I. The selected attributes from GUI are placed to generate the weight value by using C-means clustering and Deep-Neuro-Fuzzy software [6]. The weight output range is 0-10. "0" is the lowest weight value that means the natural and road condition are in the best situation, for that reason the roads get the maximum speed to ensuring faster vehicle passing. "10" is highest weight value, which means the natural or road or both are in an odd situation, for that reasons the roads (or lanes on-road) get the lowest speed value and vehicle passing would be stopped or reduced their speed.

III. Result Analysis

A. Testing GUI and Traffic Flow

We investigate the following two (2) case studies to make changes in GUI input attributes:

CASE (1): Due to the natural phenomenon occurrences, vehicle passing can be stopped or vehicle speed will be decreased in the road segment(s). "Fig. 4" and "Fig. 5" present the situation. Where changing the input attributes in GUI, generates a new weight, calculates a new corresponding speed, and sets automatically to that specific road segment(s) (edge 2 and 11). Output presents in "Fig. 5". Although the vehicles get the green signal and clear route, however, vehicles are not passing through those road segments due to the high weight occurred by heavy raining and huge wind (makes higher weights). CASE (2): Similarly, any construction or accident occurs in the road segment (edge 5) makes itself busy. Thus, vehicle flow in this segment decreased or stopped. We apply a road construction for a road segment as a medium level in the road weight attributes in "Fig. 6". This change directly reflects the simulation results presented in "Fig. 7". Here vehicles are avoiding that road segment and find out other available free routes to travel to destination. Table II present few input samples sets and their corresponding weight and speed values.

B. Analysis of Different Route-Finding Algorithms

SUMO applies Dijkstra algorithm for generating optimum routes from source to destination. Three (3) more additional algorithms are interacted with ITMS and try to find out the best optimal performer in the input maps. We experiment on 1,430 vehicles on SUMO simulation and apply the above algorithms. Their results are presented in Table III. According to Table III, the best result comes from CHWrapper algorithm as it takes the shortest path for 1,430 vehicles in optimal time-consuming. Second is considered a time unit for all algorithms. However, it is changeable according to the CPU performance and simulation configuration.

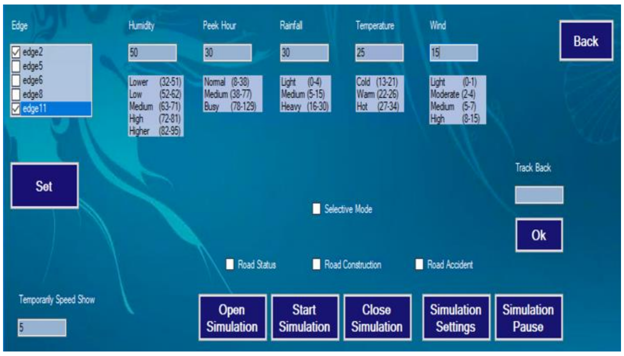

Figure 4. Sample input for natural occurrences.

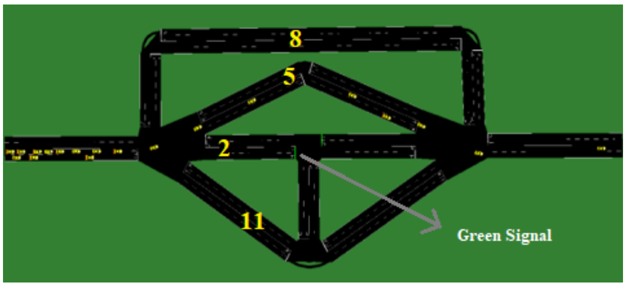

Figure 5. Road state changes due to weather change

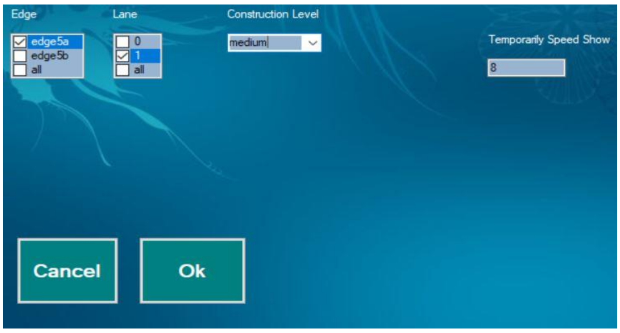

Figure 6. Specially changes due road construction

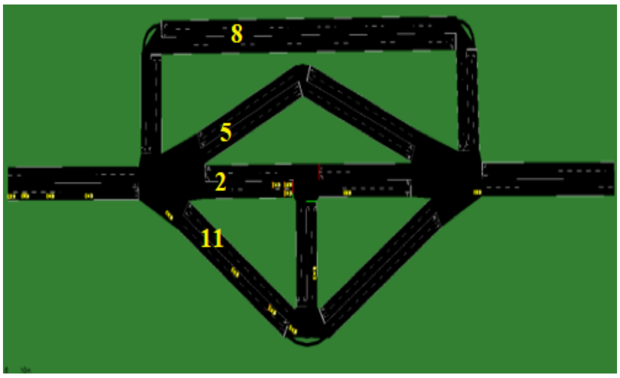

Figure 7. Vehicle flow stopped due to construction

TABLE II. WEIGHT AND SPEED VALUES FOR SOME SAMPLES.

Attributes								Calculated Weight	Speed Across Weight
Humidity	Peekhour	Rainfall	Temperature	Wind	Road Status	Road Construction	Road Accident		
80	15	4	21	5	0	0	0	3	30
70	40	0	28	2	0	0	0	7	15
60	78	0	24	1	0	1	0	9	8
65	10	0	20	4	0	0	1	10	5

TABLE III. ANALYSIS OF SIMULATION ALGORITHMS (TIME CONSUMING)

Algorithm	Time (seconds)
Dijkstra	3060
A*	3506
CHWrapper	2689

IV. DISCUSSION

In this article we successfully implemented our ITMS model in SUMO simulation environment and test the model work abilities. Deep-Neuro-Fuzzy model is working well and maintains adequate accuracy. However, the model is not yet been implemented in real time road networks. Real time implementation requires personalized infrastructure for mobile devices and such implementation is costly and time consuming. In our simulation we consider changing only on road weights parameters; however, other hidden parameters of the existing SUMO algorithms are remaining same. Thus, we need to explore the SUMO model without build-in algorithm so that we tune an experimental setup by changing the algorithms parameters. The new algorithm design in SUMO environment is a challenging task due to its complex architecture. In addition, few scripts are needed to (run explicitly) provide to input to SUMO environment. Our simulation results of three (3) algorithms highlight similar performance according to their theoretical basements, CHWrapper performs better than A* and Dijkstra performs slower.

In near future more robust dynamic and optimum route-finding model including ant colony or reinforcement-based route findings algorithms will be integrated in SUMO. IoT sensors are not yet directly integrated with simulation ITMS model. In near future, a personalized mobile network infrastructure with V2Vcommunication, edge-fog computing support, and cloud-based data storage will be implemented.

V. CONCLUSION

We successfully implemented the ITMS with open-source traffic simulation model (SUMO) and did a comprehensive analysis to explore traffic-related issues including route choice, simulate traffic light or vehicular communication, and etc. ITMS simulation model highlights that the Deep-Neuro-Fuzzy tool is capable to change the weight output according to the changes in the attributes and proportionally helps to improve the route situation. It also presents that the road weight is highly proportional to the speed. In near future, we will investigate real-time road attributes and create automatic maps to show dynamic road condition to ITMS's users.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

This work is supported by Ministry of ICT division Bangladesh. 1st author is the principle researcher of this funding project and all co-authors are the research assistants working under his guidance. The 1st author also is the corresponding author of this article. This is a group research work and co-authors have responsibility to develop different parts of the whole project. Mr. Md. Nurul Ahsan and Mr. Shah Jafor Sadeek Quaderi are responsible to develop the SUMO testbed whereas rest of the authors are involved in the development of Deep-Neuro-Fuzzy tool.

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