

# Traffic Light Signal Parameters Optimization Using Modification of Multielement Genetic Algorithm

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## ABSTRACT

A strategy to optimize traffic light signal parameters is presented for solving traffic congestion problem using modification of the Multielement Genetic Algorithm (MEGA). The aim of this method is to improve the lack of vehicle throughput ( $F_F$ ) of the works called as traffic light signal parameters optimization using the MEGA and Particle Swarm Optimization (PSO). In this case, the modification of MEGA is done by adding Hash-Table for saving some best populations for accelerating the recombination process of MEGA which is shortly called as H-MEGA. The experimental results show that the H-MEGA based optimization provides better performance than MEGA and PSO based methods (improving the  $F_F$  of both MEGA and PSO based optimization methods by about 10.01% (from 82.63% to 92.64%) and 6.88% (from 85.76% to 92.64%), respectively). In addition, the H-MEGA improve significantly the real  $F_F$  of Ooe Toroku road network of Kumamoto City, Japan about 21.62%.

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## 1. INTRODUCTION

The traffic congestion is big problems which causes many negative effects not only to road users physiological but also to economic and environmental [1]. Physiologically, the traffic congestion makes the pedestrians and drivers have to pay a lot of attentions during on the roads. Economically, the traffic jam increases the fuel consumption, which implies to transportation cost. Environmentally, the traffic jam increases the pollution of vehicle disposal gas such as  $CO_2$  raising the greenhouse effect on the environment.

There are three categories of strategy to optimize traffic signals which are worked based on the level of vehicle involvement [2]. The first category utilizes legacy devices with no vehicular involvement, which can be to redefine the signal timing of the junction using certain technique. The second category utilizes vehicles on the road to wirelessly transmit data about themselves (e.g. location, velocity). It means the signal timing is optimized by considering the reports of vehicles on the roads. The last category seems costly because it requires sophisticated devices and software to performing automatically the optimization on-board.

In this research, the first category of traffic light signal parameters optimization is proposed by modifying the Multielement Genetic Algorithm using Hash-Table which is shortly called as H-MEGA. The H-MEGA is an improvement of previous works called as traffic light signal parameters optimization using the Multielement Genetic Algorithm (MEGA) and Particle Swarm Optimization (PSO) [1, 3].

## 2. RELATED WORKS

Some works for traffic light signal parameters optimizations have been proposed which can be classified to three approaches: firstly, using artificial intelligence (GA, Fuzzy, Neural Networks) and their variations; secondly, using statistical such as stochastic[4]; and finally using vehicle involvement [2]. Among them, the approaches using

artificial intelligence play important roles for traffic light signal parameters optimizations such as approaches based on PSO [1], GA [5, 6, 7, 8, 9], fuzzy logic which determine the best signal parameters using fuzzy rule [10, 11]. However, some of them were not implemented on real road network and had lack of performances.

Traffic light optimization also can be performed by considering vehicular involvement via communication devices. The Ref. [12] also developed a signal control algorithm that allows for vehicle paths and signal control to be jointly optimized based on advanced communication technology between approaching vehicles and signal controller. However, the algorithm assumed that vehicle trajectories could be fully optimized and it was developed assuming a simple intersection with two single-lane. The Ref. [13] proposed signal setting optimization on urban road transport networks which worked based on travel demand to congested road transport network. In this case, two interacting procedures are developed to solve the system of models: (i) an optimization procedure to obtain an optimal configuration of signal setting parameters and (ii) an assignment procedure, incorporating a path choice model with explicit path enumeration and a flow propagation model, to capture the effects of signal setting configuration on user path choice behavior. The Ref. [14] presented traffic bottleneck identification and optimization. Two main factor traffic bottlenecks are signal timing at intersections together with static properties of left-turn and straight-through lanes of roads[14]. The ant colony algorithm was proposed to find out optimal coordinated signal timing for a regional network. The Ref. [15] had proposed an optimization of pedestrian phase patterns and signal timings for isolated intersection which establishes quantitative criteria for selecting pedestrian phase patterns between the exclusive pedestrian phase (EPP) and the normal two-way crossing (TWC) with both safety and efficiency factors traded-off in an economic evaluation framework. The proposed method is able to assist transportation professionals in properly selecting pedestrian phase patterns at signalized intersections. The Ref. [9] also proposed intersection signal control multi-objective optimization using GA, which works to obtain a signal control multi-object optimization method to reduce vehicle emissions, fuel consumption and vehicle delay simultaneously at an intersection. Moreover, the vehicle anti-collision alert system in FPGA has been developed to decrease the number of road accidents[16] which not only cause injuries, deaths but also traffic jam. It means the alert system is an device that can be used to drop-off traffic congestion.

In addition, a variation of GA such as optimization using MEGA has been proposed for finding traffic light signal parameters[3, 7, 17]. That method has been proved to solve traffic congestion in real Ooe Toroku road network, Kumamoto Shi, Japan. However, it is lack of network throughput (percentage of vehicle flow) and time consuming on obtaining the optimal traffic light signal parameters on the Aimsun 6.1 for simple road network (see Fig. 3(a)). To improve MEGA's performance, particle swarm optimization (PSO) was employed instead of MEGA[1]. However, it just improved 3.13% of MEGA's achievement. In addition, it also needed almost the same computational time.

### 3. THE OPTIMIZATION ALGORITHM

The optimization algorithm is based on H-MEGA that is employed to search the optimum offset, cycles, splits time of four nodes/junctions of Ooe Toroku road network. The Ooe Toroku road network (Fig. 3(b)) is located in Kumamoto City Japan, at latitude and longitude point 32.81 and 130.72 or in url: <https://www.google.com/maps/@32.8054628,130.7218806,17z>. It is one of road network having most traffic congestion in Kumamoto city. The properties of Ooe Toroku road network including the node/junction, signal model, and signal timing has been clearly presented by Ref. [1].

#### 3.1. Traffic Light Signal Parameters

Each node/junction has traffic light equipped with signal parameters: offset, cycle, Yellow, all Red, and split [3, 7]. The offset parameter is the time coordination between traffic light (node) representing the starting of green signal timing. For instance, the Node 1 and 2 having 0 and 3 seconds offset parameters means that the Node 2 starts the cycle signal timing at 3 seconds after started the cycle of Node 1. The cycle parameter represents the total time of traffic light starting from Green and returning to Green. The Yellow and all Red are usually defined constantly representing the duration of yellow and all red signal of the traffic light. The split that consists of main and sub split means the Green time percentage of main road and sub road, respectively. In this paper, the optimization algorithm searches the optimum offset, cycles, and split to get maximum vehicle gone out, minimum vehicle in and wait out, less vehicle stop, and short delay time of considered real road network.

#### 3.2. Modification of MEGA

There are some variations of genetic algorithm (GA) which were developed to solve specific problems[3, 18, 19]. For instance, the multielement GA (MEGA[3]) was developed to optimize traffic light signal parameters, the parallel GA[18] was developed for solving the university scheduling problem, and the augmented GA[19] was formed to utilize feature reduction on data mining. The algorithm of MEGA for finding the best traffic light signal parameters

is given in Fig. 1(a). In MEGA, the populations consist of many chromosomes extracted from the road network traffic lights. The MEGA, which is also included by elitism, has been proved that it could be used to find good traffic light signal parameters as presented in Refs. [7, 8, 17].

In this paper, the MEGA and PSO based optimization are improved by modifying the MEGA using Hash-Table (H-MEGA). This idea comes from the PSO algorithm which was inspired by social behavior of bird flocking or fish schooling[20]. It means the solution is searched in around current optimum solution. Therefore, a Hash-Table having key for indexing the  $n$ -best populations is added to MEGA. Like PSO, the best solution of MEGA is just searched in around the Hash-Table by performing the recombination such as selection, crossover and mutation. The different between MEGA and H-MEGA is presented in Fig. 1. There are some addition processes to improve the MEGA (Fig. 1(a)) which are shown by light green block (see Fig. 1(b)) as follows:

1. H-MEGA initialization which gives initial value Hash-Table size, number of populations and chromosomes.
2. Putting first  $n$ -best fitness to Hash-Table means first  $n$ -best populations corresponding to first  $n$  best fitness are appended to Hash-Table for next recombination process. The recombination process involving selection, crossover, and mutation are performed based on the populations existed in Hash-Table.
3. Deleting the same populations: populations result of recombination that are same as existed populations in Hash-Table are deleted for decreasing the computation time because they previously have been evaluated.

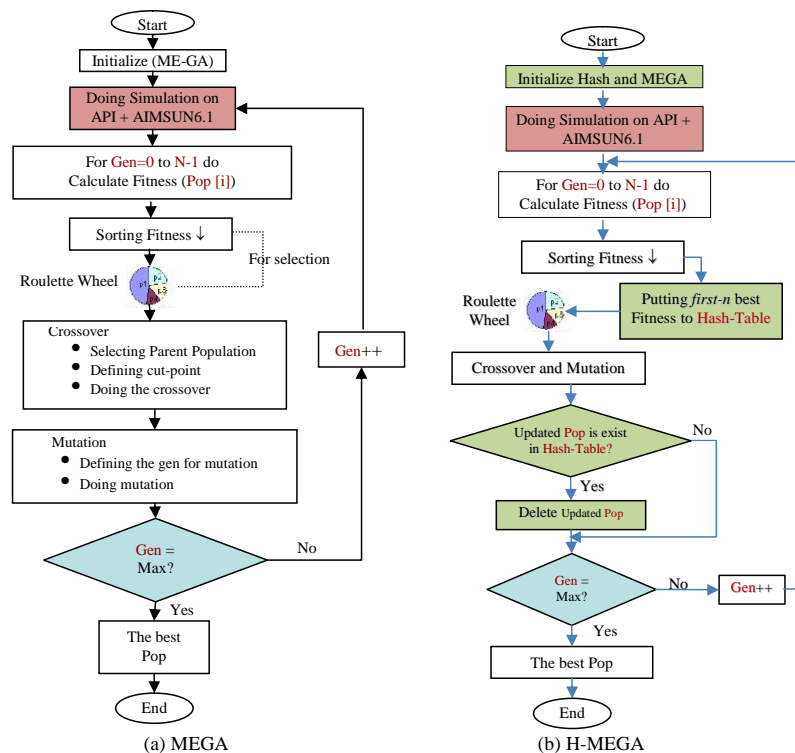


Figure 1. Flow Chart of MEGA[3] and H-MEGA.

In this case, the fitness formula for performing populations evaluation is given by  $F_p = \exp\left(\frac{V_{wo}}{C_{wo}}\right) + \exp\left(\frac{V_{in}}{C_{in}}\right) + \exp\left(\frac{t'_D}{C_{tD}}\right)$ . Where the  $t'_D$  is defined as  $t'_D = \frac{t_D}{tot_{Tr}^D}$ . The constant values ( $C_{wo}$ ,  $C_{in}$ , and  $C_{tD}$ ) are given as follows:  $C_{wo} = 100$ ,  $C_{in} = 500$ , and  $C_{tD} = 500$ . These constant values were chosen to minimize the effect of each variables to the fitness value. These values have been utilized to evaluate the PSO[1] and MEGA[8], and they could obtain good solution.

The parameters (vehicle wait out ( $V_{wo}$ ), vehicle in ( $V_{in}$ ), travel distance ( $tot_{Tr}^D$ ), and time delay ( $t_D$ )) are taken from simulation outputs. The  $V_{wo}$  means the total vehicles which are waiting to enter into the road network,  $V_{in}$  means the total vehicles that still exist in the road network, the  $tot_{Tr}^D$  is total travel distance of the vehicles in simulation, and the  $t_D$  is defined as the delay time of vehicles in simulation.

### 3.3. Optimization Process

Optimization process involves Aimsun 6.1 simulator, application interface (API) which is a DLL modul that is provided by Aimsun 6.1 written in C++, and H-MEGA modules. Aimsun 6.1 simulator is transport modeling soft-

ware which is used to perform the traffic simulation of Ooe Toroku road network. Aimsun 6.1 simulator is developed and marketed by TSS-Transport Simulation Systems and is widely used by universities, consultants, and government agencies worldwide for transportation planning, traffic simulation, and emergency evacuation studies[1]. It is employed to improve road infrastructure, reduce emissions, cut congestion and design urban environments for vehicles and pedestrians.

The coordination and communication of three modules of optimization process works based on Diagram block are given in the Fig. 2. The optimization process can be described as follows:

1. The Aimsun 6.1 gives the API initial data for  $n$  populations,  $m$ -generations, yellow time, all red time, and the range value of offset, cycles, and split,
2. The API passes the initial data to H-MEGA and orders the H-MEGA performing initialization  $n$ -populations of traffic light signal parameters.
3. Through the API, the  $n$ -populations of traffic light signal parameters are saved as output by H-MEGA .
4. The API orders the Aimsun 6.1 performing traffic simulation on road network for all  $n$ -populations of traffic light signal parameters and save the simulation results on the database.
5. After finishing traffic simulation, the API passes results to H-MEGA for performing evaluation and recombination of all traffic light signal parameters, and finally saving the results as new traffic light signal parameters.
6. Repeat the point 3 to 5 until reaching  $m$ -generations.

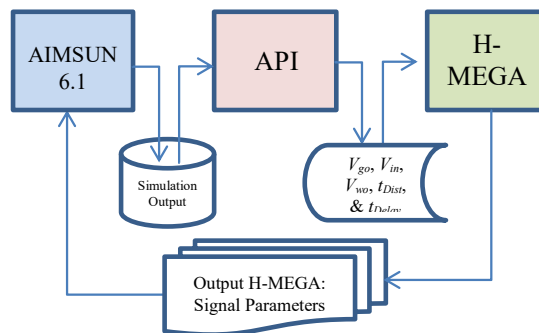


Figure 2. Diagram block of coordination and communication among Aimsun 6.1, API, and H-MEGA[1].

#### 4. EVALUATION AND DISCUSSION

In order to know the performance of H-MEGA for obtaining the optimum traffic light signal parameters, some experiments were carried out using two road networks: simple road network (Fig. 3(a)) and real road network (Fig. 3(b)). The experiments in the simple road network was to find out whether the H-MEGA can deliver optimum traffic light signal parameters. While the experiments in the real road network was to confirm that the H-MEGA could be used to find out the best traffic light signal parameters. All experiments used 5 minutes warming up and signal parameters constraints as follows: firstly,  $0 \leq Offset \leq 120$  and  $\delta Offset = 1$ ; secondly,  $60 \leq Cycle \leq 180$  and  $\delta Cycle = 5$ ; and thirdly,  $10 \leq Split \leq 90$  and  $\delta Split = 5$ .

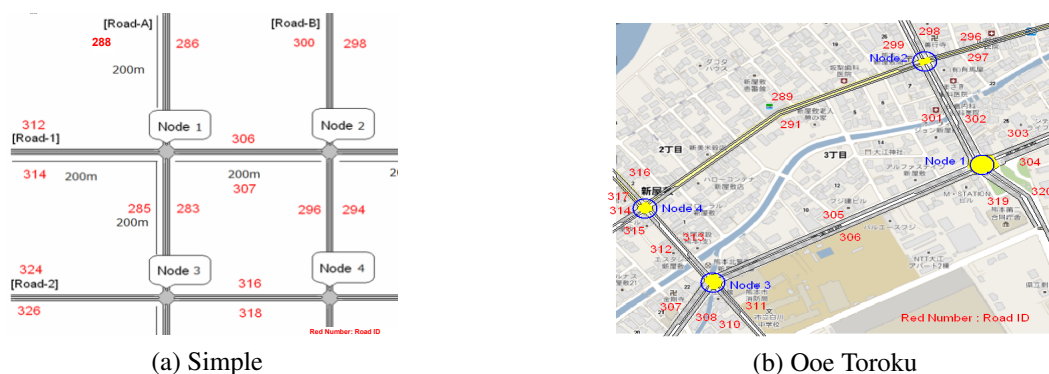


Figure 3. Two road networks for experiments[3, 7, 8, 17]

### 4.1. Experiment on Simple Road Network

Experiments on simple road network were carried out using two network states having vehicle flow (VF) 4800 per hour which its distribution is shown in Table 1. The first network state had straightway and turn left, while the second network state had straightway and turn right signals[3]. The vehicle turning percentage of each junction for simple network is 50%. The first experimental results show that the proposed method can find the best traffic

Table 1. Vehicle flow distribution in simple road network model[3, 8].

Road ID*	286	292	298	302	310	312	320	324	Total
VF	800	400	400	800	800	400	400	800	4800

\*: Road ID of Fig. 3(a)

Table 2. Throughput of simple road network model.

No	Pattern	VF	Method	$V_{go}$	$V_{in}$	$V_{wo}$	$\Delta=VF-V_{wo}$	Delay Time	$F_F(\%)$
1	The First Network State	4800	MEGA	4431	231	299	369	183.80	89.32
			PSO	4308	242	427	492	199.15	86.56
			<b>H-MEGA</b>	<b>4449</b>	<b>266</b>	<b>256</b>	<b>351</b>	<b>199.94</b>	<b>89.50</b>
2	The Second Network State	4800	MEGA	3269	347	1422	1531	470.90	64.89
			PSO	3408	421	1183	1392	460.97	68.00
			<b>H-MEGA</b>	<b>3509</b>	<b>368</b>	<b>1139</b>	<b>1291</b>	<b>474.45</b>	<b>69.96</b>

Table 3. The effect of nElites to H-MEGA on the second network states of simple road network.

Pattern	Method	nElites	$V_{go}$	$V_{in}$	$V_{wo}$	D	Delay Time	$F_F(\%)$
The First Network State	H-MEGA	2	4449	266	256	351	199.94	89.50
		4	4447	256	258	353	193.53	89.64
		<b>6</b>	<b>4467</b>	<b>251</b>	<b>238</b>	<b>333</b>	<b>194.04</b>	<b>90.13</b>
		8	4437	254	272	363	200.71	89.40
		10	4411	290	258	389	197.07	88.95

light signal parameters for both tested networks state. In addition, the proposed method provided almost similar performance as two most related methods (MEGA[3, 7, 8] and PSO[1], which is shown by almost similar throughput ( $F_F$ ) about 89.50% for the first network state and 69.96% for the second network state (See Table 2). It means that H-MEGA method is proved that it can be employed to search the best traffic light signal parameters for solving the traffic congestion on the simple road network

The second simulation was carried out to know the effect of number of best populations on finding the best traffic light signal parameters on simple road network. In this simulation, the number of best populations (nElites) saving in Hash-Table was varied from 2 ~ 10. The simulation results show that the best nElites for H-MEGA to search the best traffic light signal parameters is six (6) which can provide the highest  $F_F$  among the others, as shown in Table 3. In addition, this simulation result also shows that H-MEGA provides higher  $F_F$  compared to that of MEGA and PSO of previous experiments (see Table 2). It confirms that the H-MEGA can be employed to obtain the best traffic light signal parameters of simple road network.

Regarding to computational time, the H-MEGA needs much shorter computational time (41.73 minutes) than that of MEGA and PSO (62.54 and 50.85 minutes, respectively). The computational time is defined as a total time that is required by Aimsun 6.1, API, and H-MEGA to accomplish the simulation with 40 populations and 50 generations. Mostly computational time in the simulation is influenced by Aimsun 6.1 which takes the almost 0.671 seconds to simulate replication of road network for 1 hour vehicles movement in the road network. It means that the H-MEGA not only improve the traffic light signal parameters but also the computational time of the existing methods. It can be achieved because the H-MEGA searches optimum traffic light signal parameters in the entire some best populations saved in Hash-Table and the H-MEGA also does not performance the evaluation on populations which are the same as those of in the Hash-Table.

### 4.2. Experiment on Real Ooe Toroku Road Network

Further evaluation of H-MEGA was carried out in real Ooe Toroku road network (see Fig 3(b)). The Ooe Toroku road network had 5510 vehicles flow (VF) per hour, which were distributed as presented in Table 4. It also had 3708 pedestrian flow per hour that were distributed into four junctions/nodes: 636, 1386, 415, and 860 people for node 1, 2, 3 and 4, respectively. The turning percentage of VF per hour of each road in Ooe Toroku road network was set by real data that were obtained from the Ooe Toroku site which were manually counted at peaks sessions (8:00 AM to 9:00 AM)[1, 8].

In this simulation, the H-MEGA was compared to the related works: MEGA (base-line)[8] and PSO[1]. The fitness of population evaluation during the simulation show that all methods tend to find best traffic light signal parameters of real road network, as presented in the Fig. 4. The H-MEGA tends to give better performance in terms  $F_F$  than MEGA and PSO, because the fitness of H-MEGA is smaller than that of the others. Factually, by using the best traffic light signal parameters for Ooe Toroku network obtained by H-MEGA (presented Table 5), the  $F_F$  of H-MEGA (92.64%) is much higher than that of MEGA (82.63%) and PSO (85.76%) while the real  $F_F$  is about 71.02% (see Table 6). From Table 6, the proposed method can improve significantly the traffic congestion of real Ooe Toroku road network by about 21.61% of the real  $F_F$ . While the MEGA and PSO can improve by about 11.60% and 14.74% of

the real  $F_F$ . This simulation results are inline to simple road network achievement. It reconfirms that the H-MEGA not only can obtain the best traffic light signal parameters for solving the traffic congestion but also can improve the performances of MEGA and PSO for real Ooe Toroku Road Network.

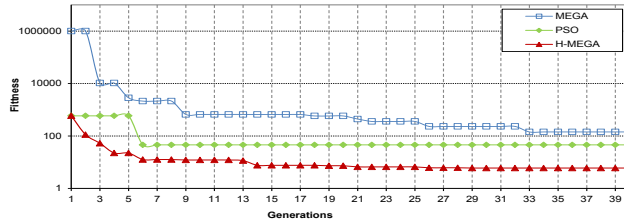


Figure 4. Fitness of H-MEGA compared to existing methods.

Table 4. The vehicles flow of Ooe Toroku road network[1, 7, 17]. obtained by H-MEGA.

Vehicles	Flow/hour of Road ID*								Total
	297	298	304	307	310	314	316	319	
Car	486	586	1594	1122	318	164	432	456	5158
Bus	8	18	24	30	0	0	2	12	94
Truck	24	28	64	64	12	6	30	30	258

\*: Road ID of Fig. 3(b)

Table 5. The best traffic light signal parameters of Ooe Toroku

Junctions	Offset (s)	Cycle (s)	Main Split (%)	Sub Split (%)
Node 1	0	135	65	35
Node 2	13	95	45	40
Node 3	86	175	70	30
Node 4	14	70	60	30

The traffic congestion condition of before and after optimization were verified by simulating the Ooe Toroku road network using the original traffic light signal parameters[1] and the best one (Table 5). The simulation results were compared in Fig. 5, which show that the real traffic congestions are happen in the 8 roads singed by red roman number (see Fig. 5(a)).The heavy traffic congestions are happen in road section I, II, III, V, VII and VIII which is indicated by many vehicles queue symbolized by small blue rectangular. However, when using the best traffic light signal parameters, the traffic congestions decrease significantly, as shown in Fig. 5(b). In detail, heavy traffic congestions are just happen in road section I and VI. It is still happen because the vehicles flow from in the section I (Road ID 316 and 317 (Fig. 3(b)), is high enough 432 with road width just 3 meter which mean the road density is overflow. From this verification, the traffic congestion can be solved by resetting the traffic light signal parameters using appropriate ones which can be searched by artificial intelligence such GA, PSO, Neural Network, etc. Overall, this verification supports the previous conclusion that the H-MEGA is alternative solution for searching the optimum traffic light signal parameters and it also can improve the performances of MEGA[8] and PSO[1].

Table 6. Throughput of H-MEGA on Ooe Toroku road network compared to mostly related works.

No	Methods	Vehicle	VF	$V_{go}$	$V_{in}$	$V_{wo}$	$\Delta = VF - V_{go}$	Delay Time	$tot_{Tr}^D$ (km)	$F_F(\%)$
1	Real	Bus	94	81	20	32	13	NA	NA	71.02
		Car	5158	3085	1132	1340	2073			
		Truck	258	159	55	65	99			
		Pedestrian	3708	3239	34	0	469			
		<b>Total</b>	<b>9218</b>	<b>6564</b>	<b>1241</b>	<b>1437</b>	<b>2654</b>			
2	Base Line[8]	Bus	94	86	12	5	8	913.99	5790.43	82.63
		Car	5158	3784	894	381	1374			
		Truck	258	254	37	23	4			
		Pedestrian	3708	3453	162	79	255			
		<b>Total</b>	<b>9218</b>	<b>7577</b>	<b>1105</b>	<b>488</b>	<b>1641</b>			
3	PSO[1]	Bus	94	82	7	5	12	1682.42	6089.83	85.76
		Car	5158	4052	742	329	1106			
		Truck	258	273	50	17	-15			
		Pedestrian	3708	3502	150	13	206			
		<b>Total</b>	<b>9218</b>	<b>7909</b>	<b>949</b>	<b>364</b>	<b>1309</b>			
4	H-MEGA	Bus	94	97	6	0	-3	795.20	6961.81	92.64
		Car	5158	4543	528	45	615			
		Truck	258	294	29	3	-36			
		Pedestrian	3708	3623	69	0	85			
		<b>Total</b>	<b>9218</b>	<b>8557</b>	<b>632</b>	<b>48</b>	<b>661</b>			

Note: \* The delay time divided by  $V_{go}$

### 5. CONCLUSION AND FUTURE WORKS

The proposed traffic light signal parameters optimization using H-MEGA has been implemented successfully to find the best traffic light signal parameters, which is shown by higher throughput of both simple and real road

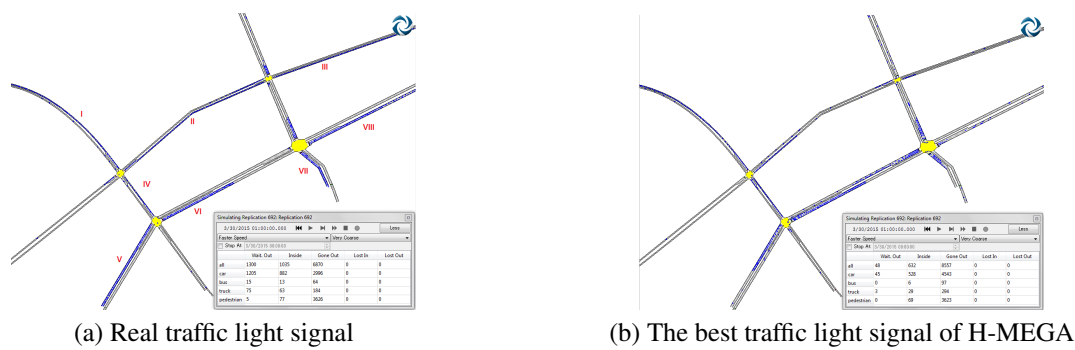


Figure 5. Traffic congestion verification of Ooe Toroku road network using Aimsun 6.1 simulator using real and best traffic light signal parameters.

networks. In detail, the H-MEGA can increase significantly the throughput ( $F_F$ ) of real Ooe Toroku road network by about 21.62% (from 71.02% to 92.64%). It means, the H-MEGA is successfully to search the best traffics light signal parameters of considered junctions that affects the decrease traffic congestion on the Ooe Toroku road network. In terms of computational time, the proposed method needs much shorter time for accomplishing the simulation among mostly related methods (MEGA and PSO).

In future, the Aimsun 6.1 simulator will be modeled by Neural Network for decreasing the computational time of accomplishing the simulation. In addition, the proposed methods will be formulated for finding the best traffic light signal parameters on complex road network .

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## REFERENCES

- [1] I. G. P. S. Wijaya, K. Uchimura, and G. Koutaki, "Traffic light signal parameters optimization using particle swarm optimization," in *2015 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, May 2015, pp. 11–16.
- [2] R. Florin and S. Olariu, "A survey of vehicular communications for traffic signal optimization," *Vehicular Communications*, vol. 2, no. 2, pp. 70–79, 2015. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S2214209615000121>
- [3] I. G. P. S. Wijaya, K. Uchimura, G. Koutaki, T. Nishihara, M. S., S. Ishigaki, and H. Sugitani, "The improvement mega based traffic signal control optimization using new fitness model," *Journal on Computing*, vol. 2, no. 2, pp. 64–69, 2012.
- [4] X. Yu and W. Reckert, "Stochastic adaptive control model for traffic signal systems," *Transportation Research Part C*, vol. 14, pp. 263–282, 2006.
- [5] L. Singh, S. Tripathi, and H. Arora, "The optimization for traffic signal control using genetic algorithm," *International Journal of Recent Trends in Engineering*, vol. 2, no. 2, pp. 4–6, 2009.
- [6] S. Takahashi, H. Kazama, T. Fujikura, and H. Nakamura, "Adaptive search of an optimal offset for the fluctuation of traffic flow using genetic algorithm," *IEEJ Trans. on Industry Applications*, vol. 123, no. 3, pp. 204–210, 2003.
- [7] T. Nishihara, N. Matsumura, K. Kanamaru, I. Wijaya, G. Koutaki, K. Uchimura, H. Sugitani, and S. Ishigaki, "The verification with real-world road network on optimization of traffic signal parameters using multi-element genetic algorithms," in *Proceeding of 19th ITS World Congress*, Austria, 2012.
- [8] I. G. P. S. Wijaya, K. Uchimura, G. Koutaki, S. Ishigaki, and H. Sugitani, "Fitness evaluation of multi element genetic algorithm for traffic signal parameters optimization," in *Proceeding of 3rd International Conference on Soft Computing, Intelligent System and Information Technology*, Bali Indonesia, 2012, pp. 58–64.
- [9] Z. Zhou and M. Cai, "Intersection signal control multi-objective optimization based on genetic algorithm," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 1, no. 2, pp. 153–158, 2014. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S2095756415301008>
- [10] C. Chou and J. Teng, "A fuzzy logic controller for traffic junction signals," *Information Sciences*, vol. 143, pp. 73–97, 2002.



- [11] S. Rahman and N. Ratrout, "Review of the fuzzy logic based approach in traffic signal control prospects in Saudi Arabia," *Transp Sys Eng and IT*, vol. 9, no. 5, pp. 58–70, 2009.
- [12] Z. Li, L. Elefteriadou, and S. Ranka, "Signal control optimization for automated vehicles at isolated signalized intersections," *Transportation Research Part C: Emerging Technologies*, vol. 49, pp. 1–18, 2014. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0968090X14002939>
- [13] F. A. Marcian, G. Musolino, and A. Vitetta, "Signal setting optimization on urban road transport networks: The case of emergency evacuation," *Safety Science*, vol. 72, pp. 209–220, 2015. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0925753514001866>
- [14] S. Yuan, X. Zhao, and Y. An, "Identification and optimization of traffic bottleneck with signal timing," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 1, no. 5, pp. 353–361, 2014. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S2095756415302816>
- [15] W. Ma, D. Liao, Y. Liu, and H. K. Lo, "Optimization of pedestrian phase patterns and signal timings for isolated intersection," *Transportation Research Part C: Emerging Technologies*, no. 0, pp. –, 2014. [Online]. Available: <http://www.sciencedirect.com/science/article/pii/S0968090X14002460>
- [16] A. Z. Jidin, L. S. Li, and A. F. Kadmin, "Implementation of algorithm for vehicle anti-collision alert system in FPGA," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 2, pp. 775–783, 2017.
- [17] I. G. P. S. Wijaya, K. Uchimura, G. Koutaki, and T. Nishihara, "Traffic signal control optimization using genetic algorithm and signaling model modification," in *Proceeding of 20th ITS World Congress*, Tokyo, Japan, 2013.
- [18] A. Berisha, E. Bytyçi, and A. Tershnjaku, "Parallel genetic algorithms for university scheduling problem," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 2, pp. 1096–1102, 2017.
- [19] S. Sivasankar, S. Nair, and M. Judy, "Feature reduction in clinical data classification using augmented genetic algorithm," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 5, no. 6, pp. 1516–1524, 2015.
- [20] J. Kennedy and R. Eberhart, "Particle swarm optimization," in *Proceedings of IEEE International Conference on Neural Networks*, Piscataway, NJ, 1995, p. 19421948.

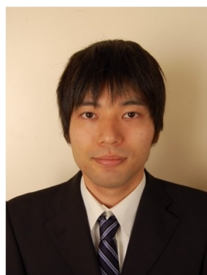
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