International Journal of Engineering & Technology, 7 (2.14) (2018) 177-181

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

An improved harmony search algorithm for optimized link state routing protocol in vehicular ad hoc network

Mustafa Raad Hammoodi [1] *, Ravie Chandren Muniyand [1]

[1] *Center of Cyber Security, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia*
**Corresponding author E-mail: mustafaalraad@gmail.com*

Abstract

Vehicle Ad-hoc Network (VANET) is a direct application of Mobile Ad-hoc Network (MANET). Nodes in VANET are vehicles that communicate using vehicle to vehicle (V2V) or vehicle to infrastructure (V2I). These types of communications have led to the emergence of various applications that provide safer driving. Due to the high changing of topology and frequent fragmentation of VANET, routing pack-ets in this type of network is a hard task. In this work, the authors deal with the well-known MANET proactive Optimized Link State Rout-ing protocol (OLSR). The deployment of OLSR in VANET gives the moderate performance; this is due to its necessity of constant ex-changing of control packets. The performance of OLSR is highly dependent on its parameters, thus finding optimal parameters configura-tions that best fit VANETs environment and improves the network is essential before its deployment. Therefore, this research proposes a modified Harmony Search optimization (HSO) by incorporating selection methods in its memory consideration; roulette wheel selection to obtain fine-tuned OLSR for high density and velocity scenario. The experimental analysis showed that the OLSR with the proposed ap-proach acquired promising results regarding packet delivery ratio, end-to-end delay and overhead when compared with previous approaches.

Keywords: *Meta-Heuristic; VANET; Optimization Method; OLSR; Routing Protocol*

1. Introduction

Vehicular Ad Hoc Networks (VANETs) have emerged as a subclass of Mobile Ad Hoc Networks (MANETs), where the nodes are vehicles. The idea of vehicles communicating with each other or with roadside units and forming a network that supports many types of applications has attracted the attention of researchers. The nodes in a VANET communicate with each other using two types of communication. The first type is Vehicle-to-Vehicle (V2V) communication, where the vehicles communicate with each other to exchange information. The second type is Vehicle-to-Infrastructure (V2I) communication, where the vehicles communicate with roadside units (RSU) that gather and broadcast information. These types of communication have led to the emergence of an intelligent transportation system (ITS) that can support several applications by exchanging different kinds of information to make driving safer and more efficient. For instance, when an accident occurs, the vehicles can broadcast useful messages about the accident and warn other drivers to slow down or to take another route. For this reason, it is exciting for researchers to work on and develop such kinds of networks that can save human lives [1].

VANETs possess an ad hoc nature, where the nodes move at very high speeds, sometimes exceeding 100 km/h, on highways. Therefore, even though VANETs are considered to have emerged from MANETs, they are a different type of ad hoc network as they differ in many features. For example, the energy of the nodes and the computational processors are not considered as constraints as the vehicle can be equipped with sufficient suppliers. Also, the mobility patterns of the nodes in VANETs are regarded as being non-random because the vehicles are required to follow and obey the topology and rules of the road. All these features have significant implications for decisions on their design and implementation [2]. In a VANET, the routing protocol plays an essential role in the deployment of its application. It is necessary to send a packet through several vehicles (multi-hops) to reach the required node destination. Due to the features of a VANET, it is essential to design an efficient and reliable routing strategy. This is one of the most challenging problems in the field for this kind of network. An adaptable routing strategy is required due to the dynamic nature of VANETs, such as their network topology, and the density and high speed of the nodes. Additionally, the routing protocols need to provide different quality of service (QoS) levels to different types of applications and services. The different types of routing protocols that have been designed for MANETs have been proposed for application in VANETs directly or after modifying them [3].

This paper aims to configure the parameters of the OLSR, which is a well-known proactive protocol, designed for MANETs. This protocol was selected primarily because it has a set of features that makes it suitable for VANETs. It presents very competitive delays during the data packet transmission in large networks (a vital feature for VANET applications), it can adapt significantly to constant topology changes, and its simple operation makes it easy to integrate. However, there are many challenges when it comes to deploying the OLSR in a VANET due to the high speed of vehicles, the high dynamic nature of the network and the high density of the velocities present in this kind of network. The exchange of messages between vehicles to broadcast information leads to a high overhead in the network. Thus, a large number of dropped packets will lead to fewer delivered packets, which is a primary feature of any routing protocol. As such, all these features make the OLSR a good candidate for optimal tuning. Therefore, it is proposed that an enhanced optimization method is applied based on the Harmony Search algorithm (HS), which is a meta-heuristic algorithm inspired from a natural phenomenon that has been used for solving many optimization problems [4].

2. Related work

In this section, the tasks related to this study, including on different types of meta-heuristic algorithms that have been used to optimize the OLSR protocol in ad hoc networks, are presented. In the study by [5], the OLSR performance after the tuning of the soft state refresh intervals was analyzed. After the simulation studies, it was observed that the OLSR routing performance was more sensitive to the HELLO interval values compared to the Topology Control (TC) interval values. Although a small HELLO interval value speeded up the detection of the neighbour and the link failure, however, this improvement was not linear to the decrease in the interval values. It was concluded that the performance of the OLSR routing scheme was dependent on the values of the HELLO interval timer. Thus, the protocol can be improved by developing fast and useable routes for the quick detection of the neighbouring nodes.

In [6], the authors addressed the NP-completion issue of the OLSR in determining the minimal Multipoint Relay (MPR). The Ant Colony (ACO) algorithm was used to solve the minimum set of MPR issues. In the first step, the researchers defined the out-degree and in-degree of the nodes, and based on their constraints; the Ant Colony algorithm was provided with a minimal set of MPRs in this study. After that, three Ant Colony optimization models, i.e., the Ant-Cycle, Ant-Quantity and the Ant-Density, were improved. Meanwhile, the convergence curve analysis for these models was described using MATLAB. The results showed that the Ant-Cycle model had a better convergence rate based on the fact that it solved a minimal set of MPRs. However, the algorithm could be further optimized and the time complexity was high when the algorithm tried to find the optimal solution.

The authors in [7] addressed the challenging features of VANETs, which include high node mobility, the limitations of the Wi-Fi in the coverage and the capacity of the channels, the presence of many obstacles that generate a data packet loss, topology changes, and network fragmentation. Hence, they proposed four different techniques, namely, Differential Evolution (DE), Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and Simulated Annealing (SA) for improving the OLSR performance in VANETs. They also defined a set of representative VANET scenarios (for the city of Málaga) for an accurate evaluation of the OLSR network performance using NS2. In their experiments, the authors noted that the tuned OLSR algorithm showed a better QoS compared to the standard scheme for parameters like E2E delays, PDR, and the overhead metrics. However, the OLSR can be further optimized for a better quality of service, thereby making it more suitable for VANETs.

In [8], the researchers tried to deal with the issue of decreasing the power consumption in the OLSR routing protocols used for vehicular networks for green energy in wireless networks. The authors proposed to change the OLSR parameters based on metaheuristics using the parallel Evaluation Annealing (EA). The results that were obtained using the NS2 showed that there was a significant improvement compared to the standard OLSR configuration about the power consumption and the time needed to deliver the packets. However, the results showed that the packet delivery ratio suffered degradation.

In [9], the authors proposed a heuristic for the effective selection of MPRs in the OLSR routing protocol. The MPR selection was seen as a very essential and important function of the OLSR protocol. The researchers proposed using a novel fuzzy logic-based routing metric for the selection of the MPRs. In determining the quality of the nodes within the network, they considered the total sum of the factors for quality such as the stability, energy and buffer occupancy. They captured these metrics during the initialization of the OLSR protocol, and these values were regularly updated whenever a new MPR was chosen from the nodes. This method was validated with the help of a statistical study of the predicted values, while the approach was verified in MATLAB. This improved the life of the network, lowered the power consumption in a MANET setting, and increased the network efficiency.

In [10], the authors addressed the issue of MPR node disconnection caused by the existing mobility in the VANETs with the help of the QoS-OLSR protocol. Hence, the authors proposed a novel QoS-OLSR protocol based on the Intelligent Water Drop (IWD) algorithm. The MPR selection was carried out by using the IWD algorithm to help select the best path within a limited time. After that, the authors used an MPR failure management algorithm to tackle the link failure scenarios, and MATLAB and Mobisim software to simulate the IWD-QoS-OLSR algorithm. The simulation results confirmed that their proposed protocol improved the connectivity and the PDR, and also reduced the path length and the probability of the loss of the data packets. They also noticed that the performance of the network decreased with the higher velocity of the nodes.

3. Optimized link state routing protocol

The IETF community is credited with the design of the Optimized Link State Routing (OLSR) protocol, which is mentioned as an experimental protocol in the Request for Comments 3626 [11]. It applies the shortest path routing algorithm, which is an extension of the traditional link-state approach, to decrease the overhead of link state updates, particularly in dense ad hoc networks.

The exchange of HELLO messages amongst nodes allows them to learn about their local vicinity and the link status with their neighbours (i.e., considering the link to be bidirectional or unidirectional). Through periodic topology control messages, this local information is distributed throughout the entire network. After obtaining the information through TC and HELLO messages, each node creates its view of the network topology independently and runs the Dijkstra algorithm to select the shortest route to the potential destination. Each protocol message is tagged by the OLSR with a sequence number to differentiate between fresh and stale information. Regarding network resources, flooding with TC messages can be a costly operation. Each node forwards a copy of the message through regular blind flooding. OLSR uses the MPR technique to check on the cost of delivering the flooded messages, which also keeps the number of nodes required for forwarding a message to a minimum, even though it still reaches the entire non-partitioned section of the network. In the MPR approach, a node, N is assumed to know its 2-hop neighbourhood. In OLSR, this is achieved by employing neighbourhood information to enrich the HELLO messages. Then, a subset of relays is selected by N amongst its 1-hop neighbours. This covers the same 2-hop nodes, similar to that of the whole 1-hop neighbourhood. This subset is referred to as the MPR set of N, where the MPR selector of each node in the set is defined by N. If a message is to reach the entire 2-hop neighbourhood, then the forwarding of the message occurs for only those nodes that were selected by the source as MPRs. A set of defined parameters regulates OLSR schemes.

Table 1: OLSR Parameters

Parameter	Standard Value	Range
Hello_Interval	2.0 s	$R \in [1.0, 30.0]$
Mid_Interval	2.0 s	$R \in [1.0, 30.0]$
Tc_Interval	5.0 s	$R \in [1.0, 30.0]$
Willingness	3	$R \in [7]$
Neighb_Hold_Time	3× HEL-	$R \in [3.0, 100.0]$
Mid_Hold_Time	LO_INTERVAL	$R \in [3.0, 100.0]$
Top_Hold_Time	3× TC_MID	$R \in [3.0, 100.0]$

Dup_Hold_Time	3× TC_INTERVAL 30.0 s	$R \in [3.0, 100.0]$

4. Harmony search optimization

The basic Harmony Search Algorithm was coined first by [12]. For example, think of a group of musicians who are a part of one orchestra. The appropriate blend of composed notes that are performed by each musician is finally turned into beautiful music. Every composition of notes played by the musicians is referred to as the harmony. After production, each harmony should be aesthetically checked to determine if the harmony obtained is the same. Successive exercises are performed until the harmony in consideration is produced. Musicians at any given time will practice and repeat their performance to produce better harmonies. Consequently, each of the descriptions given about orchestra performance can be considered similar to the components of the Harmony Search Algorithm.
This process is imitated every time the HS algorithm selects a variable. Similarly, any of the three rules presented below should be followed:

i) Selecting any value taken from the HS memory;
ii) Selecting an adjacent value taken from the HS memory;
iii) Selecting a random value given the possible value range. The HS algorithm's three rules are efficiently directed with the use of two vital parameters: pitch adjusting rate (PAR) and harmony memory considering rate (HMCR).

They are five steps of HSA comprises process. These steps are:

1) Parameter initialization,
2) HM initialization and evaluation,
3) Improvise a new harmony,
4) HM update, and
5) Termination criterion.

The basic HSA tends to select the variables from the HM randomly based on the HMCR. In this paper, the random selection in HSA memory consideration is replaced by the roulette wheel selection method. In this method, the selection probability depends on the absolute fitness value of any solution compared to the complete fitness values of the other solutions stored in HM.

- PAR=0.5, HMCR=0.9, NO_Iteration=100, Counter=0; Size=50
- Declare: PAR, HMCR, Bandwidth, NO_Iteration,Counter, Size, AdjustedHarmoics, FitnessHM(size), HM(Size), Roulette_ProbHM(Size), BestHarmonics, Best_Sol
- HM←Initiate_HM()
- FitnessHM=Evaluate_Fintness(HM)
- While (counter< Max_number_ of_ iterations)
    - For i =1:Size
    - Roulette_ProbHM(i)= FitnessHM(i)/sum(FitnessHM)
    - End
- BestHarmonics=Select(HM, Roulette_ProbHM,HMCR)
- AdjustedHarmoics=Adjust(BestHarmonics,PAR)
- Accept(HM,AdjustedHarmoics, BestHarmonics)
- End
- Best_Sol=Find_Best(HM)

Fig. 1: Pseudo Code.

5. Optimization framework of OLSR

The optimization strategy that was utilized to obtain efficient OLSR parameter configurations automatically was performed by coupling two different stages: 1) a procedure for optimization and 2) a simulation stage. A meta-heuristic method was carried out by an optimization block, which in this case is the HSO of which has been developed to search for optimal (or quasi-optimal) solutions within continuous search spaces. A simulation procedure was utilized to assign a quantitative quality value (fitness) to the computed configurations' OLSR performance regarding communication cost. For this, MATLAB network simulator was used to perform this procedure. For this particular paper, MATLAB was modified so that it can automatically interact with the optimization procedure and therefore accept new routing parameters. When the HSO process used requires an assessment of the solution; the tentative OLSR configuration's simulation procedure is invoked over the defined VANET scenario. MATLAB was then started so that it can evaluate the VANET based on the circumstances that have been defined by the OLSR routing parameters which are shown in table 1 these circumstances and parameters were generated using the optimization algorithm. Once the simulation is completed, MATLAB can then produce global information about the packet overhead, the PDR, and the E2E delay of the entire mobile vehicular network scenario. In turn, this information is used to calculate the communication cost (comm_cost) function based on the following:

$$\text{comm\_cost} = w2 \bullet \text{Overhead} + w3 \bullet \text{E2E Delay} - w1 \bullet \text{PDR}. \quad (1)$$

The communication cost function is used to represent the fitness function of this research's optimization problem. To enhance the QoS, one will have to maximize the PDR and minimize both the E2E Delay and overhead. As seen in (1), an aggregative minimizing function was used. Because of this, formulation of the PDR was done with a negative sign. Additionally, for this equation, factors w1, w2, and w3 were utilized to weigh each metric's influence on the resultant fitness value. Since the goal of this research is to promote the PDR for the sake of efficient packet communication, it was decided that different biased weights will be used in the fitness function, being w1 = 0.5, w2 = 0.2 and w3 = 0.3. With this, the PDR will have more priority compared to packet overhead and E2E Delay.

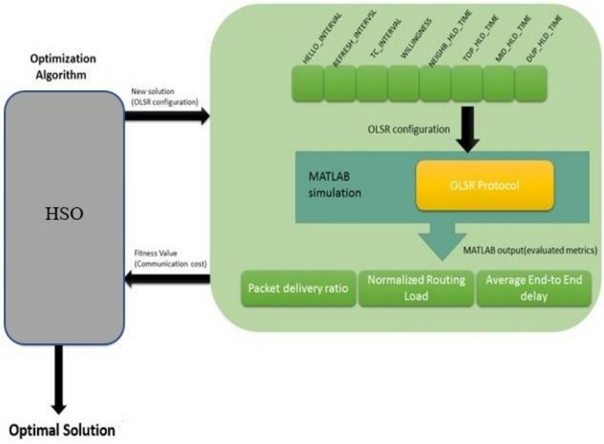

Fig. 2: Optimization Framework of HSO with OLSR.

6. Simulation environment

The simulation environment was created using MATLAB software to validate the proposed method and to compare it with two other optimization methods previously used by [7] namely the Genetic Algorithm and Practical Swarm Optimization with OLSR, using 70 nodes and a simulation time of 1200 seconds. The map that was used was based on a GPS satellite imagery of a part of Bangi, Malaysia. The speed limits for the roads on the map ranged from 60-100 km/h with a communication range radius of 150 m^2.

Table 2: Simulation Environment

Parameter	Value
Simulator	MATLAB
Channel type	Wireless
Simulation time (s)	1200
Nodes number	70
Type of Routing protocol	OLSR
Simulation area (m^2)	500∗500
Speed of nodes (km/h)	60 to 100
Movement type	nonrandom
Communication range (m)	150
Data packet buffer size (bit)	1000
Routing table size (bit)	100

7. Results and evaluation

Figure 3 shows the PDR results obtained by our approach and the compared approaches. PDR The packet delivery ratio or the fraction of data packets that come from an application and that is delivered entirely and correctly by the destination. PDR plays an important role in every routing protocol as there is no margin for errors to occur, especially in the real world environment.

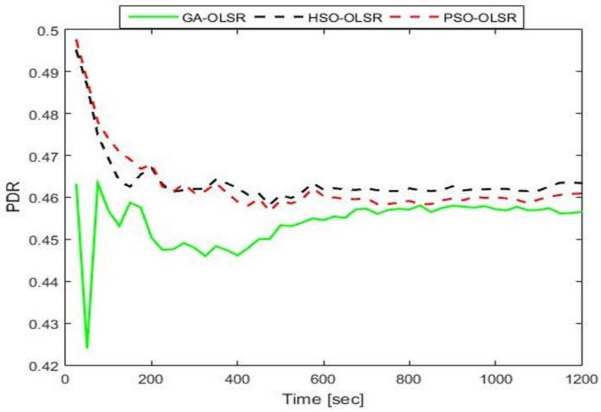

Fig. 3: PDR Results.

From the figure above, it can be observed that OLSR with HSO obtained better results when compared with GA and PSO, as it was able to obtain better OLSR parameters that were able to deliver the packets more correctly. At the beginning of the simulation, the HSO achieved the high rate of PDR, then it decreased gradually to about 0.46 and remained between ratios of 0.46 to 0.47. Meanwhile, the results PDR ratios obtained by PSO showed that at the beginning of the simulation, the algorithm tends to achieve the higher ratio of PDR and then it decreased gradually and stayed between 0.45 to 0.46. Finally, the GA produced about 0.465 at the beginning of the simulation, and it increased slightly achieving ratios between 0.45 to 0.46.
Figure 4 shows the results of OLSR obtained by HSO, GA, and PSO regarding end to end delay. This refers to the difference between the time that an application sends a data packet and the time that the destination receives this packet.

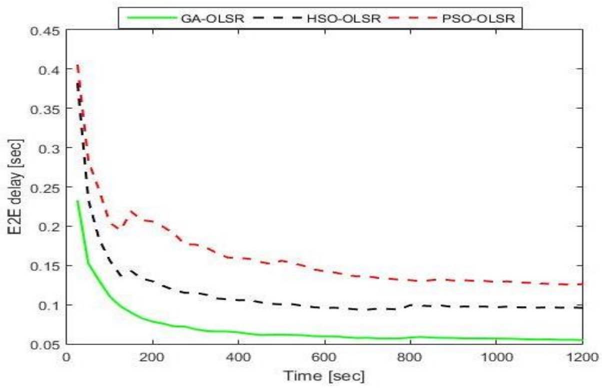

Fig. 4: E2E Delay Results.

From Figure 4, it can be seen that the HSO outperformed the PSO regarding how long it took the packets to be delivered from the source to destination. Meanwhile, the GA achieved a better E2E delay than both HSO and PSO. This is because the GA has achieved the worst PDR and it required less time for the packets to be delivered. However, the delay produced by the HSO was close to the delay by GA and it is considered as an acceptable delay in VANET networks.
Figure 5 shows the obtained results by the HSO, GA and PSO regarding the overhead metric. Overhead is the network routing load or the ratio of transmissions of the administrative routing packet and the data packets delivered where every hop is separately counted.

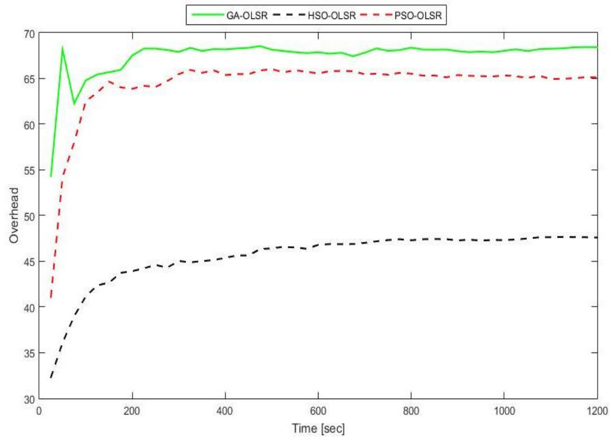

Fig. 5: Overhead Results.

It can be observed that our approach HSO outperformed both GA and PSO regarding the overhead, which is an important metric in VANET. Our approach was successful in decreasing the load of the network and delivering the packets without losing the packets, implying that the HSO is better to acquire a better trade-off between the delivering of packets and the network load.

8. Conclusion

This work investigates the evaluation performance of OLSR routing protocol in how to auto-tune the parameters of this routing protocol, and find the best configurations that are suited to improve the performance of routing protocols for Vehicular ad hoc networks, which is known for its unique and challenging features. We have presented an improved harmony search optimization method for enhancing the OLSR performance in VANET. The results have shown that the proposed approach was able to obtain the better trade-off between network metrics when compared with GA and PSP. As for future work, the experiments of our proposed approach to optimize a proactive routing protocol OLSR can be more extended with new VANET scenarios on a larger scale of urban and highway maps.

Acknowledgment

The authors acknowledge grant support from the Fundamental Research Grant Scheme, Ministry of Higher Education, Malaysia (project number FRGS/1/2015/ICT04/UKM/02/3) for this research.

References

[1] S. Al-Sultan, M. M. Al-Doori, A. H. Al-Bayatti, and H. Zedan, “A comprehensive survey on vehicular Ad Hoc network,” J. Netw. Comput. Appl., vol. 37, no. 1, pp. 380–392, 2014.
[2] V. Kumar, S. Mishra, and N. Chand, “Applications of VANETs: Present & Future,” Commun. Netw., vol. 5, no. 1, pp. 12–15, 2013.
[3] E. C. Eze, S. Zhang, and E. Liu, “Vehicular ad hoc networks (VANETs): Current state, challenges, potentials and way forward,” ICAC 2014 - Proc. 20th Int. Conf. Autom. Comput. Futur. Autom. Comput. Manuf., no. September, pp. 176–181, 2014.
[4] O. Abdel-raouf, “A Survey of Harmony Search Algorithm,” Int. J. Comput. Appl., vol. 70, no. 28, pp. 17–26, 2013.
[5] Y. Huang, S. N. Bhatti, and D. Parker, “Tuning OLSR,” IEEE Int. Symp. Pers. Indoor Mob. Radio Commun. PIMRC, pp. 5–9, 2006.
[6] X. Zhao, H. Song, H. Xia, and L. Zhong, “Using ant colony algorithm for solving minimum MPR set and OPNET simulation,” 2009 1st Int. Conf. Inf. Sci. Eng. ICISE 2009, pp. 3898–3901, 2009.

[7] J. Toutouh, J. García-Nieto, and E. Alba, "Intelligent OLSR routing protocol optimization for VANETs," IEEE Trans. Veh. Technol., vol. 61, no. 4, pp. 1884–1894, 2012.
[8] J. Toutouh, S. Nesmachnow, and E. Alba, "Fast energy-aware OLSR routing in VANETs by means of a parallel evolutionary algorithm," Cluster Comput., vol. 16, no. 3, pp. 435–450, 2013.
[9] A. Kots and M. Kumar, "The fuzzy based QMPR selection for OLSR routing protocol," Wirel. Networks, vol. 20, no. 1, pp. 1–10, 2014.
[10] D. Al-Terri, H. Otrok, H. Barada, M. Al-Qutayri, R. M. Shubair, and Y. Al-Hammadi, "QoS-OLSR protocol based on intelligent water drop for Vehicular ad-hoc networks," Wirel. Commun. Mob. Comput. Conf. (IWCMC), 2015 Int., pp. 1352–1357, 2015.
[11] C. Serrano-Cinca, Y. Fuertes-Callén, and C. Mar-Molinero, "Measuring DEA efficiency in Internet companies," Decis. Support Syst., vol. 38, no. 4, pp. 557–573, 2005.
[12] M. B. Trabia and X. Bin Lu, "A Fuzzy Adaptive Simplex Search Optimization Algorithm," J. Mech. Des., vol. 123, no. 2, p. 216, 2001.