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INTERNATIONAL CONFERENCE ON ADVANCED MECHATRONICS, INTELLIGENT MANUFACTURE, AND INDUSTRIAL AUTOMATION

# BOOK of ABSTRACT

## ICAMIMIA 2017

INTERNATIONAL CONFERENCE ON ADVANCED MECHATRONICS, INTELLIGENT MANUFACTURE, AND INDUSTRIAL AUTOMATION

**12-14th October 2017**

Gedung Pusat Robotika Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia

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# International Conference On Advanced Mechatronics, Intelligent Manufacture and Industrila Automation (ICAMIMIA) 2017

Surabaya, 12-14th October 2017

*Disruptive and Robust Innovation for Mechatronics Technology*

Program and Abstract

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## CONFERENCE PROGRAM

| Time | Activities |
|---|---|
| Thursday, 12 October 2017 | |
| 07.30 - 08.00 | Registration |
| 08.00 - 08.15 | Welcoming dance |
| 08.15 - 08.45 | Opening Ceremony:<br>1. Welcoming speech by Chair<br>2. Opening speech by Rector of ITS |
| 08.45 - 09.00 | Photo Session |
| 09.00 - 09.45 | Keynote speaker 1:<br>**Dr. Ir. Endra Pitowarno, M.Eng**<br>Politeknik Elektronika Negeri Surabaya<br>**(On the 3 rd -order Jerk-like Control Methods of the Proportional-Integral-Derivative Active Force Contro and its Application to Low-level Control of 3D- High Speed Vehicle Motion)** |
| 09.45 - 10.00 | ***Coffe break 1*** |
| 10.00 - 10.45 | Keynote speaker 2:<br>**Pascal Dricot**<br>Siemens Indonesia Ltd<br>**(Siemens Contributions to Indonesia's infrastructure** |
| 10.45 - 11.30 | Keynote speaker 3:<br>**Dr. Sreenatha G. Anavati**<br>UNSW Canberra, Australia<br>**(The Development of Neural Networks applications f Perceptron to Deep Learning)** |





| | |
|---|---|
| 11.30 - 12.15 | Keynote speaker 4:<br>**Alfina Wijanarko, S.T., PMP, CFT**<br>Rockwell Automation Southeast Asia Pte. Ltd<br>**(The Rise of Smart Machines – Integrated Industrial IoT Machines in Smart Manufacturing)** |
| 12.15 - 13.00 | **Break, Lunch** |
| 13.00 - 15.00 | Parallel Session 1 |
| 15.00 - 15.30 | ***Coffe break 2*** |
| 15.30 - 16.30 | Parallel Session 2 |
| 16.30 - 17.00 | Tour Registration |
| Friday, 13 October 2017 | |
| 08.00 - 09.00 | Registration |
| 09.00 - 09.45 | Keynote speaker 5:<br>**A/Prof. Mahardhika Pratama**<br>Nanyang Technological University, Singapore |
| 09.45 - 10.15 | ***Coffe break 1*** |
| 10.15 - 11.00 | Keynote speaker 6:<br>**Aris Budiyarto, Dipl. Ing**<br>PT. Bhimasena Research and Development, Indonesia<br>**(Research and development on vehicle design for strategic mission: Bhimasena's Role)** |
| 11.00 - 13.00 | **Break, Lunch** |
| 13.00 - 14.30 | Parallel session 3 |
| 14.30 - 14.45 | Closing ceremony (in each room) |

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## SCHEDULE OF PARALLEL SESSION ICAMIMIA 2017

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|---|---|---|---|---|---|
| | ROOM A | ROOM B | ROOM C | ROOM D | ROOM E |
| 13.00-13.15 | CM-1570391777 | DS-1570381258 | ME-1570382970 | ME-1570397241 | IC-1570384612 |
| 13.15-13.30 | CM-1570394790 | DS-1570392852 | ME-1570382977 | ME-1570397710 | IC-1570394799 |
| 13.30-13.45 | CM-1570395984 | DS-1570393301 | ME-1570383093 | ME-1570399395 | IC-1570397431 |
| 13.45-14.00 | CM-1570397845 | DS-1570402052 | ME-1570383201 | ME-1570397852 | IC-1570397943 |
| 14.00-14.15 | CM-1570398031 | DS-1570396349 | ME-1570392176 | ME-1570397987 | IC-1570398612 |
| 14.15-14.30 | CM-1570399232 | DS-1570396502 | ME-1570392833 | ME-1570398132 | IC-1570399522 |
| 14.30-14.45 | MI-1570397735 | DS-1570397426 | ME-1570393091 | ME-1570403535 | IC-1570400008 |
| 14.45-15.00 | MI-1570370419 | DS-1570397790 | ME-1570393290 | ME-1570398157 | IC-1570403533 |
| 15.00-15.30 | BREAK | | | | |
| | SESSION II | | | | |
| **15.30.15.45** | MI-1570393392 | DS-1570396178 | ME-1570394041 | ME-1570398166 | M-1570398281 |
| 15.45-16.00 | MI-1570403575 | DS-1570399186 | ME-1570396114 | ME-1570398184 | M-1570397837 |
| 16.00-16.15 | MI-1570403536 | DS-1570399670 | ME-1570396810 | ME-1570398465 | M-1570397975 |
| 16.15-16.30 | MI-1570396175 | DS-1570399561 | ME-1570399486 | ME-1570399601 | M-1570400531 |

| TIME Friday , 13 October 2017 | SESSION III | | | | |
|---|---|---|---|---|---|
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| 13.00-13.15 | E-1570394117 | E-1570399621 | ME-1570390886 | ME-1570399654 | M-1570399542 |
| 13.15-13.30 | E-1570399907 | E-1570386080 | ME-1570392809 | ME-1570392872 | M-1570399543 |
| 13.30-13.45 | E-1570396897 | ME-1570399645 | ME-1570403601 | ME-1570399650 | M-1570396908 |
| 13.45-14.00 | E-1570397358 | ME-1570398138 | ME-1570396176 | E-1570397719 | E-1570399494 |
| 14.00-14.15 | | | ME-1570399540 | | ME-155000001 |
| 14.15-14.30 | | | | | |

DS-1570392852

# Enhanced Symbiotic Organisms Search (ESOS) for Globa Numerical Optimization

**Doddy Prayogo[1], Foek Tjong Wong[1], and Steven Sugianto[1]**
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**ABSTRACT**

Symbiotic organisms search (SOS) is a simple but effect metaheuristic algorithm to solve global numerical optimizati problems. Many research has been done to propose few versions SOS to improve the performance of conventional SOS. This resea proposes a new version of SOS called Enhanced Symbiotic Organis Search (ESOS) for global numerical optimization. We propose modification of SOS by improvising the parasitism phase so that produce a more optimal solution. The performance of ESOS is verif on 26 benchmark functions and 1 engineering design problem, th compared with existing optimization methods. Based on the resea results, it can be concluded that ESOS is able to demonstrate go competitive, and effective performance for global optimization.

**Key words**: metaheuristic algorithm; Symbiotic Organisms Search; global numerical optimization; structural engineering design





DS-1570393301

# Comparative of Feasibility Study Between Diesel Mechanical Propulsion System and Combination of Diesel or Electric Propulsion System on Offshore Patrol Vessel (OPV) 80 m

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**ABSTRACT**

The modern offshore patrol vessel is designed to carry out various missions in the management of economic exclusion zones, thus having some speed of service. For example, the speed for slow patrol is 10 knots, regular patrols 18 knots and chasing 22 knots. This condition requires a flexible propulsion system, which is combination of mechanical and electrical propulsion system. The application of this propulsion system to the OPV can increase the load factor of the propulsion system, resulting in lower fuel consumption than when using a mechanical propulsion system. Based on feasibility analysis results, the choice of combination of mechanical and electrical propulsion system is more advantageous than mechanical propulsion system, although investment and maintenance cost is higher. Therefore, patrol boats should use combination of mechanical and electrical propulsion system.

**Key words**: DMP propulsion system; CODOE propulsion system; Feasibility Study; Offshore Patrol Vessels 80 m; Engine propeller matching analysis.

# Enhanced Symbiotic Organisms Search (ESOS) for Global Numerical Optimization

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***Abstract*—Symbiotic organisms search (SOS) is a simple yet effective metaheuristic algorithm to solve a wide variety of optimization problems. Many studies have been carried out to improve the performance of the SOS algorithm. This research proposes an improved version of the SOS algorithm called the "enhanced symbiotic organisms search" (ESOS) for global numerical optimization. The conventional SOS is modified by implementing a new searching formula into the parasitism phase to produce a better searching capability. The performance of the ESOS is verified using 26 benchmark functions and one structural engineering design problem. The results are then compared with existing metaheuristic optimization methods. The obtained results show that the ESOS gives a competitive and effective performance for global numerical optimization.**

***Keywords—metaheuristic algorithm, symbiotic organisms search, global numerical optimization, structural engineering design***

## I. INTRODUCTION

In the last few decades, global numerical optimization has become an interesting and challenging field of study to develop. Many of the optimization problems were solved by gradient-based optimization methods. However, technology has advanced rapidly in the last few decades, causing optimization problems to be varied and difficult to resolve. As a result, gradient-based optimization methods become less efficient in solving some complex problems. Due to these limitations, researchers have sought to find other optimization methods that are more effective than gradient-based optimization methods.

Recently, numerous metaheuristic optimization methods have been extensively researched and have evolved into potential alternatives to gradient-based methods. A "metaheuristic" is defined as an algorithmic framework that has a particular pattern, often nature-inspired, that iteratively simulates a set of randomly generated solutions to achieve better optimal solutions [1]. Notable examples of metaheuristic algorithms include the genetic algorithm (GA) [2], simulated annealing (SA) [3], particle swarm optimization (PSO) [4], differential evolution (DE) [5], ant colony optimization (ACO) [6], harmony search (HS) [7], artificial bee colony (ABC) [8], firefly algorithm (FA) [9], cuckoo search (CS) [10], and teaching–learning-based optimization (TLBO) [11].

However, there are limitations of existing metaheuristic methods. For example, GA uses complicated operators (on selection and crossover), often trapped in local optima, and has a weak local search capability [12]. PSO has a poor exploration capability in solving complex multimodal problems and can be easily trapped in local optima [12]. As a result, in agreement with the "no-free-lunch" theory [13], new metaheuristic optimization methods must be developed to solve specific and more complex optimization problems [14-16]. Furthermore, there is a growing number of studies in combining metaheuristic algorithms with other techniques to handle advanced problems [17-20].

Symbiotic organisms search (SOS) proposed by Cheng and Prayogo [21] is a promising new metaheuristic method that can produce a better solution in comparison with other traditional metaheuristic methods such as GA, PSO, and DE. This method simulates symbiotic behaviors between living creatures of different species in an ecosystem with the goal of survival. Although quite new, SOS has been utilized to solve many difficult optimization problems. In this research, an improved version of SOS is proposed called "enhanced symbiotic organisms search" (ESOS), which modifies the mechanism of the parasitism phase to produce a better exploration strategy. The proposed ESOS method is then used to solve complicated mathematical benchmark problems and one structural engineering design problem.

## II. METHODOLOGY

### A. Brief Introduction to the SOS Algorithm

First developed by Cheng and Prayogo [21], SOS is a metaheuristic algorithm inspired by the symbiotic relationships among organisms in their ecosystem as illustrated in Fig. 1. Initially developed for continuous numerical optimization, SOS has been widely used for solving various optimization problems in a variety of research areas. Similar to well-known metaheuristic algorithms, SOS comprise a sequence of operations that can generate potential best solutions at each iteration.

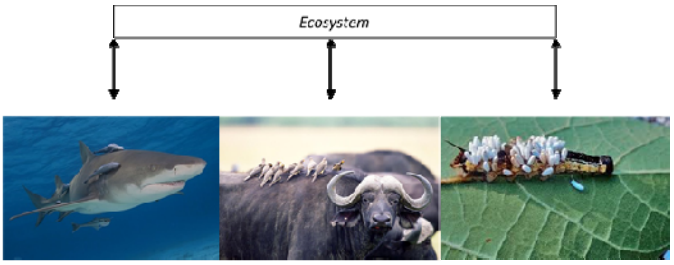


Fig. 1. Illustrations of symbiotic mutualism, commensalism, and parasitism.

The algorithm is constructed in three main phases: mutualism, commensalism, and parasitism. In the mutualism phase, two candidate solutions benefit from the interaction; in the commensalism phase, one of the candidates receives an advantage while the other candidate is not affected; and in the parasitism phase, one candidate benefits while the other is harmed. The cycle of these symbiotic interactions continues until the specific criteria are satisfied.

### *B. Modification in the SOS Algorithm*

Since its introduction by Cheng and Prayogo [21], SOS has been widely applied in many research fields [22-26]. The three phases that comprise the SOS structure offer unique searching characteristics [21]. For example, mutualism and commensalism benefit SOS with their good exploration capabilities, and parasitism has a strong exploiting characteristic with its cloning and random-based mutation operator. Additionally, parasitism has the capability to remove inferior solutions. Nevertheless, improving the performance of SOS has become even more necessary as the complexity of numerical problems has increased tremendously.

In this research, enhanced SOS (ESOS) is introduced as an improved version of SOS by modifying the current parasitism phase. In addition to the commonly known cloning and mutation concept, a sub-phase, called "cleptoparasitism" is introduced in the parasitism phase. The proposed sub-phase is originally adopted from the crow search algorithm (CSA) [27]. The cleptoparasitism sub-phase mimics the ingenious behavior of crows that keep their food reserves in hiding places for future retrieval. The following pseudo-code explains the mechanism of the modified parasitism phase:

```
Generate a uniform random number, rand1, between [0, 1]
    if rand1 < 0.5 then
    /* parasitism sub-phase */
        Generate parasite_vector
        Evaluate its fitness value
        Select the fittest organism between parasite_vector and its host
    elseif rand1 > 0.5 then
    /* cleptoparasitism sub-phase */
        Generate cleptoparasite_vector
        Evaluate its fitness value
        Select the fittest organism between cleptoparasite_vector and its host
    end if
end for
```

Similar to the canonical SOS, the ecosystem passes through the mutualism and commensalism phases in sequence before entering the modified parasitism phase. The modified parasitism phase is now of two sub-phases: the original parasitism sub-phase and the cleptoparasitism sub-phase.

In the cleptoparasitism sub-phase, *ri* is introduced as a uniform random number with a value determined by Askarzadeh [27], as seen in (1):

$$ri = rand(0,1) \tag{1}$$

Thereafter, *fl* is the range of the range between the *m*-organism and (*m* + 1)-organism in a single loop. The value of *fl* is determined by the user taking a random number with a uniform distribution between -2 and 2. There is a possibility of random numbering for *fl* that results in better search performance, but the researcher has not done so due to time constraints. The definition of *fl* can be seen in (2):

$$fl = rand(-2,2) \tag{2}$$

The *coef* is the coefficient of the difference in value possessed by the best position of organism ($x_{best}$) and the current position of the *m*-organism ($x_m$), which can be seen in (3); and the new position of the *m*-organism ($x_m$') obtained through (4):

$$coef = ri \times fl \tag{3}$$

$$x_m' = x_m + coef\,(x_{best} - x_m) \tag{4}$$

## III. ESOS Validation on Numerical Benchmark Problems

In this section, the performance of ESOS is tested through complex benchmark problems. For comparison purpose, PSO, DE, and the original SOS algorithm are employed. The experimental setting is described as follows: the population sizes of PSO, DE, SOS, and ESOS are set to 50 each; the maximum number of function evaluations is set to be 250,000; and the iteration stops only if the function evaluations exceed the maximum number allowed.

To maintain an equivalent comparison, PSO, DE, SOS, and ESOS algorithms are tested under the same conditions and

parameter settings for the four algorithms as shown in Table I. The number of ecosystems is denoted by $n$; $w$ is the inertia weight; $c$ is the crossover rate; and $F$ is the scaling factor. A set of 26 benchmark functions is used to evaluate the algorithms. The experiment is repeated over 30 times and the average results for mean (M) and standard deviation (SD) are recorded in Table II and Table III. Bolded numbers represent the best mean value for each function.

TABLE I. PARAMETER SETTINGS FOR NUMERICAL BENCHMARK PROBLEMS

| | |
|---|---|
| **PSO** | $n = 50$, $w = 1$, $c_1 = 2$, $c_2 = 2$ |
| **DE** | $n = 50$, $F = 0.4$, $c = 0.5$ |
| **SOS** | $n = 50$ |
| **ESOS** | $n = 50$ |

TABLE II. COMPARISON OF ANALYSIS BETWEEN ESOS AND OTHER METAHEURISTICS (F1-F13)

| **Functions** | | **Min.** | **PSO** | **DE** | **SOS** | **ESOS** |
|---|---|---|---|---|---|---|
| F1-Beale | M | 0 | 0.00049 | 7245.70 | **0** | **0** |
| | SD | | 0.00075 | 0 | 0 | 0 |
| F2-Easom | M | -1 | -0.9263 | -1 | **-1** | **-1** |
| | SD | | 0.05701 | 0 | 0 | 0 |
| F3-Matyas | M | 0 | 5.39E-05 | 4.90 | **0** | **0** |
| | SD | | 5.54E-05 | 0 | 0 | 0 |
| F4-Boachevsky1 | M | 0 | 0.41971 | 9.3E-17 | **0** | **0** |
| | SD | | 0.22651 | 1.1E-16 | 0 | 0 |
| F5-Booth | M | 0 | 0.01673 | 76.97 | **0** | **0** |
| | SD | | 0.01671 | 63.50 | 0 | 0 |
| F6-Michalewicz2 | M | -1.8013 | -1.8002 | -0.8013 | **-1.8013** | **-1.8013** |
| | SD | | 0.00126 | 3.4E-16 | 9.03E-16 | 9.03E-16 |
| F7-Schaffer | M | 0 | 0.03034 | 0.0487 | **0** | **0** |
| | SD | | 0.01538 | 0.19061 | 0 | 0 |
| F8-Six Hump Camel Back | M | -1.03163 | -1.0310 | 0.0082 | **-1.03163** | **-1.03163** |
| | SD | | 0.00090 | 9.0E-10 | 6.78E-16 | 6.78E-16 |
| F9-Boachevsky2 | M | 0 | 0.25366 | 1.1E-17 | **0** | **0** |
| | SD | | 0.19874 | 2.3E-17 | 0 | 0 |
| F10-Boachevsky3 | M | 0 | 0.24715 | 1.9E-16 | **0** | **0** |
| | SD | | 0.15172 | 2.2E-16 | 0 | 0 |
| F11-Shubert | M | -186.73 | -186.63 | 189.57 | **-186.73** | **-186.73** |
| | SD | | 0.12542 | 22.74 | 4.70E-08 | 3.95E-14 |
| F12-Colville | M | 0 | 7.44825 | 23.29 | 9.64E-12 | **2.07E-12** |
| | SD | | 3.95789 | 118.28 | 1.19E-11 | 4.30E-12 |
| F13-Michalewicz5 | M | -4.6877 | -3.5903 | -2.24 | **-4.6877** | **-4.6877** |
| | SD | | 0.22732 | 2.9E-08 | 2.27E-15 | 1.51E-15 |

TABLE III. COMPARISON OF ANALYSIS BETWEEN ESOS AND OTHER METAHEURISTICS (F14-F26)

| **Functions** | | **Min.** | **PSO** | **DE** | **SOS** | **ESOS** |
|---|---|---|---|---|---|---|
| F14-Zakharov | M | 0 | 9.73168 | 5.3E-83 | 7.4E-247 | **1.6E-254** |
| | SD | | 5.61788 | 1.8E-82 | 0 | 0 |
| F15-Michalewicz10 | M | -9.6602 | -5.1983 | -3.2790 | -9.65588 | **-9.65711** |
| | SD | | 0.32766 | 1.0E-07 | 0.012404 | 0.015359 |
| F16-Step | M | 0 | 2014.11 | 3.4E-18 | 1.64E-33 | **1.34E-33** |
| | SD | | 2009.55 | 1.9E-17 | 4.11E-33 | 3.20E-33 |
| F17-Sphere | M | 0 | 2343.93 | 4.8E-67 | **0** | **0** |
| | SD | | 1948.64 | 2.6E-66 | 0 | 0 |
| F18-Sum Squares | M | 0 | 364.59 | 7.8E-32 | **0** | **0** |
| | SD | | 266.11 | 4.2E-31 | 0 | 0 |
| F19-Quartic | M | 0 | 2.26620 | 6.2081 | 0.000205 | **0.000185** |
| | SD | | 1.78097 | 4.68605 | 7.51E-05 | 8.47E-05 |
| F20-Schwefel 2.22 | M | 0 | 21.17 | 1.1E-66 | **0** | **0** |
| | SD | | 8.10003 | 1.7E-66 | 0 | 0 |
| F21-Schwefel 1.2 | M | 0 | 27564.87 | 4.5E-19 | **0** | **0** |
| | SD | | 22372.68 | 2.5E-18 | 0 | 0 |
| F22-Rosenbrock | M | 0 | 428791.9 | 1969.32 | 9.887101 | **0.576513** |
| | SD | | 556753.5 | 3607.47 | 1.430548 | 0.435882 |
| F23-Dixon-Price | M | 0 | 6415.98 | 15.38 | **0.666667** | **0.666667** |
| | SD | | 13932.88 | 38.31 | 2.50E-16 | 1.13E-16 |
| F24-Rastrigin | M | 0 | 202.88 | 87.82 | **0** | **0** |
| | SD | | 54.48 | 36.74 | 0 | 0 |
| F25-Griewank | M | 0 | 17.76 | 0.03580 | **0** | **0** |
| | SD | | 13.23 | 0.19608 | 0 | 0 |
| F26-Ackley | M | 0 | 8.99452 | 8.1E-15 | 4.2E-15 | **3.97E-15** |
| | SD | | 3.05423 | 1.7E-15 | 9.01E-16 | 1.23E-15 |

To further find out about the superiority of the ESOS compared with the original SOS algorithm, we show the convergence profiles for Rosenbrock mathematical benchmark problem in each iteration as shown in Fig. 2. The SOS algorithm has a slightly better convergence rate in comparison with the ESOS algorithm. However, as the iteration progresses to a greater value, ESOS converges faster. The ESOS and SOS algorithms found the best value of 0.13893 and 4.64578, respectively, after 1200 iterations. This proves that improvisation in one phase of the SOS algorithm produces a positive impact on the computation of more optimal results.

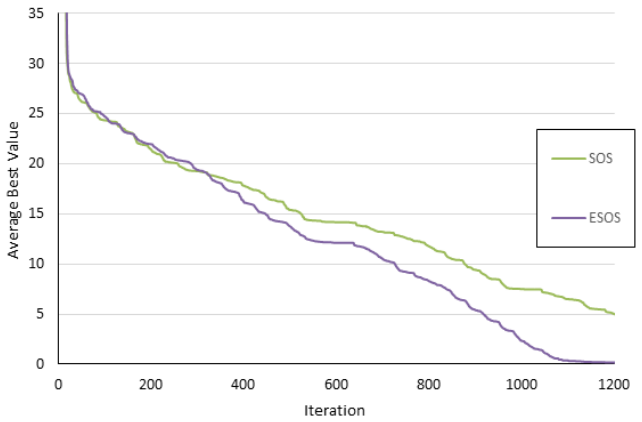


Fig. 2. Convergence profiles for the SOS and ESOS algorithm on Rosenbrock mathematical benchmark problem.

## IV. Practical Example of Structural Problem

Practical performance of the ESOS algorithm is investigated by using 72-bar space truss structure problem. PSO, DE, and SOS algorithms are used as comparisons. For all four methods, the best weight (minimum), standard deviation, and average (mean) were obtained from 30 independent runs, with the maximum value for the function evaluation set at 50,000.

The objective of the 72-bar space truss problem is to obtain the lightest structural weight and was previously investigated by Li et al. [28]. This test problem uses two linear inequality constraints, stress ($\sigma$) and displacement ($\Delta$), and one design variable, cross-sectional area ($x$). The following objective of design optimization on structural problem is to find a minimum weight ($W$) of structures, so we can get a minimum cost of construction. The objective function for this problem can be seen in (5):

$$W = \sum_{m=1}^{N_m} L_m m_m \tag{5}$$

with $N_m$ is the total number of truss members, $L_m$ is the length of each truss members, and $m_m$ is the coefficient of weight per length of truss members, as follows:

$$m_m = 2.71447x \tag{6}$$

The boundary conditions for cross-sectional area of truss ($x$) can be seen in (7) and the following limitations are the design constraints for structural problem tested, that can be seen in (8) and (9) as follows:

$$64.52 \le x \le 2064.51 \tag{7}$$

$$g_m = \frac{\sigma_m}{(\sigma_m)all} - 1 \le 0; m = 1, 2, 3, ..., N_m \tag{8}$$

$$\delta_{jk} = \frac{d_{j,k}}{(d_{j,k})all} - 1 \le 0; \text{j} = 1, 2, 3, ..., N_j \tag{9}$$

In (8) and (9), $g_m$ and $\delta_{jk}$ are the optimization constraints for stress and displacements, respectively. For the $m$-th member, $\sigma_m$ is the computed axial stresses and $(\sigma_m)_{\text{all}}$ is its allowable. While for $j$-th joint on the $k$-th direction, $d_{jk}$ is the computed displacements and $(d_{jk})_{\text{all}}$ is its allowable, and $N_j$ is the total number of joints.

Due to the symmetry of existing structures and according to previous research, these structures are divided into 16 groups of elements. The load case for 72-bar space truss problem is listed in Table IV and the structure is shown in Fig. 3. A performance comparison of the statistical results between ESOS and other metaheuristics is presented as Table V. In this table, bold texts indicate the best results. The ESOS and SOS algorithms achieve the best (minimum) weight of the structure, i.e., 1714.98 N. However, the ESOS algorithm outperforms SOS in best average and standard deviation for the weight of the structure. For best mean and standard deviation, the SOS algorithm achieves, respectively, 1717.95 N and 4.29 while the ESOS algorithm achieves 1715.90 N and 2.89.

TABLE IV. Load Case for 72-Bar Space Truss Problem

| Nodes | Load (kg) | | |
|---|---|---|---|
| | $P_x$ | $P_y$ | $P_z$ |
| 17 | 2267.96 | 2267.96 | -2267.96 |

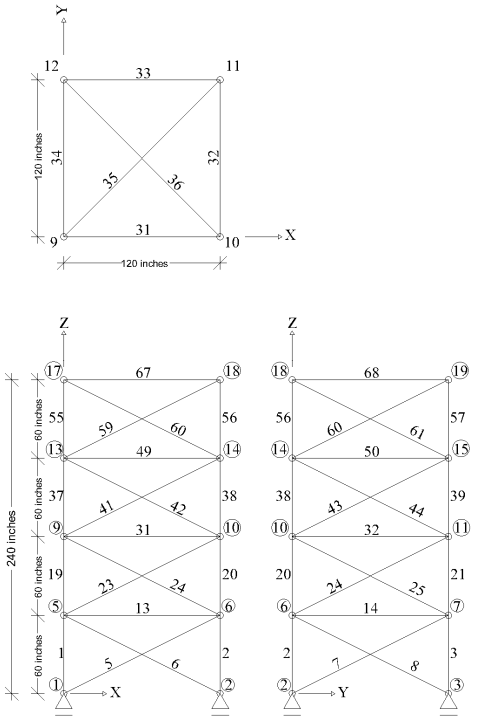


Fig. 3. A 72-bar space truss structure.

TABLE V. COMPARISON OF STATISTICAL RESULTS FOR ESOS AND OTHER METAHEURISTICS

| Algorithms | Best | Mean | St. Dev. |
|---|---|---|---|
| PSO | 5510.87 | 7725.08 | 1072.46 |
| DE | 1778.42 | 3193.12 | 990.52 |
| SOS | **1714.98** | 1717.95 | 4.29 |
| ESOS | **1714.98** | **1715.90** | **2.89** |

## V. CONCLUSIONS

This research proposes the ESOS method for global numerical optimization. This method modifies the conventional SOS method by implementing a new searching formula in the parasitism phase, with the intention of producing a better searching capability. We compared ESOS performance with PSO, DE, and the original SOS algorithm across 26 benchmark functions and one structural engineering design problem. The computational results and comparisons verify the superiority of ESOS in solving some complex mathematical benchmark problems better than other tested algorithms. Furthermore, for the structural problem, ESOS demonstrated consistent performance to produce optimal solutions. This is confirmed from the smaller standard deviation produced by ESOS compared with other metaheuristic algorithms including SOS. Thus, the implemented improvisation in the parasitism phase produced a large positive impact on the computational results. The ESOS algorithm delivers competitive, superior, and effective performance for global numerical optimization.

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