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CONTENT

Binary Sooty Tern Optimization Algorithms for solving Wind Turbine Placement Problem

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***Abstract*—Sooty Tern Optimization Algorithm (STOA) is a recently developed nature-inspired continuous optimization algorithm. Sooty Tern is a sea bird and STOA is mathematically modeled the attacking and migration behaviors of Sooty Tern is a continuous optimization algorithm. The continuous optimization algorithms are converted to binary optimization algorithms with transfer functions. In literature, 17 transfer functions are used for mapped continuous search space values to binary search space values. In this work, 17 different binary variants of STOA (BSTOA1-BSTOA17) are proposed for solving the wind turbine placement problem (WTPP). 100 dimensional (10x10 grid type) WTPP is solved by these 17 variants of STOA. Experimental results have shown that binary variants of STOA are produced competitive solutions for WTPP.**

Keywords*—*Sooty Tern Optimization Algorithm, Binary Sooty Tern Optimization Algorithm, Wind Turbine Placement Problem, transfer functions

I. Introduction

Sooty Tern Optimization Algorithm (STOA) [1] is a continuous optimization algorithm modeled the life behavior of a sooty tern. Sooty tern is a sea bird lived in nature and its attacking and migration characteristics are modeled as a smart search algorithm as a metaheuristic. Sooty tern is a sea bird that lives in nature and its attacking and migration characteristics are modeled as a smart search algorithm. STOA is a metaheuristic algorithm that only can solve continuous optimization problems. Continuous optimization algorithms have continuous variables in a predetermined search space. Binary optimization problems have only two decision variables 0 and 1. The continuous optimization algorithms cannot solve binary optimization algorithms directly and they must be remodified for binary search space. Transfer functions [2] are commonly used for transferring the continuous variables to the binary search space. In literature, as far as now, 17 transfer functions [3] are used for mapping continuous variables to binary variables.

In this work, STOA is combined with these 17 transfer functions. Consequently, 17 novel binary STOAs (BSTOA1-BSTOA17) are proposed in this work. To determine the quality of these binary variants wind turbine placement problem (WTPP) [4] is used as a benchmark problem. 100 dimensional (10x10 grid type) WTPP is solved by these 17 variants of STOA.

The remainder of the paper is organized as follows. STOA briefly explained in Section 2. Transfer functions and, binary variants of STOA are described in Section 3 and Section 4, respectively. The details of WTPP and parameters of the experimental setup are given in Section 5. Results and Discussion are presented in Section 6. Finally, the work is concluded in Section 7.

II. Sooty Tern Optimization Algorithm (STOA)

Sooty terns live in colonies and attack their prey with their intelligence. Sooty terns migrate to rich food areas. The attacking and migrating behaviors are mathematically modeled and a new nature-inspired continuous optimization algorithm, Sooty Tern Optimization Algorithm (STOA) is proposed by Dhiman and Gaur [1]. The pseudocode of STOA is given in Fig.1.

Fig. 1. The pseudocode of STOA [1]

```
Input: Population X
Output: Best search agent, Xbest
FUNCTION STOA
Initialize the peculiar parameters
Calculate the fitness of each search agent
Xbest ← best search agent
   WHILE (iteration < Maxiterations) DO
      FOR each search agent DO
      Update the positions of search agents
      END FOR
   Update the peculiar parameters
   Calculate the fitness value of each search agent
   Update Xbest if there is any better solution than
Xbest
   iteration ← iteration + 1
   END WHILE
   return Xbest
END FUNCTION
```

The detailed explanation about STOA can be found in [1].

III. Transfer Functions

The details and equations of transfer functions that used in this work can be found in [3]. The continuous variable given as an input to transfer function and the output maybe 0 or 1. To facilitate the understanding Sigmoid transfer function (Transfer Function 1, i.e.) is given in Eq. 1.

$$STFR = \frac{1}{(1 + e^{-c})} \quad (1)$$

where c is the continuous input variable. If the Sigmoid Transfer Function result (STFR) is bigger than a random number between 0 and 1 the binary value is 1 otherwise the binary value is 0 as presented in Eq.2

$$ctob(STFR) = \begin{cases} 1, & rand < STFR \\ 0, & rand \geq STFR \end{cases} \quad (2)$$

where ctob is a function that produces a binary output.

IV. Binary Variants of Sooty Tern Optimization Algorithm

The scheme of the binary variants of Sooty Tern Optimization Algorithm (STOA) is given in Figure 2.

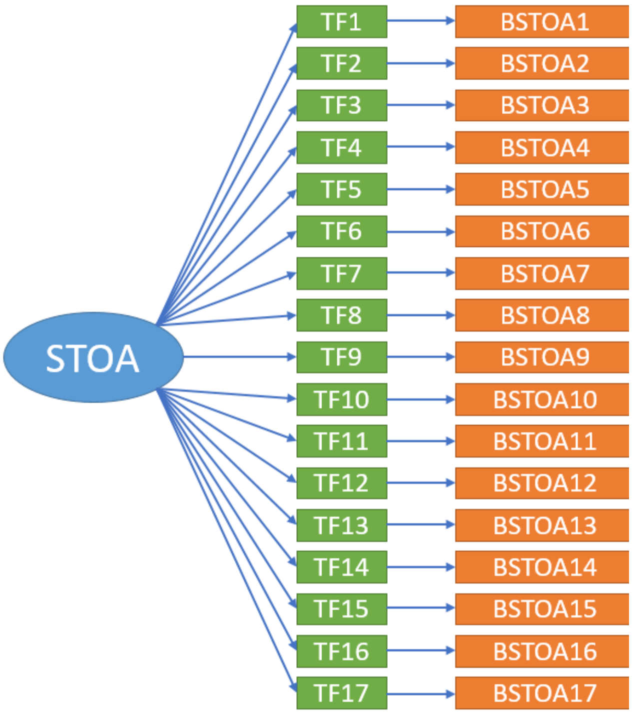

Fig. 2. Binary variants of STOA

The continuous variables are converted to binary variables before they sent into the objective function.

V. Experimental Setup

The details of the WTPP can be found in [4]. In this work, 100 dimensional (10x10 grid type) WTPP is solved by 17 binary variants of STOA. 2^{100} possible solutions are optimized by these binary algorithms. The wind direction is fixed as 0° and the wind speed is fixed as 12 m/s.

The sooty tern population size is set as 50 and the maximum iteration number is set as 12000. The maximum function evaluation number is fixed as 600000 same as the works in [4, 5]. The upper bound of the continuous search space is set as 8 and the lower bound of the search space is set as -8. 30 different runs were conducted to cope with the random nature of the algorithms.

VI. Results and Discussion

The fitness value, the total produced power, the number of tribunes (NoT), the average power and the efficiency values are given in Tables 1-5 for 17 BSTOAs. The mean values are given in Table 1. The maximum values are given in Table 2. The minimum values are given in Table 3. The median values are given in Table 4. The standard deviation values are given in Table 5.

TABLE I. The Mean Values

	Fitness	**Total Power**	**NoT**	**Average Power**	**Efficiency**
BSTOA1	0.00155971	14720.6273	33.33	442.6088	0.8538
BSTOA2	0.00156049	15210.7763	34.63	440.3015	0.8493
BSTOA3	0.00158828	15079.0592	35.53	425.7536	0.8213
BSTOA4	0.00159755	13106.8915	30.23	436.1978	0.8414
BSTOA5	0.00162536	12535.9746	30.43	419.1184	0.8085
BSTOA6	0.00159793	13047.9339	30.00	437.6431	0.8442
BSTOA7	0.00233848	26284.1378	100.00	262.8414	0.5070
BSTOA8	0.00160718	12361.4186	28.67	432.5338	0.8344
BSTOA9	**0.00155655**	14897.4385	32.63	456.8835	0.8813
BSTOA10	0.00155744	14893.2590	32.80	454.9095	0.8775
BSTOA11	0.00162691	21453.2664	66.83	324.7075	0.6264
BSTOA12	0.00165091	547.5380	1.07	515.6890	0.9948
BSTOA13	0.00163808	15391.6237	40.30	383.1015	0.7390
BSTOA14	0.00160366	12721.3824	29.60	432.8648	0.8350
BSTOA15	0.00164878	13761.6470	34.27	403.5679	0.7785
BSTOA16	0.00159944	14914.0673	33.37	447.4497	0.8631
BSTOA17	0.00162647	16147.8925	40.30	402.5844	0.7766

The best variant is BSTOA9 in terms of the mean values. The worst variant is BSTOA7 in terms of the mean values.

TABLE II. The Maximum Values

	Fitness	**Total Power**	**NoT**	**Average Power**	**Efficiency**
BSTOA1	0.00159523	15988.8082	38	470.9151	0.9084
BSTOA2	0.00157570	17197.4310	42	470.3435	0.9073
BSTOA3	0.00164280	17457.9199	46	453.0915	0.8740
BSTOA4	0.00164397	17287.2006	43	480.1804	0.9263
BSTOA5	0.00181546	20555.5139	66	482.8890	0.9315
BSTOA6	0.00163385	15710.2159	40	474.6995	0.9157
BSTOA7	0.00239014	26284.1378	100	262.8414	0.5070
BSTOA8	0.00164717	13982.0089	35	461.3128	0.8899
BSTOA9	**0.00157444**	16471.8481	38	472.8759	0.9122
BSTOA10	0.00157769	16154.7858	38	474.1882	0.9147
BSTOA11	**0.00241272**	26284.1378	100	356.1447	0.6870
BSTOA12	0.00166147	1036.8000	2	518.4000	1.0000
BSTOA13	0.00168423	17714.9196	49	419.0931	0.8084
BSTOA14	0.00164474	16503.8937	43	475.0159	0.9163
BSTOA15	0.00166889	16210.4544	44	446.9484	0.8622
BSTOA16	0.00163401	16164.8310	37	469.9922	0.9066
BSTOA17	0.00165800	17766.5446	48	443.0681	0.8547

The best variant is BSTOA9 in terms of the maximum values. The worst variant is BSTOA11 in terms of the maximum values.

TABLE III. THE MINIMUM VALUES

	Fitness	Total Power	NoT	Average Power	Efficiency
BSTOA1	0.00154754	11772.8768	25	405.4547	0.7821
BSTOA2	0.00154623	13468.6278	29	409.4626	0.7899
BSTOA3	0.00155273	13067.2139	29	379.5200	0.7321
BSTOA4	0.00157512	10349.5985	23	399.9196	0.7714
BSTOA5	0.00158676	9056.4452	19	311.4472	0.6008
BSTOA6	0.00157243	8544.5906	18	392.7554	0.7576
BSTOA7	**0.00229447**	26284.1378	100	262.8414	0.5070
BSTOA8	0.00157199	10063.9044	23	399.4860	0.7706
BSTOA9	0.00154609	14115.6997	30	433.4697	0.8362
BSTOA10	**0.00154292**	13666.4349	29	422.3040	0.8146
BSTOA11	0.00157104	19479.8689	55	262.8414	0.5070
BSTOA12	0.00161763	518.4000	1	437.0695	0.8431
BSTOA13	0.00158707	13200.6175	32	356.3481	0.6874
BSTOA14	0.00157727	10124.9739	23	383.8115	0.7404
BSTOA15	0.00162164	10240.7888	24	368.4194	0.7107
BSTOA16	0.00156533	13629.7752	29	431.6931	0.8327
BSTOA17	0.00157771	13575.7327	31	368.1134	0.7101

The best variant is BSTOA10 in terms of the minimum values. The worst variant is BSTOA7 in terms of the minimum values.

TABLE IV. THE MEDIAN VALUES

	Fitness	Total Power	NoT	Average Power	Efficiency
BSTOA1	0.00155904	14646.2272	34	445.7286	0.8598
BSTOA2	0.00155986	15166.8584	35	440.2213	0.8492
BSTOA3	0.00158788	15039.7566	35	430.3446	0.8301
BSTOA4	0.00159394	12810.2497	29	442.0757	0.8528
BSTOA5	0.00161637	12424.7990	29	421.6447	0.8134
BSTOA6	0.00159511	13288.4902	30	437.9103	0.8447
BSTOA7	**0.00233801**	26284.1378	100	262.8414	0.5070
BSTOA8	0.00160748	12471.9151	30	435.3162	0.8397
BSTOA9	0.00155701	14790.5955	32	458.2211	0.8839
BSTOA10	**0.00155592**	14815.7222	32	457.3932	0.8823
BSTOA11	0.00158883	20827.0338	63	329.1148	0.6349
BSTOA12	0.00165358	518.4000	1	518.4000	1.0000
BSTOA13	0.00163959	15585.5988	41	381.7001	0.7363
BSTOA14	0.00160245	12561.6731	29	430.6622	0.8308
BSTOA15	0.00165151	14036.0269	35	404.7432	0.7808
BSTOA16	0.00160069	14869.8674	33	447.2999	0.8628
BSTOA17	0.00163041	15984.3317	40	404.6043	0.7805

The best variant is BSTOA10 in terms of the minimum values. The worst variant is BSTOA7 in terms of the minimum values.

TABLE V. THE STANDART DEVAITION VALUES

	Fitness	Total Power	NoT	Average Power	Efficiency
BSTOA1	0.00000987	819.5627	2.67	15.2839	0.0295
BSTOA2	0.00000732	767.2321	2.82	15.5572	0.0300
BSTOA3	0.00001712	867.7527	3.22	19.1999	0.0370
BSTOA4	0.00001883	1501.9520	4.72	20.3497	0.0393
BSTOA5	0.00004125	2189.7509	8.30	30.3635	0.0586
BSTOA6	0.00001457	1718.0434	5.00	18.8788	0.0364
BSTOA7	0.00002042	0.0000	0.00	0.0000	0.0000
BSTOA8	0.00001753	999.2733	3.04	17.0108	0.0328
BSTOA9	**0.00000623**	512.7619	1.65	8.7694	0.0169
BSTOA10	0.00000822	670.5566	2.34	13.1509	0.0254
BSTOA11	**0.00015361**	1716.6185	11.01	23.6624	0.0456
BSTOA12	0.00000899	112.9263	0.25	14.8488	0.0286
BSTOA13	0.00002099	1143.4987	4.05	15.6865	0.0303
BSTOA14	0.00001765	1559.7370	4.97	21.7597	0.0420
BSTOA15	0.00001209	1290.0554	4.38	19.5858	0.0378
BSTOA16	0.00001550	690.6007	2.09	8.9985	0.0174
BSTOA17	0.00002239	900.0362	4.07	20.6884	0.0399

The robust variant is BSTOA9 in terms of the standard deviation values. The no robust variant is BSTOA11 in terms of the standard deviation values.

VII. CONCLUSION

This paper presents 17 new binary optimization algorithms that combine the sooty tern continuous optimization algorithm and 17 widely used transfer functions in literature. Wind Turbine Placement Problem (WTPP) is a binary optimization problem and WTPP is used as a benchmark problem in this work. 100 dimensional (10x10 grid type) WTPP is solved by these 17 binary variants of STOA.

This work is a work-in-progress study. This short paper/extended abstract is prepared for presenting the preliminary results of this work in the International Conference on Interdisciplinary Applications of Artificial Intelligence (ICIDAAI-2021) to be held Online, Yalova, Turkey, 21-23 May 2021.

In future, the full paper of the work will be include these information: The peculiar parameter analysis of STOA, The determination of the effects of the different iteration numbers, The analyzing the solution quality of the new binary variants on the 400 dimensional (20x20 grid type) WTPPs.

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