## **Bio-Inspired Feature Selection: An Improved Binary Particle Swarm Optimization Approach**

**Background:** Feature selection is an effective approach to reduce the number of features of data, which enhances the performance of classification in machine learning. The goal of feature selection in this work is to reduce the number of selected features while maximizing the classification accuracy, which can be regarded as a multi-objective optimization problem.

**Problem:** In this paper, we formulate a joint feature selection problem to reduce the number of the selected features while enhancing the accuracy.

**Method:** An improved binary particle swarm optimization (IBPSO) algorithm is proposed to solve the formulated problem.

**Experimental Setting:** In the feature selection tests, the genetic algorithm (GA), binary firefly algorithm (BFA), binary cuckoo search (BCS), BPSO, and binary bat algorithm (BBA) are introduced as the comparison algorithms. Moreover, the key parameter setups of these comparison algorithms as well as the proposed IBPSO are listed in Table 3. In addition, the maximum number of iterations for each algorithm is set as 200, the population size (number of searching agents) is 20, and the dimension of solution is equal to the feature number of each dataset. Note that the performance of a metaheuristic's algorithm is directly affected by the population size and the number of iterations. Specifically, if the algorithm is with large population size, it may achieve better optimization performance than the algorithm with small population size. Moreover, if an algorithm has more numbers of iterations, then it may obtain better results than the algorithm with less numbers of iterations. Thus, we use the same population size and the number of iterations for each algorithm to make a fair comparison between different algorithms.

Algorithm	Values of key parameters					
GA	Mutation rate $= 0.05$ , Crossover rate $= 0.5$					
BFA	Random coefficient = $0.1$ , Absorption coefficient = $0.3$					
BCS	Discovery probability = $0.25$ , $\alpha = 1$					
BPSO	$c_1 = 1.5, c_2 = 2.0$					
BBA	$A = 0.25, Q_{max} = 2, Q_{min} = 0$					
IBPSO	$c_1 = 1.75, c_2 = 2.0, \alpha = 1, \omega_{max} = 2, \omega_{min} = 0$					

**TABLE 3** Parameter Setups of Different Algorithms

Each algorithm is independently run for 30 times to solve the feature selection problems of these selected datasets, and the numerical statistics results will be presented. Moreover, in each test, we use 80 % of the instances for training, and the rest ones are used for testing, which is a common way adopted by several previous works.

The computer used for the tests is with an Intel(R) Xeon(R) E5-2630 v4 CPU and the RAM is 32 GB. Moreover, the abovementioned algorithms for feature selections are implemented by Python.

## **Experimental Result:**

**Performance Evaluations of Different Algorithms:** The results of the selected 16 datasets are shown in two separated tables. It can be seen from the tables that the proposed IBPSO algorithm achieves the best average fitness function values on 12 datasets, which means it has better performance than other comparison algorithms.

**Feature Selection Accuracies:** Similarly, the numerical statistics results of different algorithms for each dataset are presented in these tables. As can be seen, IBPSO algorithm achieves the best average accuracies of feature selection results on 10 datasets and the best accuracy results on 13 datasets. Thus, IBPSO algorithm has the best performance in terms of feature selection accuracies on these selected datasets compared to other algorithms.

Beastcancer	Dataset	Algorithm	Best	Worst	SD	Mean	CPU Time
Breastcancer	Breastcancer	GA	0.0272	0.0272	0.0000	0.0272	69.9977
BPSO   0.0272   0.0272   0.0000   0.0272   136.9305   BBA   0.0272   0.0272   0.0000   0.0272   142.7571   18PSO   0.0272   0.0000   0.0272   142.7571   18PSO   0.0272   0.0000   0.0272   142.7571   18PSO   0.0389   0.0416   0.0008   0.0396   83.9037   18ESO   0.0389   0.0412   0.0004   0.0405   168.6450   169.0009   1.0004   179.6460		BFA	0.0272	0.0309	0.0013	0.0288	138.5477
BBA		BCS	0.0272	0.0272	0.0000	0.0272	20.8977
BPSO		BPSO	0.0272	0.0272	0.0000	0.0272	136.9305
BreastEW BCS		BBA	0.0272	0.0272	0.0000	0.0272	142.7571
BreastEW BCS		IBPSO	0.0272	0.0272	0.0000	0.0272	146.9765
BreastEW   BCS   0.0433   0.0470   0.0010   0.0448   179.9466   BPSO   0.0399   0.0409   0.0003   0.0404   171.6200   BBA   0.0392   0.0399   0.0002   0.0396   167.6903   IBPSO   0.0389   0.0392   0.0002   0.0396   168.3109   0.0389   0.0392   0.0000   0.0396   168.3109   0.0389   0.0392   0.0000   0.0396   168.3109   0.0388   0.0392   0.0002   0.0396   168.3109   0.0006   0.0046   0.0046   0.0046   0.0059   188.3626   0.0046   0.00123   0.0028   0.0086   115.8868   0.0046   0.0046   0.0004   0.0046   198.0611   0.0046   0.0046   0.0046   0.0046   0.0046   199.2861   0.0046   0.0046   0.0046   0.0046   0.0046   199.2861   0.0046   0.0046   0.0046   0.0046   0.0046   197.6734   0.0057   0.2132   0.0058   0.0586   0.0046		GA	0.0389	0.0416	0.0008	0.0396	83.9037
BPSO		BFA	0.0399	0.0412	0.0004	0.0405	168.6450
BBA   0.0392   0.0000   0.0039   167.6903	DEW	BCS	0.0433	0.0470	0.0010	0.0448	179.9466
BPSO	BreastEW	BPSO	0.0399	0.0409	0.0003	0.0404	171.6200
Exactly    BFA		BBA	0.0392	0.0399	0.0002	0.0396	167.6903
Exactly  BEA BCS 0.0046 0.0123 0.0028 0.0086 115.8868 1198.0611 115.8868 117.00046 0.0004 0.0046 0.0007 0.2097 0.2097 0.0000 0.2097 0.2097 0.0000 0.2097 177.7468 18PSO 0.2097 0.2097 0.0000 0.2097 184.6734 184.6734 184.6734 184.6734 184.6734 184.6734 185.6860 185.8868 185.8868 185.89600 185.8960 185.89600 185.89600 185.89600 185.89600 185.89600 185.89600 185.8		IBPSO	0.0389	0.0392	0.0002	0.0390	168.3109
Exactly  BCS BPSO 0.0046 0.0046 0.0000 0.0046 0.0000 0.0046 198.0611 199.2861 1BPSO 0.0046 0.0046 0.0000 0.0046 199.2861 198.0611 199.2861 198.0612 199.2861 198.0611 199.2861 198.0611 199.2861 198.0611 199.2861 198.0611 199.2861 198.0611 199.2861 198.0611 199.2861 198.0613 108.0000 0.2097 178.1391 177.0541 186.8110 0.2097 0.2097 0.0000 0.2097 186.8110 177.7468 189.0000 0.2097 0.0000 0.2097 184.6734 184.6734 189.0000 0.1490 0.1607 0.0045 0.1525 113.1633 189.0051 0.1525 113.1633 189.001490 0.1490 0.0000 0.1490 114.3146 115.8868 10.0000 0.0000 0.1490 0.1490 0.1490 0.0000 0.1490 0.1490 0.1490 0.0000 0.1490 114.3146 114.3146 114.3146 115.8868 109.0000 0.2097 184.6734 114.3146 114.4943 114.6943 114.3146 114.3146 115.8868 100000 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.1490 0.0000 0.1490 0.0000 0.1490 0.0000 0.1490 0.0000 0.1490 0.000		GA	0.0046	0.0046	0.0000	0.0046	100.7601
BPSO		BFA	0.0046	0.0173	0.0038	0.0059	188.3626
BBA   0.0046   0.0000   0.0046   199.2861	T	BCS	0.0046	0.0123	0.0028	0.0086	115.8868
BPSO   0.0046   0.0046   0.0046   197.6734	Exactly	BPSO	0.0046	0.0046	0.0000	0.0046	198.0611
Exactly2 BFA 0.2097 0.2260 0.0057 0.2132 97.3038 BFA 0.2097 0.2097 0.0000 0.2097 178.1391 BFSO 0.2097 0.2309 0.0081 0.2173 117.0541 BFSO 0.2097 0.2097 0.0000 0.2097 177.7468 BFSO 0.2097 0.2097 0.0000 0.2097 177.7468 BFSO 0.2097 0.2097 0.0000 0.2097 177.7468 BFSO 0.2097 0.2097 0.0000 0.2097 184.6734 BFSO 0.1490 0.1648 0.0061 0.1529 57.3660 BFA 0.1490 0.1607 0.0045 0.1525 113.1633 BCS 0.1490 0.1607 0.0045 0.1525 113.1633 BFSO 0.1490 0.1490 0.0000 0.1490 114.3146 BFSO 0.1490 0.1490 0.0000 0.1490 114.3146 BFSO 0.1490 0.1490 0.0000 0.1490 114.3146 BFSO 0.1490 0.1490 0.0000 0.1490 117.7609 BFSO 0.5385 0.5836 0.0136 0.5602 54.3051 BFSO 0.5583 0.5798 0.0063 0.5703 013.0773 BFSO 0.5583 0.5704 0.0063 0.5614 108.7586 BFSO 0.5385 0.5704 0.0006 0.5558 108.5527 BFSO 0.5385 0.5704 0.0009 0.5558 108.5527 BFSO 0.0946 0.1035 0.0094 0.5551 112.4991 BFSO 0.0946 0.1035 0.0094 0.0094 142.5023 BFSO 0.0946 0.1035 0.0099 0.0994 142.5023 BFSO 0.0946 0.1035 0.0029 0.0994 142.5023 BFSO 0.0946 0.1035 0.0029 0.0994 142.5023 BFSO 0.0547 0.0993 0.0066 0.0849 141.3256 BFSO 0.0547 0.0993 0.0066 0.0849 141.3256 BFSO 0.0547 0.0999 0.0011 0.0749 148.5394 GA 0.2534 0.2846 0.0100 0.2644 57.9660 BFSO 0.2589 0.2850 0.0080 0.2751 116.4804		BBA	0.0046	0.0046	0.0000	0.0046	199.2861
Exactly2 BFA 0.2097 0.2097 0.0000 0.2097 178.1391 BCS 0.2097 0.2309 0.0081 0.2173 117.0541 BPSO 0.2097 0.2097 0.0000 0.2097 186.8110 BBA 0.2097 0.2097 0.0000 0.2097 177.7468 IBPSO 0.2097 0.0000 0.2097 184.6734 GA 0.1490 0.1648 0.0061 0.1529 57.3660 BFA 0.1490 0.1638 0.0051 0.1525 113.1633 BCS 0.1490 0.1638 0.0051 0.1525 113.1633 BCS 0.1490 0.1638 0.0051 0.1572 62.2022 BPSO 0.1490 0.1490 0.0000 0.1490 114.3146 BBA 0.1490 0.1490 0.0000 0.1490 114.3146 BBA 0.1490 0.1490 0.0000 0.1490 114.6943 IBPSO 0.1490 0.1490 0.0000 0.1490 117.7609 BCS 0.5583 0.5836 0.0136 0.5602 54.3051 BFA 0.5511 0.5660 0.0046 0.5624 108.4117 BCS 0.5583 0.5798 0.0063 0.5703 103.0773 BCS 0.5583 0.5798 0.0063 0.5614 108.7586 BBA 0.5385 0.5704 0.0100 0.5558 108.5527 IBPSO 0.5385 0.5704 0.0100 0.5558 108.5527 IBPSO 0.5385 0.5704 0.0004 0.5551 112.4991 BCS 0.0063 0.0066 0.0947 138.3002 BCS 0.1092 0.1198 0.0041 0.1151 145.1466 BPSO 0.0946 0.1035 0.0029 0.0994 142.5023 BBA 0.0754 0.0993 0.0066 0.0849 141.3256 IBPSO 0.0547 0.0993 0.0066 0.0849 141.3256 BPSO 0.0547 0.0999 0.0113 0.0749 148.5394 GA 0.2534 0.2846 0.0100 0.2644 57.9660 BFA 0.2603 0.2763 0.0055 0.2700 114.3705 BCS 0.2589 0.2850 0.0080 0.2751 116.4804		IBPSO	0.0046	0.0046	0.0000	0.0046	197.6734
BCS   0.2097   0.2309   0.0081   0.2173   117.0541     BPSO   0.2097   0.2097   0.0000   0.2097   186.8110     BBA   0.2097   0.2097   0.0000   0.2097   177.7468     IBPSO   0.2097   0.2097   0.0000   0.2097   177.7468     IBPSO   0.2097   0.0000   0.2097   177.7468     BFA   0.1490   0.1648   0.0061   0.1525   113.1633     BCS   0.1490   0.1638   0.0051   0.1572   62.2022     BPSO   0.1490   0.1490   0.0000   0.1490   114.3146     BBA   0.1490   0.1490   0.0000   0.1490   114.3146     BBA   0.1490   0.1490   0.0000   0.1490   114.6943     IBPSO   0.1490   0.1490   0.0000   0.1490   117.7609     GA   0.5385   0.5583   0.0063   0.5703   103.0773     BFA   0.5511   0.5660   0.0046   0.5624   108.4117     BCS   0.5583   0.5704   0.0063   0.5614   108.7586     BBA   0.5385   0.5704   0.0100   0.5558   108.5527     IBPSO   0.5385   0.5704   0.0094   0.5551   112.4991     GA   0.0747   0.1075   0.0089   0.0938   69.3591     BFA   0.0750   0.1038   0.0076   0.0947   138.3002     BBA   0.0754   0.0993   0.0066   0.0849   141.3256     BBA   0.2534   0.2846   0.0100   0.2644   57.9660     BFA   0.2603   0.2763   0.0055   0.2701   116.4804     BCS   0.2589   0.2850   0.0080   0.2751   116.4804		GA	0.2097	0.2260	0.0057	0.2132	97.3038
BPSO   0.2097   0.2097   0.0000   0.2097   186.8110		BFA	0.2097	0.2097	0.0000	0.2097	178.1391
BBA   0.2097   0.2097   0.0000   0.2097   186.8110	E1-2	BCS	0.2097	0.2309	0.0081	0.2173	117.0541
BPSO   0.2097   0.2097   0.0000   0.2097   184.6734	Exactly2	BPSO	0.2097	0.2097	0.0000	0.2097	186.8110
HeartEW		BBA	0.2097	0.2097	0.0000	0.2097	177.7468
HeartEW   BFA   0.1490   0.1607   0.0045   0.1525   113.1633     BCS   0.1490   0.1638   0.0051   0.1572   62.2022     BPSO   0.1490   0.1490   0.0000   0.1490   114.3146     BBA   0.1490   0.1490   0.0000   0.1490   114.6943     BPSO   0.1490   0.1490   0.0000   0.1490   117.7609     GA   0.5385   0.5836   0.0136   0.5602   54.3051     BFA   0.5511   0.5660   0.0046   0.5624   108.4117     BCS   0.5583   0.5798   0.0063   0.5703   103.0773     BPSO   0.5583   0.5764   0.0063   0.5614   108.7586     BBA   0.5385   0.5704   0.0100   0.5551   103.7586     BBA   0.0750   0.1038   0.0076   0.0947   138.3002     SonarEW   BCS   0.0946   0.1035   0.0029   0.0947   138.3002     BBA   0.0754   0.0993   0.0066   0.0849   141.3256     BBSO   0.0547   0.0929   0.0113   0.0749   148.5394     GA   0.2534   0.2846   0.0100   0.2644   57.9660     BFA   0.2603   0.2763   0.0055   0.2700   114.3705     BCS   0.2589   0.2850   0.0080   0.2751   116.4804		IBPSO	0.2097	0.2097	0.0000	0.2097	184.6734
HeartEW   BFA   0.1490   0.1607   0.0045   0.1525   113.1633     BCS   0.1490   0.1638   0.0051   0.1572   62.2022     BPSO   0.1490   0.1490   0.0000   0.1490   114.3146     BBA   0.1490   0.1490   0.0000   0.1490   114.6943     BPSO   0.1490   0.1490   0.0000   0.1490   117.7609     GA   0.5385   0.5836   0.0136   0.5602   54.3051     BFA   0.5511   0.5660   0.0046   0.5624   108.4117     BCS   0.5583   0.5798   0.0063   0.5703   103.0773     BPSO   0.5583   0.5764   0.0063   0.5614   108.7586     BBA   0.5385   0.5704   0.0100   0.5551   103.7586     BBA   0.0750   0.1038   0.0076   0.0947   138.3002     SonarEW   BCS   0.0946   0.1035   0.0029   0.0947   138.3002     BBA   0.0754   0.0993   0.0066   0.0849   141.3256     BBSO   0.0547   0.0929   0.0113   0.0749   148.5394     GA   0.2534   0.2846   0.0100   0.2644   57.9660     BFA   0.2603   0.2763   0.0055   0.2700   114.3705     BCS   0.2589   0.2850   0.0080   0.2751   116.4804		GA	0.1490	0.1648	0.0061	0.1529	57.3660
BPSO		BFA		0.1607	0.0045	0.1525	113.1633
BPSO 0.1490 0.1490 0.0000 0.1490 114.6943 IBPSO 0.1490 0.1490 0.0000 0.1490 114.6943 IBPSO 0.1490 0.1490 0.0000 0.1490 117.7609 GA 0.5385 0.5836 0.0136 0.5602 54.3051 0.5660 0.0046 0.5624 108.4117 BPSO 0.5583 0.5798 0.0063 0.5703 103.0773 BPSO 0.5583 0.5704 0.0063 0.5614 108.7586 BBA 0.5385 0.5704 0.0100 0.5558 108.5527 IBPSO 0.5385 0.5704 0.0094 0.5551 112.4991 GA 0.0747 0.1075 0.0089 0.0938 69.3591 BPSO 0.5000 0.1038 0.0076 0.0947 138.3002 BPSO 0.0946 0.1035 0.0029 0.0994 142.5023 BBA 0.0754 0.0993 0.0066 0.0849 141.3256 IBPSO 0.0547 0.0929 0.0113 0.0749 148.5394 GA 0.2534 0.2846 0.0100 0.2644 57.9660 BPSO 0.2589 0.2850 0.0080 0.2751 116.4804	IItPW	BCS	0.1490	0.1638	0.0051	0.1572	62.2022
BPSO   0.1490   0.1490   0.0000   0.1490   117.7609	HeartEW	BPSO	0.1490	0.1490	0.0000	0.1490	114.3146
Care		BBA	0.1490	0.1490	0.0000	0.1490	114.6943
BFA   0.5511   0.5660   0.0046   0.5624   108.4117		IBPSO	0.1490	0.1490	0.0000	0.1490	117.7609
Lymphography		GA	0.5385	0.5836	0.0136	0.5602	54.3051
BPSO   0.5583   0.5764   0.0063   0.5614   108.7586     BBA   0.5385   0.5704   0.0100   0.5558   108.5527     IBPSO   0.5385   0.5704   0.0094   0.5551   112.4991     GA   0.0747   0.1075   0.0089   0.0938   69.3591     BFA   0.0750   0.1038   0.0076   0.0947   138.3002     BCS   0.1092   0.1198   0.0041   0.1151   145.1466     BPSO   0.0946   0.1035   0.0029   0.0994   142.5023     BBA   0.0754   0.0993   0.0066   0.0849   141.3256     BBSO   0.0547   0.0929   0.0113   0.0749   148.5394     GA   0.2534   0.2846   0.0100   0.2644   57.9660     BFA   0.2603   0.2763   0.0055   0.2700   114.3705     BCS   0.2589   0.2850   0.0080   0.2751   116.4804		BFA	0.5511	0.5660	0.0046	0.5624	108.4117
BBA 0.5385 0.5704 0.0100 0.5558 108.5527 BBPSO 0.5385 0.5704 0.0100 0.5551 112.4991 0.003 0.5585 0.5704 0.0094 0.5551 112.4991 0.003 0.503 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.004 0.005 0.002 0.0094 0.005 0.00	Tb. a annuaban	BCS	0.5583	0.5798	0.0063	0.5703	103.0773
BPSO   0.5385   0.5704   0.0094   0.5551   112.4991	Lymphography	BPSO	0.5583	0.5764	0.0063	0.5614	108.7586
SonarEW		BBA	0.5385	0.5704	0.0100	0.5558	108.5527
SonarEW BFA 0.0750 0.1038 0.0076 0.0947 138.3002 BCS 0.1092 0.1198 0.0041 0.1151 145.1466 BPSO 0.0946 0.1035 0.0029 0.0994 142.5023 BBA 0.0754 0.0993 0.0066 0.0849 141.3256 IBPSO 0.0547 0.0929 0.0113 0.0749 148.5394 GA 0.2534 0.2846 0.0100 0.2644 57.9660 BFA 0.2603 0.2763 0.0055 0.2700 114.3705 BCS 0.2589 0.2850 0.0080 0.2751 116.4804		IBPSO	0.5385	0.5704	0.0094	0.5551	112.4991
SonarEW         BCS BPSO         0.1092 0.0946         0.1198 0.0035         0.0041 0.0029         0.1151 0.0994         145.1466 142.5023           BBA IBPSO         0.0754 0.0547         0.0993 0.0999         0.0066 0.0849         141.3256 141.3256           GA BFA 0.2534         0.2846 0.2534         0.0100 0.2644         0.2644 57.9660         57.9660 114.3705           BFA 0.2603         0.2763 0.0055         0.0055 0.2700         0.2751 116.4804		GA	0.0747	0.1075	0.0089	0.0938	69,3591
BPSO 0.0946 0.1035 0.0029 0.0994 142.5023 BBA 0.0754 0.0993 0.0066 0.0849 141.3256 IBPSO 0.0547 0.0929 0.0113 0.0749 148.5394 GA 0.2534 0.2846 0.0100 0.2644 57.9660 BFA 0.2603 0.2763 0.0055 0.2700 114.3705 BCS 0.2589 0.2850 0.0080 0.2751 116.4804		BFA	0.0750	0.1038	0.0076	0.0947	138.3002
BPSO 0.0946 0.1035 0.0029 0.0994 142.5025 BBA 0.0754 0.0993 0.0066 0.0849 141.3256 IBPSO 0.0547 0.0929 0.0113 0.0749 148.5394 GA 0.2534 0.2846 0.0100 0.2644 57.9660 BFA 0.2603 0.2763 0.0055 0.2700 114.3705 BCS 0.2589 0.2850 0.0080 0.2751 116.4804	SonarEW	BCS	0.1092	0.1198	0.0041	0.1151	145.1466
BPSO 0.0547 0.0929 0.0113 0.0749 148.5394  GA 0.2534 0.2846 0.0100 0.2644 57.9660  BFA 0.2603 0.2763 0.0055 0.2700 114.3705  BCS 0.2589 0.2850 0.0080 0.2751 116.4804		BPSO	0.0946	0.1035	0.0029	0.0994	142.5023
GA 0.2534 0.2846 0.0100 0.2644 <b>57.9660</b> BFA 0.2603 0.2763 0.0055 0.2700 114.3705 BCS 0.2589 0.2850 0.0080 0.2751 116.4804		BBA	0.0754	0.0993	0.0066	0.0849	141.3256
BFA 0.2603 0.2763 0.0055 0.2700 114.3705 BCS 0.2589 0.2850 0.0080 0.2751 116.4804		IBPSO	0.0547	0.0929	0.0113	0.0749	148.5394
BCS 0.2589 0.2850 0.0080 0.2751 116.4804	SpectEW	GA	0.2534	0.2846	0.0100	0.2644	57.9660
BCS 0.2589 0.2850 0.0080 0.2751 116.4804		BFA	0.2603	0.2763	0.0055	0.2700	114.3705
ODESIEW PROPERTY OF THE PROPER				0.2850	0.0080		116.4804
BPSO   0.2585   0.2731   0.0048   0.2661   116.6135		BPSO	0.2585	0.2731	0.0048	0.2661	116.6135
BBA 0.2488 0.2662 0.0053 0.2575 116.1148				0.2662	0.0053	0.2575	116.1148
IBPSO 0.2507 0.2777 0.0079 0.2623 119.6393		IBPSO	0.2507	0.2777	0.0079	0.2623	119.6393

**TABLE 4** Fitness Values Obtained by Different Algorithms (Datasets 1 to 8)

Dataset	Algorithm	Best	Worst	SD	Mean	CPU Time
CongressEW	GA	0.0224	0.0279	0.0017	0.0256	75.2692
	BFA	0.0224	0.0285	0.0016	0.0252	146.5245
	BCS	0.0269	0.0320	0.0016	0.0289	132.6274
	BPSO	0.0224	0.0256	0.0013	0.0237	148.4214
	BBA	0.0224	0.0281	0.0023	0.0249	148.0824
	IBPSO	0.0224	0.0275	0.0020	0.0243	151.8781
	GA	0.0846	0.1141	0.0105	0.0997	78.1663
IonosphereEW	BFA	0.0901	0.1154	0.0070	0.1052	154.8571
	BCS	0.1023	0.1384	0.0095	0.1270	167.1765
	BPSO	0.0961	0.1132	0.0059	0.1050	157.9756
	BBA	0.0791	0.1066	0.0088	0.0943	153.9433
	IBPSO	0.0705	0.1147	0.0140	0.0905	159.0922
	GA	0.0238	0.0359	0.0034	0.0295	982.3659
	BFA	0.0338	0.0454	0.0032	0.0389	1617.9190
KryskpEW	BCS	0.0324	0.0403	0.0023	0.0379	2082.1176
KIVSKPEW	BPSO	0.0276	0.0371	0.0026	0.0322	1915.5977
	BBA	0.0259	0.0353	0.0029	0.0286	1982.8664
	IBPSO	0.0210	0.0276	0.0024	0.0241	2116.3775
	GA	0.1564	0.1564	0.0000	0.1564	89.3500
	BFA	0.1564	0.1564	0.0000	0.1564	188.8746
Tic-tac-toe	BCS	0.1564	0.1564	0.0000	0.1564	13.8251
Tic-tac-toe	BPSO	0.1564	0.1564	0.0000	0.1564	177.2706
	BBA	0.1564	0.1564	0.0000	0.1564	196.1019
	IBPSO	0.1564	0.1564	0.0000	0.1564	204.5367
	GA	0.0493	0.0630	0.0033	0.0558	58.6129
	BFA	0.0493	0.0590	0.0028	0.0535	115.3932
Vote	BCS	0.0551	0.0611	0.0024	0.0579	102.7837
vote	BPSO	0.0493	0.0539	0.0017	0.0503	117,6988
	BBA	0.0493	0.0520	0.0008	0.0496	116.0473
	IBPSO	0.0493	0.0539	0.0016	0.0509	118.0201
	GA	0.1577	0.1761	0.0054	0.1677	3739.2315
	BFA	0.1778	0.1834	0.0019	0.1810	6207.9586
WFTW	BCS	0.1715	0.1809	0.0027	0.1764	9771.4048
WaveformEW	BPSO	0.1644	0.1769	0.0037	0.1721	7674.0827
	BBA	0.1625	0.1733	0.0035	0.1669	7524.7088
	IBPSO	0.1573	0.1698	0.0033	0.1621	7356.3544
	GA	0.0584	0.0944	0.0107	0.0702	53.8582
	BFA	0.0584	0.0757	0.0060	0.0639	108.6919
7	BCS	0.0584	0.0764	0.0055	0.0668	89.2766
Zoo	BPSO	0.0584	0.0674	0.0027	0.0593	105.4454
	BBA	0.0584	0.0680	0.0028	0.0596	106.7008
	IBPSO	0.0584	0.0668	0.0025	0.0593	107.3102
Lungcancer	GA	0.0264	0.0283	0.0006	0.0275	49.9007
	BFA	0.0271	0.0281	0.0003	0.0277	102.6213
	BCS	0.0281	0.0549	0.0113	0.0373	100.4391
	BPSO	0.0271	0.0287	0.0004	0.0280	103.4912
	BBA	0.0269	0.0280	0.0003	0.0276	102.6021
	IBPSO	0.0256	0.0269	0.0004	0.0264	107.6533
	10100	310200	310203	3.0004	3.0204	207,0000

**TABLE 5** Fitness Values Obtained by Different Algorithms (Datasets 9 to 16)

Conclusion: In this paper, the feature selection problem is investigated. First, a joint feature selection problem is formulated, and then we propose an efficient algorithm called IBPSO to solve the formulated problem. In IBPSO, we first introduce the Lévy flight mechanism to improve the local search performance of the algorithm. Second, a weighting inertia coefficient operator is proposed to enhance the global search ability. Moreover, we use the mutation mechanism to improve the population diversity of the algorithm. Finally, a binary method is adopted to make the continuous algorithm suitable for the binary feature selection problem. Experiments are conducted on several classical datasets for the evaluations of the proposed algorithm, and the results show that the overall performance of IBPSO outperforms GA, BFA, BCS, BPSO and BBA for solving the feature selection problem. In our future work, more test datasets will be considered to further evaluate the proposed algorithm.

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