Supplementary material

IV. Proposed Method

F. Example for Implementation

For an illustration, an imbalanced dataset Ecoli1 from the KEEL database is selected to implement the proposed algorithm. Ecoli1 has 336 samples and 7 features, with an imbalance ratio of 3.36. At first, the dataset is divided into training set $\boldsymbol{X}_{trian}$ and test set $\boldsymbol{X}_{test}$ by 5-fold cross validation, and then the feature-weighted sum y of each majority class sample in the $\boldsymbol{X}_{trian}$ is calculated by Eq.(1). According to the ascending order of y, three balanced subsets $\boldsymbol{X}_1, \boldsymbol{X}_2, \boldsymbol{X}_3$ can be obtained ($Q = 3$). For subset $\boldsymbol{X}_1$, the samples in the $\boldsymbol{X}_1$ first find their three nearest neighbor samples ($K = 3$) and then concatenate with them to form the envelope dataset $\boldsymbol{X}_{1e}$ via Eq.(8). The FCM is used to cluster $\boldsymbol{X}_{1e}$ to obtain $\mathbf{V}_{1e}$ and LGSCM is used to enhance consistency of $\boldsymbol{X}_{1e}, \mathbf{V}_{1e}$ and $\mathbf{V}_{1e}{}'$ can be obtained. The joint optimization of FCM and LGSCM as shown in Eq.(19) means a layer of DSENLG, after three layers of DSENLG, the $\mathbf{V}_{1e}{}'^{3}$ ($L = 3$) can be obtained and used to train the base classifier C_1 .The other two subsets $\boldsymbol{X}_2, \boldsymbol{X}_3$ can be transformed in the same way to obtain the envelope sample set $\mathbf{V}_{2e}{}'^{3}, \mathbf{V}_{3e}{}'^{3}$, and $\mathbf{V}_{2e}{}'^{3}, \mathbf{V}_{3e}{}'^{3}$ are used to train the base classifier C_2, C_3.

For a sample x_{test} in the test set $\boldsymbol{X}_{test}$, the deep envelope samples $x_{test\ 1e}{}^{3}, x_{test\ 2e}{}^{3}, x_{test\ 3e}{}^{3}$ can be obtained via the trained DSENLG, and then input to the C_1, C_2, C_3 to obtain the predicted labels, respectively. After that, the final prediction result of the test sample is determined by the voting mechanism.

V. Time Complexity Analysis

A theoretical analysis for DSENLG-IE with respect to the computational complexity was conducted. The time complexity $T_{\text{DSENLG-IE}}$ is computed by

$$T_{\text{DSENLG-IE}} = T_{\text{SG}} + Q \cdot T_{\text{DSENLG}} + T_{\text{EVM}} \tag{25}$$

where $T_{\text{SG}}, T_{\text{DSENLG}}, T_{\text{EVM}}$ denote computational costs for the SG, DSENLG network and EVM, respectively.

T_{SG} is affected by the number of majority samples n_1 and features s, so T_{SG} can be given by

$$T_{\text{SG}} = O\left(n_1 \cdot s\right) \tag{26}$$

$T_{\text{DSEN-LG}}$ contains the computational costs of SNC, MIFCM and LGSCM as follows

$$T_{\text{DSENLG}} = T_{\text{DSEN}} + T_{\text{GS M}} = T_{\text{SNC}} + T_{\text{MIFCM}} + T_{\text{LGSCM}} \tag{27}$$

T_{SNC} is related to the number of data $2n_2$ and features s, which can be given by

$$T_{\text{SNC}} = O\left(2n_2 s\right) \tag{28}$$

T_{MIFCM} is related to the number of iterations w, the number of features s, the number of clusters c, the number of data $2n_2$ and the number of layers of clustering L. As the time complexity of the FCM algorithm is $O\left(wsc^2 2n_2\right)$ and $c = 2(n_2 - L)$, the T_{MIFCM} can be given by

$$T_{\text{MIFCM}} = O\left(wsLn_2{}^3\right) \tag{29}$$

T_{LGSCM} includes computational costs of updating $\Theta, \mathcal{H}, \mathcal{G}$ .Suppose the number of iterations is w_1 .Then the computational costs of LGSCM can be given by

$$T_{\text{LGSCM}} = O\left(w_1 L n_2{}^3\right) + O\left(w_1 L n_2{}^2\right) \tag{30}$$

T_{EVM} is related to the number of base classifiers Q .So T_{EVM} can be given by

$$T_{\text{EVM}} = Q \tag{31}$$

Therefore, the total time complexity of DSENLG-IE is approximately equal to:

$$T_{\text{DSENLG-IE}} = O\left(n_1 \cdot s\right) + Q \cdot \begin{pmatrix} O\left(n_2 s\right) + O\left(wsLn_2{}^3\right) \\ +O\left(w_1 L n_2{}^3\right) + O\left(w_1 L n_2{}^2\right) \end{pmatrix} \tag{32}$$

VI. Experimental Results and Their Analysis

B. Ablation Study for Verification of DSENLG

To demonstrate the effectiveness of deep envelope samples obtained by DSEN-LG, ablation method was adopted to compare the proposed algorithm with the MlFCM and IE. Table II is the comparison results between the IE, MlFCM and proposed DSENLG-IE. From Table II, the proposed algorithm shows a large improvement in performance on all four metrics compared to MlFCM and IE method for most datasets. This indicates envelope samples generated through DSEN-LG network are of high quality and very effective. The DSENLG-IE is better than the IE. It means that the multilayer clustering can obtain envelope samples with high-quality, which are more helpful for imbalanced learning. The DSENLG-IE is better than the MlFCM. It means that the LGSCM can well enhance the consistency of the interlayer samples of MlFCM, thereby contributing to improving the quality of the envelope samples.

TABLE II
Ablation method for the proposed method

Dataset	Measure	IE	MlFCM	DSENLG-IE	Dataset	Measure	IE	MlFCM	DSENLG-IE
Iris0	AUC	98.80±2.78	78.15±4.03	**100.0±0.00**	Glass0	AUC	74.62±6.70	67.11±3.92	**76.35±6.29**
	F-M	98.70±3.12	35.69±3.64	**100.0±0.00**		F-M	65.52±10.0	59.79±2.90	**67.19±9.05**
	G-M	98.75±2.95	75.69±4.34	**100.0±0.00**		G-M	73.02±7.98	58.12±6.76	**74.24±7.32**
	Mcc	98.23±4.09	34.68±5.10	**100.0±0.00**		Mcc	51.64±13.5	38.10±5.74	**57.95±12.6**
Vertebral	AUC	76.96±5.15	68.33±10.6	**83.98±7.29**	Haberman	AUC	55.41±7.27	53.31±6.87	**61.81±9.38**
	F-M	68.64±7.27	58.33±14.7	**78.41±7.08**		F-M	37.86±9.36	38.89±7.01	**43.65±8.57**
	G-M	76.10±5.89	68.31±10.1	**82.98±8.10**		G-M	54.11±8.89	52.29±6.58	**60.19±7.30**
	Mcc	54.69±10.0	34.44±14.4	**71.45±8.29**		Mcc	9.76±13.32	5.98±12.31	**21.59±8.67**
Vehicle1	AUC	66.52±3.54	63.18±4.31	**82.70±6.54**	Ecoli1	AUC	85.89±4.51	81.85±5.21	**92.47±4.39**
	F-M	50.54±4.09	46.30±5.32	**67.23±6.25**		F-M	69.34±6.91	64.82±6.97	**80.42±7.52**
	G-M	66.40±3.56	62.65±4.62	**81.74±7.15**		G-M	84.94±5.21	81.19±5.29	**92.09±4.84**
	Mcc	29.33±6.45	23.97±7.87	**57.01±9.87**		Mcc	61.84±8.75	54.87±9.68	**80.48±9.12**
New-thyroid1	AUC	95.06±4.83	70.00±11.7	**99.80±1.41**	Ecoli2	AUC	71.31±5.20	74.33±4.32	**93.62±7.25**
	F-M	85.92±10.2	53.99±23.6	**99.78±1.57**		F-M	39.84±5.18	42.42±3.79	**82.79±7.79**
	G-M	94.85±5.12	60.96±18.8	**99.79±1.49**		G-M	66.16±7.71	70.86±5.04	**92.76±7.51**
	Mcc	84.10±11.4	58.01±19.1	**100.0±0.00**		Mcc	31.95±6.89	35.53±5.89	**82.01±7.24**
Musk	AUC	86.32±2.74	55.52±5.58	**98.56±0.76**	Glass6	AUC	92.02±5.97	72.97±8.45	**98.13±5.07**
	F-M	58.88±4.88	16.46±1.63	**92.59±4.20**		F-M	77.01±12.4	37.50±15.0	**95.91±7.79**
	G-M	85.61±3.01	31.90±2.62	**98.55±0.77**		G-M	91.83±6.13	67.78±9.49	**97.96±5.68**
	Mcc	55.00±5.43	11.35±5.22	**91.50±4.82**		Mcc	74.46±13.7	32.56±17.9	**95.77±7.92**
Yeast3	AUC	91.46±2.54	67.95±3.16	**97.71±1.99**	Ecoli3	AUC	86.28±3.68	78.15±4.03	**95.70±4.69**
	F-M	69.97±4.52	28.62±1.78	**83.33±1.02**		F-M	50.22±5.68	35.69±3.64	**73.37±6.77**
	G-M	91.40±2.57	64.06±2.77	**97.68±2.09**		G-M	85.79±3.59	75.69±4.34	**95.50±4.98**
	Mcc	67.93±4.81	22.81±3.97	**82.56±1.12**		Mcc	49.37±6.15	34.68±5.10	**74.30±6.93**
Page-blocks0	AUC	92.68±1.05	69.23±2.92	**98.14±0.39**	Yeast 2vs4	AUC	92.40±4.01	84.37±4.90	**99.44±1.37**
	F-M	64.61±3.00	35.59±3.62	**90.43±3.06**		F-M	65.58±8.91	51.82±7.79	**76.08±11.6**
	G-M	92.56±1.05	67.98±4.15	**98.12±0.40**		G-M	92.23±4.06	84.26±4.93	**99.44±1.39**
	Mcc	64.06±2.90	27.96±4.28	**89.80±3.21**		Mcc	64.96±9.15	49.43±8.70	**76.48±11.7**
Yeast 05679vs4	AUC	75.05±5.13	67.02±6.83	**96.77±1.11**	Vowel0	AUC	95.34±1.66	83.94±5.31	**100.0±0.00**
	F-M	31.67±3.73	26.19±4.51	**72.73±2.89**		F-M	72.67±5.09	42.88±5.40	**100.0±0.00**
	G-M	72.78±4.93	65.00±6.46	**96.72±1.15**		G-M	95.28±1.66	83.05±5.95	**100.0±0.00**
	Mcc	29.87±6.11	20.26±8.16	**73.11±2.92**		Mcc	72.34±4.86	42.98±6.50	**100.0±0.00**
Glass 016vs2	AUC	70.45±12.5	58.71±2.73	**89.39±11.6**	Ecoli 0147vs2356	AUC	75.39±5.08	74.25±7.69	**97.81±3.15**
	F-M	**29.99±11.1**	19.07±2.87	22.22±10.9		F-M	29.94±3.56	31.70±7.55	**81.97±10.5**
	G-M	68.78±13.3	41.15±7.41	**88.76±12.5**		G-M	73.50±4.68	70.62±10.6	**97.73±3.37**
	Mcc	25.27±15.8	13.45±3.14	**31.38±12.9**		Mcc	29.04±5.71	31.85±9.79	**77.34±10.8**
climate	AUC	85.60±4.43	50.00±0.00	**79.93±4.80**	Glass2	AUC	71.87±10.4	61.98±2.76	**87.69±4.45**
	F-M	47.50±6.38	0.000±0.00	**70.60±4.56**		F-M	**26.12±7.01**	18.52±2.56	24.72±9.54
	G-M	85.35±4.44	0.000±0.00	**74.74±4.30**		G-M	70.07±10.1	48.62±5.79	**86.70±5.05**
	Mcc	47.25±6.91	0.000±0.00	**73.87±4.09**		Mcc	24.09±11.5	15.57±2.65	**32.47±9.00**
german	AUC	54.17±8.29	54.00±14.6	**84.48±9.24**	Shuttle-c0-vs-c4	AUC	99.07±0.33	90.57±9.19	**100.0±0.00**
	F-M	14.75±4.44	14.16±5.96	**23.08±5.05**		F-M	88.76±3.57	84.48±13.0	**100.0±0.00**
	G-M	52.72±7.71	52.06±14.5	**83.05±10.6**		G-M	99.07±0.33	89.71±10.2	**100.0±0.00**
	Mcc	4.500±8.90	3.760±14.7	**29.23±10.4**		Mcc	88.55±3.51	83.83±13.7	**100.0±0.00**
Yeast 1vs7	AUC	71.74±6.88	60.30±7.95	**83.72±6.06**	Ecoli4	AUC	80.30±5.24	74.92±2.66	**98.54±4.88**
	F-M	22.83±4.01	16.92±4.73	**30.00±8.23**		F-M	26.51±5.03	20.29±1.70	**87.87±8.94**
	G-M	70.50±7.30	58.68±9.12	**82.12±6.46**		G-M	78.51±6.00	70.50±3.81	**98.37±5.72**
	Mcc	22.17±7.03	10.74±8.29	**34.50±8.12**		Mcc	30.37±5.55	23.73±2.37	**88.61±8.51**
Page-blocks 13vs4	AUC	94.47±2.45	72.19±15.8	**98.50±1.38**	Dermatology-6	AUC	91.24±5.72	97.78±1.30	**100.0±0.00**
	F-M	55.13±11.1	45.72±22.2	**77.11±9.46**		F-M	58.79±11.0	74.47±12.3	**100.0±0.00**
	G-M	94.27±2.64	65.29±21.3	**98.49±1.41**		G-M	90.94±5.93	97.75±1.33	**100.0±0.00**
	Mcc	58.41±9.70	44.34±25.5	**78.88±7.20**		Mcc	60.14±10.4	75.74±11.3	**100.0±0.00**
svmguide3	AUC	78.72±10.0	51.98±7.20	**80.70±8.98**	Yeast 1458vs7	AUC	58.38±8.88	51.85±7.52	**72.14±9.29**
	F-M	**24.49±6.03**	9.520±2.70	15.38±3.27		F-M	10.20±2.41	8.580±1.60	**15.08±3.70**
	G-M	77.36±10.8	49.86±10.3	**78.36±7.87**		G-M	55.14±7.50	43.88±6.27	**68.13±10.8**
	Mcc	**27.62±9.51**	1.760±10.4	17.37±5.21		Mcc	7.020±7.41	1.700±7.15	**18.43±7.42**
Yeast4	AUC	84.70±3.80	74.62±5.99	**87.71±4.70**	Winequalit	AUC	62.93±4.27	41.53±9.49	**71.33±9.39**

	F-M	20.68±2.11	14.56±2.38	**43.34±6.42**	y-red-4	F-M	8.790±0.83	4.750±3.94	**17.53±5.74**
	G-M	83.90±3.54	73.78±5.68	**85.19±4.89**		G-M	57.22±3.80	36.21±8.60	**69.22±9.92**
	Mcc	28.11±3.25	18.71±4.68	**47.68±6.85**		Mcc	9.680±3.17	5.650±8.11	**19.25±8.39**
Yeast 1289vs7	AUC	64.99±5.72	61.78±8.39	**81.23±8.50**	Abalone 3vs11	AUC	96.67±6.73	99.99±0.07	**100.0±0.00**
	F-M	9.510±1.31	9.060±2.42	**29.30±1.67**		F-M	96.00±8.08	99.71±2.02	**100.0±0.00**
	G-M	63.11±4.76	60.78±8.14	**71.24±8.26**		G-M	96.33±7.41	99.99±0.07	**100.0±0.00**
	Mcc	10.60±4.03	8.410±6.05	**34.32±2.50**		Mcc	96.25±7.58	99.72±1.96	**100.0±0.00**
Yeast5	AUC	94.90±1.31	86.39±1.55	**97.55±5.15**	Ozone-one hr	AUC	68.32±2.51	60.79±2.25	**84.95±1.95**
	F-M	38.17±6.16	18.49±1.85	**63.43±9.52**		F-M	8.760±0.62	7.080±0.41	**58.20±4.42**
	G-M	94.75±1.39	85.29±1.82	**97.52±5.95**		G-M	62.31±3.03	48.59±2.24	**77.24±3.23**
	Mcc	46.02±5.24	27.22±2.04	**66.92±8.83**		Mcc	12.57±1.60	8.480±1.68	**44.99±4.56**
krvsk 3vs11	AUC	98.54±0.32	64.21±1.65	**100.0±0.00**	Abalone21 vs8	AUC	54.44±3.64	74.04±11.8	**91.95±1.57**
	F-M	66.39±5.17	7.360±0.36	**100.0±0.00**		F-M	5.140±0.89	10.47±3.70	**51.85±3.22**
	G-M	98.53±0.32	53.23±3.08	**100.0±0.00**		G-M	29.77±8.94	72.44±11.5	**91.17±1.68**
	Mcc	69.51±4.30	10.42±0.85	**100.0±0.00**		Mcc	4.620±2.49	15.47±7.85	**56.87±2.91**
Yeast6	AUC	82.39±4.41	79.01±5.10	**96.01±2.03**	Winequalit y-white3vs7	AUC	77.32±5.75	67.99±12.4	**92.63±6.79**
	F-M	14.99±1.65	11.70±1.55	**30.30±4.05**		F-M	10.48±1.68	10.88±4.87	**35.39±22.7**
	G-M	81.89±4.09	77.89±4.67	**95.92±3.47**		G-M	75.89±4.90	64.82±15.5	**91.99±8.05**
	Mcc	22.54±2.94	18.57±3.38	**40.54±3.30**		Mcc	16.91±3.49	13.14±8.99	**46.85±20.3**
Winequali ty-red 8vs67	AUC	71.33±8.76	64.28±6.25	**76.50±8.75**	krvsk0vs8	AUC	97.16±0.73	60.36±13.3	**98.17±2.02**
	F-M	7.740±1.68	6.170±1.17	**10.18±2.75**		F-M	40.80±6.94	4.750±1.43	**58.30±3.89**
	G-M	68.96±7.87	61.80±4.64	**75.24±8.72**		G-M	97.12±0.75	55.30±11.0	**98.14±2.06**
	Mcc	12.30±5.00	8.200±3.48	**16.19±5.53**		Mcc	49.16±5.63	57.20±7.22	**64.55±3.31**
Shuttle-2vs5	AUC	99.30±0.23	57.96±11.5	**100.0±0.00**	kddbuffero ver flowvsback	AUC	98.17±3.87	75.00±5.34	**100.0±0.00**
	F-M	68.77±7.45	11.76±13.0	**100.0±0.00**		F-M	97.96±4.37	66.67±8.73	**100.0±0.00**
	G-M	99.29±0.24	54.37±10.7	**100.0±0.00**		G-M	98.06±4.12	70.71±3.69	**100.0±0.00**
	Mcc	71.99±6.18	15.63±14.7	**100.0±0.00**		Mcc	98.04±4.17	70.47±10.3	**100.0±0.00**
krvsk 0vs15	AUC	98.25±0.51	78.07±13.3	**100.0±0.00**	kdd root kitback	AUC	96.70±7.17	70.00±8.12	**98.76±5.04**
	F-M	42.81±7.48	9.900±6.29	**100.0±0.00**		F-M	**95.93±9.09**	57.14±10.3	87.19±2.95
	G-M	98.24±0.52	70.06±18.2	**100.0±0.00**		G-M	96.31±8.15	63.25±8.36	**98.58±5.93**
	Mcc	51.26±5.98	18.52±4.89	**100.0±0.00**		Mcc	**96.28±8.20**	63.03±10.5	84.53±2.64
skinnonsk in	AUC	89.55±0.29	55.82±0.17	**99.29±0.86**	cod	AUC	96.70±5.64	53.34±0.43	**98.62±0.19**
	F-M	1.600±0.12	0.380±0.02	**78.32±3.93**		F-M	23.02±15.2	0.280±0.04	**54.67±1.64**
	G-M	88.93±0.33	34.13±0.49	**99.11±0.86**		G-M	96.62±5.84	25.78±1.66	**98.61±0.19**
	Mcc	7.990±0.33	1.490±0.04	**82.18±3.83**		Mcc	33.40±15.9	0.960±0.02	**61.48±1.97**

C. Algorithm Comparison

1) Comparison with Classical IE Methods

Tables V lists the average AUC, F-M, G-M and Mcc values obtained by classical imbalanced ensemble methods and proposed DSENLG-IE method. It can be seen an overwhelming improvement of DSENLG-IE over the other imbalanced ensemble methods on all four criteria. In particular, when considering AUC and G-M, it is observable the method proposed in this paper provided the best performance on 40 and 39 datasets respectively, and never showed the worst performance on any dataset. For F-M and Mcc, the proposed method provided the best performance on 29 and 31 datasets respectively. Thus, DSENLG-IE perform best in most imbalanced datasets.

TABLE V
COMPARISON RESULTS OF THE ENSEMBLE METHODS ON 46 EXPERIMENTAL DATASETS

Data set	Mea sure	RBO[20]	SBO[21]	UBAG[22]	SBAG[10]	BBAG[37]	EYEE[38]	BACE[38]	GBDT[8]	DSENLG-IE
Iris0	AUC	99.90±0.70	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	99.00±2.00	**100.0±0.00**
	F-M	99.89±0.74	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	98.95±2.11	**100.0±0.00**
	G-M	99.90±0.72	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	98.97±2.05	**100.0±0.00**
	Mcc	99.85±1.04	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	98.52±2.97	**100.0±0.00**
Glas s0	AUC	78.40±6.84	72.03±2.65	79.19±2.50	77.84±6.31	**80.97±5.19**	79.54±7.01	77.14±7.00	76.60±6.44	76.35±6.29
	F-M	70.27±8.72	62.09±3.89	71.81±4.20	69.88±8.30	**73.46±6.27**	71.62±8.73	68.37±8.54	68.42±8.84	67.19±9.05
	G-M	77.56±7.42	70.92±3.41	78.93±2.16	77.25±6.68	**80.87±5.20**	79.33±7.27	76.50±7.67	75.63±7.10	74.24±7.32
	Mcc	56.87±11.7	44.51±4.29	57.17±8.05	55.41±12.2	**59.49±9.73**	56.90±12.9	52.34±12.2	54.14±12.9	57.95±12.6
Vert ebral	AUC	74.00±4.48	74.57±5.36	82.40±3.88	80.36±3.97	82.64±2.36	79.62±4.63	78.43±6.03	78.29±6.00	**83.98±7.29**
	F-M	64.32±6.09	65.33±7.93	75.35±4.93	73.18±5.46	75.78±3.07	71.21±5.41	70.15±7.39	70.39±8.03	**78.41±7.08**
	G-M	73.04±5.27	73.19±6.35	82.19±3.96	80.04±4.12	82.45±2.54	79.39±4.53	78.06±6.28	77.42±6.63	**82.98±8.10**
	Mcc	47.69±7.66	50.96±10.3	63.11±7.42	60.26±8.11	63.76±4.74	55.99±8.84	55.59±10.7	57.51±10.9	**71.45±8.29**
Habe rman	AUC	53.29±4.33	57.41±6.98	59.47±6.51	52.00±8.36	58.89±1.56	56.06±2.80	51.95±4.99	54.43±4.35	**61.81±9.38**
	F-M	30.50±7.85	40.62±8.01	43.01±7.45	30.40±9.85	42.16±2.11	40.10±2.00	34.04±6.35	23.07±10.6	**43.65±8.57**
	G-M	47.55±7.64	56.81±7.09	58.82±6.65	46.75±8.88	57.88±1.70	55.52±2.38	50.65±5.46	36.59±12.5	**60.19±7.30**
	Mcc	6.240±8.40	13.67±13.1	17.31±11.9	4.970±16.9	16.99±2.99	11.04±5.38	3.620±9.07	13.60±13.2	**21.59±8.67**
Vehi cle1	AUC	66.51±5.23	70.29±4.56	78.03±3.79	72.62±3.32	75.10±4.23	79.12±3.30	76.12±3.77	53.78±2.83	**82.70±6.54**
	F-M	49.55±8.93	55.56±6.30	64.67±4.67	59.01±4.72	61.53±5.43	65.87±4.05	62.55±4.55	14.91±9.90	**67.23±6.25**
	G-M	63.22±7.82	69.06±5.12	77.91±3.81	71.53±3.81	74.72±4.60	79.03±3.28	75.88±3.96	26.58±12.7	**81.74±7.15**
	Mcc	34.03±9.72	39.60±8.56	51.20±6.83	44.54±6.31	47.00±7.45	52.93±5.97	48.29±6.45	17.91±9.50	**57.01±9.87**
Ecoli	AUC	84.31±5.21	86.15±5.44	87.70±4.01	88.00±4.28	87.17±4.89	88.39±5.33	88.17±3.95	82.52±7.21	**92.47±4.39**
	F-M	75.80±7.99	77.33±7.31	77.14±5.42	80.38±6.32	77.44±6.94	78.07±7.29	77.96±5.23	75.53±11.4	**80.42±7.52**

1	G-M	83.68±5.71	85.71±5.90	87.52±4.19	87.70±4.53	86.93±5.13	88.18±5.60	88.03±4.06	80.73±9.29	**92.09±4.84**
	Mcc	69.04±10.3	70.84±9.35	70.45±7.01	74.78±8.27	70.82±9.06	71.79±9.59	71.48±6.94	70.97±12.3	**80.48±9.12**
New	AUC	98.84±2.27	98.10±2.93	98.47±1.74	97.96±2.98	98.23±2.33	98.42±1.62	98.22±2.67	96.49±5.29	**99.80±1.41**
-thy	F-M	97.10±3.97	96.23±4.63	93.30±7.09	95.61±5.14	94.06±6.43	92.99±6.77	95.81±4.94	95.22±6.30	**99.78±1.57**
roid	G-M	98.81±2.34	98.05±3.02	98.44±1.79	97.91±3.07	98.20±2.39	98.39±1.66	98.17±2.76	96.29±5.71	**99.79±1.49**
1	Mcc	96.62±4.65	95.64±5.40	92.36±7.96	94.92±5.99	93.19±7.32	92.00±7.62	95.16±5.71	94.75±6.81	**100.0±0.00**
	AUC	90.14±5.05	84.02±6.30	89.29±7.92	87.75±7.21	89.01±7.40	87.02±6.84	87.16±7.98	87.12±4.49	**93.62±7.25**
Ecoli	F-M	**83.43±3.96**	70.21±8.79	77.19±12.8	82.55±7.52	77.28±11.3	74.32±10.0	77.22±9.39	80.65±7.76	82.79±7.79
2	G-M	89.55±5.73	83.25±7.12	88.85±8.37	86.57±8.19	88.62±7.72	86.50±7.31	86.07±9.36	86.38±6.16	**92.76±7.51**
	Mcc	81.38±3.88	64.79±10.7	73.38±15.3	81.37±7.62	73.33±13.6	70.00±12.2	74.26±10.4	78.60±7.58	**82.01±7.24**
	AUC	87.03±1.32	92.67±0.51	95.21±0.61	91.38±1.40	93.22±1.05	95.00±0.77	96.55±1.29	67.55±2.05	**98.56±0.76**
Mus	F-M	78.83±1.23	86.87±1.47	88.91±1.86	87.23±1.76	85.82±2.71	88.63±1.97	**93.87±1.39**	51.84±4.40	92.59±4.20
k	G-M	86.49±1.60	92.55±0.52	95.20±0.62	91.10±1.51	93.16±1.06	94.98±0.78	96.51±1.33	59.16±3.40	**98.55±0.77**
	Mcc	75.18±1.51	84.46±1.74	86.95±2.15	85.08±2.01	83.24±3.18	86.62±2.25	**92.77±1.63**	55.94±3.42	91.50±4.82
	AUC	91.98±6.05	89.92±7.78	92.84±3.64	89.98±7.16	91.17±6.87	93.05±4.18	92.57±2.30	86.74±8.27	**98.13±5.07**
Glas	F-M	85.39±9.35	83.73±10.2	84.02±12.3	82.47±8.23	81.87±12.1	85.17±5.98	81.80±6.30	80.23±11.9	**95.91±7.79**
s6	G-M	91.55±6.54	89.03±8.70	92.58±3.76	89.28±7.80	90.80±7.26	92.84±4.32	92.34±2.39	85.22±10.6	**97.96±5.68**
	Mcc	83.62±10.5	82.59±11.0	82.61±12.6	80.42±9.48	79.57±13.8	83.21±7.08	80.00±6.29	79.16±11.1	**95.77±7.92**
	AUC	84.85±4.52	87.88±3.09	93.94±2.08	88.45±2.14	91.10±2.41	89.39±2.54	86.74±2.54	85.75±4.49	**97.71±1.99**
Yeas	F-M	62.65±4.75	65.88±5.13	77.50±4.20	81.25±5.94	69.77±3.41	72.73±3.61	71.23±2.32	68.76±7.76	**83.33±1.02**
t3	G-M	84.63±5.65	87.83±3.41	93.94±2.12	87.92±2.28	91.10±2.51	89.28±2.57	86.38±2.76	84.62±6.16	**97.68±2.09**
	Mcc	58.54±4.78	62.65±3.41	75.67±4.59	79.04±6.87	67.47±4.00	69.70±4.14	67.65±2.72	81.36±7.58	**82.56±1.12**
	AUC	78.70±8.84	77.00±8.62	86.93±7.10	76.72±8.26	85.94±7.35	87.04±5.71	85.67±6.93	66.33±9.03	**95.70±4.69**
Ecoli	F-M	59.14±12.8	55.54±13.0	62.06±10.0	58.74±13.6	62.22±10.6	62.46±8.16	64.54±9.51	44.79±11.2	**73.37±6.77**
3	G-M	75.91±12.1	74.05±12.0	86.48±7.68	73.34±11.6	85.35±8.12	86.69±6.07	84.97±7.78	53.63±11.4	**95.50±4.98**
	Mcc	55.88±13.1	51.21±14.0	59.41±11.5	55.02±14.6	59.28±12.0	59.80±9.09	61.51±10.8	46.14±11.6	**74.30±6.93**
Page	AUC	87.48±3.40	93.79±1.72	95.67±1.09	93.89±1.39	95.15±1.12	95.70±1.07	95.32±0.88	80.54±2.58	**98.14±0.39**
-bloc	F-M	78.10±4.43	84.13±3.75	81.20±2.29	86.29±2.07	81.49±2.55	81.25±2.20	85.73±2.09	73.79±3.91	**90.43±3.06**
ks0	G-M	86.78±3.98	93.71±1.78	95.66±1.09	93.79±1.46	95.14±1.13	95.69±1.07	95.29±0.89	78.23±3.27	**98.12±0.40**
	Mcc	75.84±4.67	82.51±3.99	79.93±2.43	84.77±2.30	80.07±2.66	79.98±2.35	84.34±2.24	73.28±3.68	**89.80±3.21**
Yeas	AUC	93.92±6.61	98.92±9.14	95.70±3.44	94.37±5.44	98.39±5.01	95.16±2.31	98.39±7.62	90.00±5.50	**99.44±1.37**
t	F-M	67.14±12.8	69.74±11.8	65.61±7.49	73.47±10.1	66.13±8.34	66.13±9.15	71.55±7.84	69.82±8.79	**76.08±11.6**
2vs4	G-M	93.84±7.99	98.92±10.4	95.60±3.48	94.30±6.16	98.37±5.23	95.04±2.28	98.37±8.24	89.44±7.21	**99.44±1.39**
	Mcc	64.20±14.1	67.20±10.9	63.52±8.13	71.22±10.7	64.11±9.23	64.08±9.92	69.60±8.43	69.42±8.80	**76.48±11.7**
Yeas	AUC	89.21±5.02	89.74±3.98	93.42±4.99	88.44±4.72	93.16±3.99	91.88±3.43	89.21±6.44	84.47±7.79	**96.77±1.11**
t	F-M	60.00±8.18	62.07±5.55	**81.82±2.86**	76.19±7.59	62.86±5.80	64.00±5.51	60.00±8.33	77.78±6.97	72.73±2.89
0567	G-M	89.21±7.49	89.74±5.85	93.34±5.29	88.03±5.79	92.91±4.71	86.12±3.84	89.21±8.15	83.22±6.30	**96.72±1.15**
9vs4	Mcc	58.62±8.79	60.60±5.94	**80.12±3.73**	73.68±9.20	62.90±6.71	60.98±6.25	58.62±9.68	76.29±7.08	73.11±2.92
	AUC	94.55±4.45	95.20±3.48	96.85±1.94	96.27±2.71	96.41±2.33	97.19±1.72	97.15±2.02	90.57±5.83	**100.0±0.00**
Vow	F-M	88.72±6.38	89.43±5.55	83.01±5.73	92.31±4.34	82.90±6.01	83.98±5.09	90.37±4.72	86.56±7.07	**100.0±0.00**
el0	G-M	94.35±4.74	95.07±3.66	96.82±1.96	96.18±2.85	96.38±2.36	97.17±1.73	97.12±2.06	89.88±6.69	**100.0±0.00**
	Mcc	87.76±6.99	88.55±6.00	82.30±5.74	91.66±4.71	82.05±6.21	83.25±5.20	89.64±5.03	86.01±6.89	**100.0±0.00**
Glas	AUC	80.48±11.9	84.64±11.8	81.79±14.4	72.14±7.86	79.05±12.1	88.57±12.4	80.00±13.8	63.81±2.70	**89.39±11.6**
s	F-M	57.14±19.3	**66.67±18.8**	54.55±14.0	50.00±18.2	50.00±12.6	42.86±12.1	30.00±9.44	33.33±7.22	22.22±10.9
016v	G-M	79.28±29.2	84.09±30.0	81.50±23.6	68.66±25.9	78.07±21.5	87.83±22.7	77.46±21.4	56.06±10.4	**88.76±12.5**
s2	Mcc	53.56±22.5	**62.88±20.4**	50.26±19.0	44.29±20.3	46.34±16.5	45.87±15.9	32.54±16.3	27.62±8.11	31.38±12.9
Ecoli	AUC	81.78±8.88	82.11±9.93	86.16±7.91	83.53±11.3	84.90±8.10	85.40±8.96	89.01±8.29	70.72±12.9	**97.81±3.15**
0147	F-M	67.54±14.2	61.42±14.4	63.72±11.6	73.42±17.9	63.96±12.2	61.06±12.4	73.94±13.0	52.88±13.7	**81.97±10.5**
vs23	G-M	79.42±11.4	80.08±12.5	85.17±9.74	80.76±14.9	83.86±9.19	84.38±10.5	88.17±9.49	60.73±12.3	**97.73±3.37**
56	Mcc	66.05±15.2	59.07±15.7	61.81±12.4	72.96±17.9	61.43±13.3	58.96±13.7	72.57±14.0	54.93±13.3	**77.34±10.8**
	AUC	70.39±8.93	72.73±6.92	**85.62±6.38**	80.81±8.66	81.82±7.45	85.35±5.39	81.31±6.74	75.00±6.45	79.93±4.80
clim	F-M	45.73±15.4	45.83±10.9	54.29±8.92	60.00±14.0	51.49±8.40	60.87±6.79	63.16±8.85	66.67±17.1	**70.60±4.56**
ate	G-M	64.69±13.2	69.29±9.46	**85.25±7.24**	79.56±12.2	80.95±8.31	85.02±5.76	79.98±7.87	70.71±17.3	74.74±4.30
	Mcc	41.41±16.9	40.88±12.2	52.64±10.0	56.31±14.5	48.64±10.0	58.18±7.68	59.71±10.0	68.97±17.7	**73.87±4.09**
	AUC	69.83±4.81	60.10±8.63	70.07±13.8	57.13±7.50	66.55±9.52	69.46±6.24	67.10±11.1	59.94±5.29	**87.69±4.45**
Glas	F-M	**33.59±2.85**	21.46±11.9	28.50±11.9	20.38±17.0	27.68±10.8	28.83±6.06	23.91±6.97	28.57±15.5	24.72±9.54
s2	G-M	67.20±7.17	44.22±22.8	66.30±21.0	32.37±26.5	63.51±12.6	68.11±8.18	65.10±13.0	48.70±18.8	**86.70±5.05**
	Mcc	28.44±3.93	13.20±14.0	24.26±16.7	15.95±18.1	21.78±13.2	24.12±7.88	19.05±12.1	22.60±18.1	**32.47±9.00**
	AUC	67.35±11.2	82.52±10.9	82.73±9.16	81.15±10.8	83.68±8.56	82.85±10.6	**84.67±8.61**	82.67±13.2	84.48±9.24
germ	F-M	39.00±21.0	64.44±17.1	59.41±13.7	**73.43±9.06**	62.06±14.3	59.68±16.7	69.25±13.1	72.18±12.3	23.08±5.05
an	G-M	55.82±24.5	79.95±14.4	80.88±11.7	77.11±17.0	82.04±11.1	80.68±13.8	82.98±10.7	78.44±10.0	**83.05±10.6**
	Mcc	36.42±22.6	63.10±17.3	58.36±14.4	**74.71±7.98**	60.65±14.6	58.58±17.5	68.14±13.7	73.03±10.9	29.23±10.4
Shutt	AUC	98.90±6.99	99.95±0.08	99.91±0.08	99.95±0.09	99.91±0.11	99.90±0.12	99.91±0.04	99.43±1.12	**100.0±0.00**
le-c0	F-M	96.70±13.8	99.37±1.14	98.73±1.17	99.29±1.23	98.74±1.46	98.71±1.52	98.82±1.18	98.83±1.51	**100.0±0.00**
-vs-c	G-M	97.90±13.9	99.95±0.08	99.91±0.08	99.95±0.09	99.91±0.11	99.90±0.12	99.91±0.08	99.42±1.14	**100.0±0.00**
4	Mcc	96.61±13.8	99.33±1.21	98.65±1.23	99.25±1.30	98.66±1.54	98.63±1.60	98.74±1.25	98.76±1.60	**100.0±0.00**
	AUC	61.35±3.44	63.74±8.35	71.96±8.88	60.15±9.02	70.55±11.5	75.41±11.6	73.26±7.97	59.31±7.53	**83.72±6.06**
Yeas	F-M	28.49±5.22	25.59±10.3	31.13±9.80	28.31±8.71	28.48±10.8	**33.51±9.57**	27.18±5.93	27.29±8.31	30.00±8.23
t	G-M	49.89±7.80	56.75±14.6	70.16±10.8	41.49±10.8	67.17±16.7	73.62±13.5	72.42±7.94	38.39±11.7	**82.12±6.46**
1vs7	Mcc	25.03±4.71	20.15±12.0	28.04±12.0	25.61±8.00	25.36±14.1	31.72±13.4	25.91±8.63	29.97±10.2	**34.50±8.12**
	AUC	89.67±9.28	86.71±7.42	90.61±5.46	89.84±9.40	91.99±5.99	92.15±5.92	91.71±6.46	82.18±12.6	**98.54±4.88**
Ecoli	F-M	76.06±15.3	74.81±7.46	69.88±5.80	85.48±13.3	63.43±7.79	68.55±16.5	81.11±11.8	71.84±13.9	**87.87±8.94**
4	G-M	88.61±10.9	85.37±8.79	90.15±5.79	88.65±10.8	91.73±6.23	91.82±6.18	91.25±6.83	76.01±11.3	**98.37±5.72**
	Mcc	75.61±15.9	74.82±7.53	69.47±5.93	85.79±12.8	63.84±8.42	69.40±15.8	80.07±12.6	73.09±13.6	**88.61±8.51**

Page	AUC	98.05±4.29	96.21±6.54	98.74±0.97	97.34±3.94	98.90±1.00	98.80±0.70	**99.76±0.37**	96.25±5.54	98.50±1.38
-bloc	F-M	89.57±10.5	92.61±9.92	84.63±9.25	94.28±6.33	86.62±10.6	84.71±8.36	**96.77±4.97**	92.92±7.63	77.11±9.46
ks13	G-M	97.95±4.64	95.86±7.52	98.73±0.99	97.23±4.12	98.89±1.02	98.78±0.78	**99.76±0.38**	96.00±6.03	98.49±1.41
vs4	Mcc	89.52±10.6	92.52±9.94	84.88±8.68	94.11±6.60	86.89±10.2	84.94±7.88	**96.71±5.01**	92.89±7.62	78.88±7.20
Der	AUC	99.99±0.10	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	97.72±4.79	**100.0±0.00**	99.93±0.22	97.37±5.54	**100.0±0.00**
mato	F-M	99.78±1.56	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	96.98±5.71	**100.0±0.00**	98.89±3.33	95.05±7.25	**100.0±0.00**
logy-	G-M	99.99±0.10	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	97.56±5.14	**100.0±0.00**	99.93±0.22	97.14±6.15	**100.0±0.00**
6	Mcc	99.78±1.57	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	97.03±5.62	**100.0±0.00**	98.88±3.37	95.13±6.99	**100.0±0.00**
	AUC	57.08±11.8	62.67±11.8	67.89±12.8	55.48±7.56	67.10±16.1	66.56±16.0	72.36±8.46	57.03±9.75	**80.70±8.98**
svmg	F-M	16.26±12.5	**25.01±18.3**	21.24±10.3	15.37±10.1	20.78±12.5	20.12±12.1	20.52±5.21	18.94±14.2	15.38±3.27
uide	G-M	30.34±21.3	48.28±26.6	62.41±22.3	21.16±27.0	59.33±27.7	57.87±28.7	71.32±8.23	23.80±19.8	**78.36±7.87**
3	Mcc	12.13±10.1	21.18±20.0	19.28±14.1	15.23±12.2	18.50±17.6	17.82±17.2	**21.30±8.00**	19.71±16.1	17.37±5.21
Yeas	AUC	56.01±10.1	57.18±10.0	62.65±8.40	51.06±3.30	63.31±13.0	60.66±12.9	63.30±7.91	50.42±2.27	**72.14±9.29**
t	F-M	13.93±10.4	13.86±10.6	14.49±4.43	4.440±3.89	14.54±6.69	13.74±7.82	11.78±2.29	2.090±7.12	**15.08±3.70**
1458	G-M	40.01±22.8	43.72±25.1	58.89±10.2	8.100±16.2	59.06±16.8	55.62±17.5	60.54±6.59	3.260±11.0	**68.13±10.8**
vs7	Mcc	8.670±13.0	9.23±12.83	11.94±7.61	2.970±9.22	12.35±11.7	10.31±12.5	10.95±6.52	1.700±9.33	**18.43±7.42**
	AUC	74.42±8.23	75.98±1.78	82.24±6.18	68.48±4.35	81.61±9.49	79.25±4.25	81.04±3.07	60.13±1.41	**87.71±4.70**
Yeas	F-M	38.82±9.91	38.81±3.85	29.76±4.97	40.14±7.27	30.87±7.82	28.43±4.16	28.98±4.05	27.75±3.23	**43.34±6.42**
t4	G-M	70.40±11.1	73.49±2.45	81.81±6.61	61.36±6.88	80.63±10.4	78.53±4.84	80.72±3.24	45.94±2.96	**85.19±4.89**
	Mcc	37.77±10.9	38.14±3.40	33.62±6.60	38.73±7.26	34.19±10.2	31.23±4.68	32.47±4.44	27.45±3.60	**47.68±6.85**
Wine	AUC	54.75±5.08	55.89±5.23	67.73±6.74	51.61±2.87	62.18±6.80	67.51±6.66	55.46±7.47	51.52±3.46	**71.33±9.39**
quali	F-M	9.950±5.88	11.29±6.04	16.59±4.02	6.010±7.74	13.29±4.48	16.66±4.36	7.580±1.82	5.330±9.51	**17.53±5.74**
ty-re	G-M	36.12±15.6	39.70±13.9	65.02±9.21	13.04±16.2	56.95±11.1	64.74±9.08	54.65±7.23	10.27±16.9	**69.22±9.92**
d-4	Mcc	6.370±6.67	7.800±6.88	16.80±6.17	4.860±8.84	11.70±6.48	16.75±6.31	3.910±5.36	4.490±10.9	**19.25±8.39**
Yeas	AUC	54.05±8.28	65.20±3.98	74.33±8.92	54.29±4.40	66.69±11.6	74.17±11.5	61.98±8.57	57.86±6.35	**81.23±8.50**
t	F-M	11.70±7.50	19.22±5.55	17.85±4.74	13.89±11.3	14.72±6.27	18.98±6.23	8.970±2.33	22.87±6.86	**29.30±1.67**
1289	G-M	27.37±21.2	59.79±5.85	71.66±11.1	24.38±19.9	62.16±17.1	**72.45±13.0**	59.67±9.25	33.61±12.2	71.24±8.26
vs7	Mcc	8.060±9.27	17.95±5.94	20.99±7.69	13.21±13.1	14.99±10.1	21.74±9.80	8.590±6.12	25.22±9.04	**34.32±2.50**
Abal	AUC	99.51±0.48	99.98±0.09	99.63±0.45	99.98±0.10	99.63±0.45	99.60±0.43	99.90±0.21	99.93±0.18	**100.0±0.00**
one	F-M	87.65±10.8	99.43±2.80	90.64±10.5	99.43±2.80	90.64±10.5	89.71±10.0	97.14±5.71	98.00±4.96	**100.0±0.00**
3vs1	G-M	99.50±0.49	99.98±0.10	99.63±0.45	99.98±0.10	99.63±0.45	99.60±0.43	99.90±0.21	99.93±0.18	**100.0±0.00**
1	Mcc	88.33±10.1	99.45±2.71	91.14±9.82	99.45±2.71	91.14±9.82	90.22±9.36	97.23±5.54	98.06±4.80	**100.0±0.00**
	AUC	89.95±7.84	87.01±8.12	95.40±3.60	86.57±6.90	95.36±3.54	95.07±3.92	93.41±6.76	74.50±8.43	**97.55±5.15**
Yeas	F-M	61.05±10.3	67.05±12.2	57.02±7.87	**69.70±9.17**	57.63±7.60	55.29±6.57	67.23±9.45	55.94±14.5	63.43±9.52
t5	G-M	89.10±9.51	85.67±9.92	95.32±3.70	85.26±8.38	95.28±3.64	94.97±4.05	92.97±7.85	69.12±12.7	**97.52±5.95**
	Mcc	62.30±10.5	66.80±12.6	60.77±7.09	**69.50±9.31**	61.26±6.71	59.25±6.21	68.47±9.54	56.55±14.6	66.92±8.83
	AUC	64.75±7.27	64.27±6.17	80.79±5.34	67.65±4.51	78.30±5.52	80.40±5.03	80.15±5.54	59.59±3.13	**84.95±1.95**
Ozon	F-M	36.36±7.63	33.33±7.23	30.11±3.58	47.62±5.14	30.14±3.69	24.81±3.63	20.58±3.13	27.27±8.65	**58.20±4.42**
e-on	G-M	55.95±13.4	55.25±11.1	**80.26±5.94**	59.64±4.41	77.36±6.42	79.89±5.57	79.84±5.82	44.54±4.53	77.24±3.23
ehr	Mcc	37.52±8.68	34.28±8.13	37.72±4.99	**49.58±5.11**	33.95±5.03	29.22±4.90	25.83±4.70	27.86±8.26	44.99±4.56
Krvs	AUC	98.71±1.84	96.49±3.57	97.82±2.42	95.12±4.59	97.41±2.63	97.35±2.52	98.18±2.52	93.62±4.10	**100.0±0.00**
k	F-M	93.03±5.14	94.65±4.67	83.64±5.94	93.56±5.58	83.94±7.24	83.39±6.66	95.28±5.05	92.18±4.68	**100.0±0.00**
3vs1	G-M	98.68±1.88	96.35±3.83	97.78±2.50	94.87±4.92	97.36±2.71	97.30±2.59	98.13±2.60	93.30±4.43	**100.0±0.00**
1	Mcc	93.04±5.06	94.66±4.57	84.12±5.51	93.64±5.45	84.27±6.97	83.78±6.33	95.22±5.09	92.28±4.51	**100.0±0.00**
Abal	AUC	84.83±2.86	83.56±4.31	85.87±9.92	79.03±5.03	87.35±2.63	86.51±1.43	88.42±1.22	69.88±1.36	**91.95±1.57**
one	F-M	50.08±3.52	56.34±3.61	35.27±3.23	**59.40±3.03**	35.88±2.99	35.60±1.33	45.06±3.08	44.24±2.63	51.85±3.22
21vs	G-M	81.93±8.40	78.58±4.23	84.75±9.25	71.06±7.78	85.17±8.05	84.38±6.85	86.97±3.50	55.80±3.03	**91.17±1.68**
8	Mcc	51.94±3.81	57.56±3.16	39.96±3.97	**61.02±3.14**	41.06±4.53	40.52±1.79	49.28±3.43	45.03±2.75	56.87±2.91
	AUC	94.31±9.34	90.79±1.35	95.34±6.56	92.51±8.61	96.37±6.84	**98.10±7.43**	93.60±6.32	91.65±8.30	96.01±2.03
Yeas	F-M	29.79±11.1	48.00±9.51	34.15±5.43	**80.00±1.49**	40.00±6.04	56.00±6.66	27.45±6.00	60.00±7.74	30.30±4.05
t6	G-M	94.14±12.2	90.65±11.6	95.23±7.13	92.26±1.25	96.30±7.64	**98.09±8.29**	93.38±7.34	91.46±8.16	95.92±3.47
	Mcc	39.38±11.6	51.86±8.15	43.21±6.52	**79.67±1.52**	48.15±6.96	61.17±7.96	37.25±6.44	61.77±7.16	40.54±3.30
Wine	AUC	71.31±11.1	72.73±10.6	81.53±12.6	84.09±10.4	84.38±12.7	82.10±12.6	81.25±11.5	87.50±9.37	**92.63±6.79**
quali	F-M	21.05±15.8	28.57±11.0	21.43±8.81	31.58±25.0	33.33±9.06	23.08±7.87	20.69±8.16	28.57±9.14	**35.39±22.7**
ty-w	G-M	68.05±29.6	69.08±23.5	81.27±20.1	83.60±29.2	83.85±18.4	81.79±20.1	81.01±19.4	86.60±8.17	**91.99±8.05**
hite 3vs7	Mcc	18.76±17.0	29.25±12.8	27.35±12.0	36.36±27.1	37.84±12.1	28.89±11.3	26.64±10.2	27.48±10.3	**46.85±20.3**
Wine	AUC	57.37±1.13	57.09±7.51	61.09±2.44	54.45±6.64	60.90±2.41	60.57±2.37	58.00±8.88	54.22±6.40	**76.50±8.75**
quali	F-M	10.23±1.12	9.840±8.98	7.190±3.81	**13.27±3.80**	7.380±4.40	7.050±4.08	5.120±1.44	11.16±1.52	10.18±2.75
ty-re	G-M	30.68±3.08	33.70±7.75	55.00±1.87	17.75±4.81	52.70±4.18	53.35±3.06	52.37±7.59	18.36±2.45	**75.24±8.72**
d 8vs6 7	Mcc	9.070±1.38	8.300±8.68	7.270±3.16	14.33±2.16	7.430±8.49	7.010±8.23	5.010±7.21	10.71±1.68	**16.19±5.53**
krvs	AUC	86.32±8.68	89.42±7.19	91.72±8.44	85.67±4.22	90.72±7.28	94.10±5.58	94.60±7.21	70.19±10.7	**98.17±2.02**
k	F-M	53.45±8.77	74.17±8.89	31.87±7.68	**77.07±6.94**	32.43±8.99	33.68±6.15	59.07±8.41	46.24±19.4	58.30±3.89
0vs8	G-M	84.72±8.12	88.48±8.26	91.20±9.49	83.25±4.45	90.37±7.80	93.89±5.99	94.20±7.15	61.25±17.8	**98.14±2.06**
	Mcc	55.36±8.47	74.58±8.89	39.95±8.90	**78.68±5.07**	39.93±9.18	42.35±6.50	62.46±8.48	47.53±19.0	64.55±3.31
Shutt	AUC	99.97±0.09	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
le-2v	F-M	98.24±5.38	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
s5	G-M	99.97±0.09	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
	Mcc	98.35±5.01	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
kddb	AUC	99.49±2.59	99.33±3.27	99.16±2.51	99.00±3.96	99.82±1.17	98.33±4.41	99.67±2.33	**100.0±0.00**	**100.0±0.00**
uffer	F-M	98.81±3.96	99.20±3.92	98.63±3.92	98.80±4.75	98.76±3.18	97.77±5.54	99.60±2.80	**100.0±0.00**	**100.0±0.00**
	G-M	99.45±2.83	99.27±3.60	99.12±2.63	98.90±4.36	99.81±1.22	98.20±4.80	99.63±2.57	**100.0±0.00**	**100.0±0.00**

overf lowv sbac k	Mcc	98.84±3.82	99.26±3.63	98.64±3.92	98.89±4.40	98.80±3.08	97.87±5.25	99.63±2.59	**100.0±0.00**	**100.0±0.00**
krvs	AUC	98.90±3.37	94.25±6.90	96.99±6.26	91.63±6.54	95.51±8.29	99.51±0.50	99.91±0.15	89.15±9.00	**100.0±0.00**
k	F-M	96.41±8.16	91.94±8.81	84.72±6.46	89.36±7.96	79.38±8.41	84.56±3.36	94.16±8.39	83.60±13.2	**100.0±0.00**
0vs1	G-M	98.83±3.61	93.77±7.62	96.72±6.95	90.46±7.25	94.88±4.31	98.27±5.74	99.91±0.15	87.84±10.8	**100.0±0.00**
5	Mcc	96.57±7.83	92.29±8.44	85.45±5.77	90.38±7.32	80.44±7.84	85.41±2.67	94.50±7.65	84.45±12.4	**100.0±0.00**
kddr	AUC	96.75±5.50	95.45±5.63	93.99±7.07	94.35±7.71	93.79±7.36	93.34±7.69	95.69±5.54	94.04±5.78	**98.76±5.04**
ootk	F-M	89.51±19.1	**94.68±6.66**	92.41±9.18	93.22±9.70	91.70±10.1	91.03±10.3	94.30±6.59	92.51±6.89	87.19±2.95
itbac	G-M	96.53±5.92	95.15±6.01	93.46±7.95	93.77±8.72	93.22±9.70	92.69±8.73	95.41±5.91	93.65±6.17	**98.58±5.93**
k	Mcc	90.51±17.0	**94.92±6.37**	92.88±8.45	93.73±8.78	92.10±9.63	91.56±9.54	94.55±6.32	92.83±6.63	84.53±2.64
skinn	AUC	99.72±0.11	98.68±2.80	99.38±0.08	97.09±3.56	99.38±0.10	99.49±0.09	**99.98±0.00**	97.09±4.34	99.29±0.86
onski	F-M	39.67±9.84	95.40±4.47	21.76±2.64	**95.52±4.74**	21.97±2.75	25.33±3.52	88.62±7.19	92.61±7.70	78.32±3.93
n	G-M	99.72±0.11	98.63±2.91	99.38±0.08	96.98±3.71	99.38±0.10	99.49±0.09	**99.98±0.00**	96.93±4.61	99.11±0.86
	Mcc	49.49±7.79	95.54±4.34	34.68±2.39	**95.63±4.67**	34.87±2.49	37.83±3.03	89.36±6.49	92.80±7.59	82.18±3.83
	AUC	96.92±4.43	92.55±7.87	96.90±4.11	92.96±7.45	97.08±3.71	96.88±4.35	96.03±5.38	82.91±11.5	**98.62±0.19**
cod	F-M	16.42±8.10	82.76±6.13	10.99±1.63	**87.75±9.06**	11.16±1.34	11.11±1.64	47.01±8.28	64.39±20.9	54.67±1.64
	G-M	96.78±4.77	91.81±9.01	96.78±4.36	92.31±8.49	96.99±3.88	96.75±4.67	95.78±5.79	79.19±17.7	**98.61±0.19**
	Mcc	28.48±6.84	83.48±6.09	23.28±1.75	**88.24±9.63**	23.55±1.64	23.45±2.15	53.89±7.37	65.14±20.7	61.48±1.97

2) Comparison with State-of-the-art IE Methods

Table VIII records comparison results between the proposed DSENLG-IE method and six SOTA IE methods. The comparisons in Table VIII clearly demonstrated that the proposed DSENLG-IE provide better performance in terms of the four metrics than compared methods, suggesting that DSENLG-IE generates high-quality and high- separability envelope samples.

TABLE VIII
COMPARISON RESULTS WITH STATE-OF-THE-ART IMBALANCED ENSEMBLE METHODS

Dataset	Iris0				Glass0			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	99.00	--	--	--	88.50	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	74.73±6.66	65.85±8.34	74.45±6.85	47.40±12.8
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**78.95±6.88**	**71.31±8.55**	**78.67±6.97**	56.55±13.5
Imbalance-XGBoost[9]	98.90±2.07	98.77±2.38	98.88±2.13	98.25±3.40	76.44±5.55	67.95±7.63	75.49±6.34	53.46±10.5
DSENLG-IE	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	76.35±6.29	67.19±9.05	74.24±7.32	**57.95±12.6**
Dataset	Vertebral				Haberman			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	**64.80**	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	77.55±5.01	68.94±6.12	77.25±5.12	52.69±9.54	57.73±8.78	41.78±9.68	56.24±8.28	13.95±15.7
HOEC[42]	--	--	--	--	62.42±1.93	--	--	--
SPE[40]	78.93±6.12	70.89±7.88	78.53±6.54	56.70±11.4	60.02±6.32	**43.82±7.77**	59.31±7.02	17.92±11.3
Imbalance-XGBoost[9]	79.28±6.07	71.49±8.06	78.75±6.65	58.11±11.3	56.06±6.19	32.83±11.5	48.27±11.6	12.94±13.5
DSENLG-IE	**83.98±7.29**	**78.41±7.08**	**82.98±8.10**	**71.45±8.29**	61.81±9.38	43.65±8.57	**60.19±7.30**	**21.59±8.67**
Dataset	Vehicle1				Ecoli1			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	82.50	--	--	--	**95.70**	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	72.21±3.97	57.13±4.82	72.05±4.04	39.96±7.13	86.43±2.94	76.61±4.16	86.17±3.11	69.79±5.47
HOEC[42]	75.96±1.35	--	--	--	88.16±0.87	--	--	--
SPE[40]	77.44±3.50	63.92±4.39	77.31±3.68	50.11±6.22	86.33±4.22	78.46±5.92	85.88±4.66	72.40±7.57
Imbalance-XGBoost[9]	69.99±3.92	55.32±5.73	67.96±4.81	40.75±7.38	84.71±6.62	76.63±9.26	83.80±7.64	70.74±11.0
DSENLG-IE	**82.70±6.54**	**67.23±6.25**	**81.74±7.15**	**57.01±9.87**	92.47±4.39	**80.42±7.52**	**92.09±4.84**	**80.48±9.12**
Dataset	New-thyroid1				Ecoli2			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	99.70	--	--	--	93.40	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	98.84±2.22	97.13±4.08	98.81±2.29	96.68±4.72	86.45±5.62	72.88±10.4	86.14±5.79	68.01±12.4
HOEC[42]	--	--	--	--	91.28±1.53	--	--	--
SPE[40]	98.21±2.89	96.82±4.74	98.15±2.99	96.37±5.41	89.92±6.36	80.67±7.85	89.38±7.10	77.87±8.93
Imbalance-XGBoost[9]	96.36±4.44	93.68±6.26	96.22±4.67	92.68±7.30	84.47±6.84	75.63±10.6	83.23±7.92	72.18±12.2
DSENLG-IE	**99.80±1.41**	**99.78±1.57**	**99.79±1.49**	**1±0**	**93.62±7.25**	**82.79±7.79**	**92.76±7.51**	**82.01±7.24**
Dataset	Musk				Glass6			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	93.40	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	95.18±0.79	88.56±0.71	95.16±0.81	86.54±0.82	91.51±6.12	81.26±8.85	91.14±6.55	78.99±10.1
HOEC[42]	--	--	--	--	--	--	--	--

SPE[40]	97.17±0.98	**95.97±1.21**	97.14±1.00	**95.27±1.42**	91.64±5.68	83.00±8.67	91.30±6.07	80.74±9.97
Imbalance-XGBoost[9]	92.25±1.43	89.63±2.12	91.99±1.53	88.01±2.45	89.68±8.85	82.29±13.6	88.56±11.1	80.91±13.6
DSENLG-IE	**98.56±0.76**	92.59±4.20	**98.55±0.77**	91.50±4.82	**98.13±5.07**	**95.91±7.79**	**97.96±5.68**	**95.77±7.92**
Dataset	Yeast3				Ecoli3			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	96.90	--	--	--	93.30	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	88.49±4.32	73.00±6.18	88.14±4.71	69.99±6.96	81.43±6.36	58.59±8.97	80.38±7.35	54.40±10.3
HOEC[42]	--	--	--	--	87.34±1.96	--	--	--
SPE[40]	88.77±3.79	75.68±5.65	88.39±4.16	72.83±6.34	83.68±7.73	61.37±8.98	82.59±9.19	57.91±10.5
Imbalance-XGBoost[9]	84.42±3.93	73.96±5.68	83.28±4.76	71.16±6.04	75.70±9.93	56.94±16.7	71.57±14.1	53.86±17.1
DSENLG-IE	**97.71±1.99**	**83.33±1.02**	**97.68±2.09**	**82.56±1.12**	**95.70±4.69**	**73.37±6.77**	**95.50±4.98**	**74.30±6.93**
Dataset	Page-blocks0				Yeast2vs4			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	**98.70**	--	--	--	98.00	--	--	--
HD-Ensemble[43]	--	--	--	--	98.33±1.10	--	94.20±3.70	--
EASE[41]	93.24±1.36	83.68±1.74	93.14±1.42	81.93±1.94	98.91±5.64	75.43±8.74	98.91±6.18	73.09±9.85
HOEC[42]	92.94±0.30	--	--	--	--	--	--	--
SPE[40]	93.24±1.73	86.24±2.03	93.09±1.83	84.72±2.26	**99.46±1.53**	75.31±9.87	**99.46±1.40**	73.04±10.7
Imbalance-XGBoost[9]	92.11±2.08	85.80±2.76	91.87±2.24	84.23±3.05	95.00±6.19	76.58±10.8	**94.87±7.37**	74.53±11.8
DSENLG-IE	98.14±0.39	**90.43±3.06**	**98.12±0.40**	**89.80±3.21**	99.44±1.37	**76.08±11.6**	99.44±1.39	**76.48±11.7**
Dataset	Yeast05679vs4				Vowel0			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	98.10	--	--	--
HD-Ensemble[43]	90.84±4.10	--	82.27±7.40	--	99.99±0.20	--	97.53±1.40	--
EASE[41]	89.27±8.38	60.00±13.6	89.27±10.4	58.68±15.4	97.48±2.14	93.29±4.99	97.44±2.19	92.82±5.22
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	90.83±5.67	66.67±7.16	90.83±6.32	65.05±8.48	96.39±3.45	93.80±4.52	96.27±3.68	93.33±4.78
Imbalance-XGBoost[9]	92.92±6.92	**78.26±11.8**	92.87±7.04	**76.49±12.1**	95.24±3.60	90.52±4.90	95.09±3.81	89.71±5.32
DSENLG-IE	**96.77±1.11**	72.73±2.89	**96.72±1.15**	73.11±2.92	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Dataset	Glass016vs2				Ecoli0147vs2356			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	71.30	--	--	--	--	--	--	--
HD-Ensemble[43]	86.06±8.70	--	77.11±13.3	--	--	--	--	--
EASE[41]	60.14±13.0	22.84±16.2	48.03±27.9	14.40±19.3	87.17±7.64	73.12±12.7	86.16±8.75	71.93±13.4
HOEC[42]	--	--	--	--	84.71±1.33	--	--	--
SPE[40]	64.18±14.5	24.65±10.6	60.18±20.4	17.15±17.1	84.76±8.88	63.31±11.9	83.43±10.6	61.22±13.2
Imbalance-XGBoost[9]	51.85±6.62	**28.57±16.4**	49.28±22.6	21.76±17.1	79.41±10.9	66.98±18.3	75.40±15.6	67.33±16.7
DSENLG-IE	**89.39±11.6**	22.22±10.9	**88.76±12.5**	**31.38±12.9**	**97.81±3.15**	**81.97±10.5**	**97.73±3.37**	**77.34±10.8**
Dataset	climate				Glass2			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	76.60	--	--	--
HD-Ensemble[43]	--	--	--	--	86.65±7.41	--	76.44±14.1	--
EASE[41]	77.86±5.01	49.80±5.75	76.38±6.07	45.74±6.72	63.35±12.3	**25.13±13.6**	54.23±13.7	18.53±16.7
HOEC[42]	**85.61±1.65**	--	--	--	77.96±2.12	--	--	--
SPE[40]	80.86±6.40	45.64±8.02	**80.34±7.62**	43.23±9.28	72.52±12.2	24.07±9.93	71.19±13.0	18.21±14.3
Imbalance-XGBoost[9]	70.11±8.66	51.10±17.1	62.05±15.8	51.54±16.8	53.43±7.19	25.00±18.2	49.35±15.2	22.66±19.8
DSENLG-IE	79.93±4.80	**70.60±4.56**	74.74±4.30	**73.87±4.09**	**87.69±4.45**	24.72±9.54	**86.70±5.05**	32.47±9.00
Dataset	german				Shuttle-c0-vs-c4			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	**100.0**	--	--	--
HD-Ensemble[43]	80.01±9.90	--	69.61±16.0	--	**100.0±0.00**	--	**100.0±0.00**	--
EASE[41]	**85.67±10.2**	**74.84±16.8**	83.64±13.5	73.76±17.4	99.53±1.21	99.15±1.37	99.52±1.24	99.10±1.44
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	85.30±8.69	66.28±11.6	**83.85±10.4**	65.03±12.1	99.50±1.01	98.91±1.35	99.50±1.03	98.84±1.43
Imbalance-XGBoost[9]	82.27±9.96	73.86±15.1	79.45±12.7	**74.47±14.3**	99.94±0.09	99.17±1.26	99.94±0.09	99.12±1.33
DSENLG-IE	84.48±9.24	23.08±5.05	83.05±10.6	29.23±10.4	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Dataset	Yeast1vs7				Ecoli4			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	77.50	--	--	--	96.40	--	--	--
HD-Ensemble[43]	**84.41±8.70**	--	77.67±7.70	--	**98.83±1.90**	--	94.05±4.80	--
EASE[41]	74.22±8.44	**36.93±10.7**	72.04±11.1	34.10±12.3	89.80±8.76	79.61±12.4	88.78±10.1	79.40±12.7
HOEC[42]	77.07±1.94	--	--	--	--	--	--	--
SPE[40]	72.46±7.07	26.67±5.30	71.78±7.72	24.96±7.80	90.88±8.87	76.76±12.1	89.90±10.6	77.03±11.6
Imbalance-XGBoost[9]	61.99±8.12	33.11±9.73	44.70±12.3	34.51±11.2	81.72±12.6	71.95±20.9	78.04±16.7	73.19±20.1
DSENLG-IE	83.72±6.06	30.00±8.23	**82.12±6.46**	**34.50±8.12**	98.54±4.88	**87.87±8.94**	**98.37±5.72**	**88.61±8.51**
Dataset	Page-blocks13vs4				Dermatology-6			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	--	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	99.57±1.40	96.44±4.46	99.56±1.48	96.37±4.53	99.87±0.28	98.00±4.27	99.87±0.28	97.98±4.31

HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	**99.78±0.34**	**96.83±4.70**	**99.77±0.34**	**96.77±4.76**	99.94±0.20	99.11±3.01	99.94±0.20	99.10±3.05
Imbalance-XGBoost[9]	97.03±5.90	92.58±9.80	96.77±6.77	92.47±9.91	97.87±5.18	95.62±7.05	97.67±5.78	95.69±6.79
DSENLG-IE	98.50±1.38	77.11±9.46	98.49±1.41	78.88±7.20	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Dataset	svmguide3				Yeast1458vs7			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	63.80	--	--	--
HD-Ensemble[43]	79.43±10.8	--	67.37±18.7	--	69.16±10.9	--	63.08±10.7	--
EASE[41]	71.22±12.7	**29.80±14.6**	65.37±21.3	**27.97±17.1**	62.92±9.26	**17.33±7.88**	55.63±18.3	14.44±10.3
HOEC[42]	--	--	--	--	66.08±3.44	--	--	--
SPE[40]	63.50±10.6	14.42±5.91	60.22±10.6	12.17±10.0	58.98±7.58	10.71±2.34	57.55±7.01	7.380±6.24
Imbalance-XGBoost[9]	53.58±7.79	10.73±10.4	12.99±14.7	10.83±12.9	51.09±3.08	4.210±9.68	6.520±14.9	4.460±12.3
DSENLG-IE	**80.70±8.98**	15.38±3.27	**78.36±7.87**	17.37±5.21	**72.14±9.29**	15.08±3.70	**68.13±10.8**	**18.43±7.42**
Dataset	Yeast4				Winequality-red-4			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	**91.40**	--	--	--	--	--	--	--
HD-Ensemble[43]	--	--	--	--	--	--	--	--
EASE[41]	75.84±6.81	39.11±7.71	72.67±9.10	38.48±8.61	62.14±6.95	15.80±6.17	53.65±14.1	13.81±7.81
HOEC[42]	79.29±1.23	--	--	--	61.84±2.14	--	--	--
SPE[40]	81.80±7.09	30.25±5.45	80.96±8.71	33.82±7.09	66.32±6.91	11.60±2.22	65.49±7.80	12.34±5.06
Imbalance-XGBoost[9]	65.18±6.67	37.70±4.43	54.15±3.71	37.38±5.05	51.31±2.67	4.700±7.94	9.260±15.1	4.55±9.43
DSENLG-IE	87.71±4.70	**43.34±6.42**	**85.19±4.89**	**47.68±6.85**	**71.33±9.39**	**17.53±5.74**	**69.22±9.92**	**19.25±8.39**
Dataset	Yeast1289vs7				Abalone3vs11			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	60.50	--	--	--	--	--	--	--
HD-Ensemble[43]	78.14±8.20	--	68.73±13.1	--	--	--	--	--
EASE[41]	70.70±8.00	23.96±6.91	66.80±10.5	24.11±8.67	99.93±0.18	98.00±4.96	99.93±0.18	98.06±4.80
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	65.18±8.30	10.64±2.66	64.10±8.79	11.18±6.03	99.97±0.12	99.14±3.39	99.97±0.12	99.17±3.29
Imbalance-XGBoost[9]	55.95±6.68	16.42±6.96	25.16±14.9	17.11±8.71	99.56±2.33	96.74±6.18	99.53±2.56	96.86±5.96
DSENLG-IE	**81.23±8.39**	**29.30±1.67**	**71.24±8.26**	**34.32±2.50**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Dataset	Yeast5				Ozone-onehr			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	97.00	--	--	--	--	--	--	--
HD-Ensemble[43]	**99.12±0.50**	--	95.89±0.90	--	--	--	--	--
EASE[41]	86.04±7.59	**68.27±11.1**	84.57±9.31	**68.05±11.4**	72.22±5.23	32.02±6.19	68.03±7.31	31.44±6.93
HOEC[42]	--	--	--	--	73.97±1.88	--	--	--
SPE[40]	93.64±6.24	60.38±9.32	93.31±6.98	62.81±9.23	81.96±4.76	24.74±3.09	**81.62±5.19**	29.87±4.25
Imbalance-XGBoost[9]	79.10±8.98	62.77±13.6	75.55±11.9	62.91±13.5	55.02±4.91	15.68±3.81	53.23±8.41	17.66±5.49
DSENLG-IE	97.55±5.15	63.43±9.52	**97.52±5.95**	66.92±8.83	**84.95±1.95**	**58.20±4.42**	77.24±3.23	**44.99±4.56**
Dataset	krvsk3vs11				Abalone21vs8			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	--	--	--	--
HD-Ensemble[43]	**100.0±0.00**	--	99.87±0.10	--	--	--	--	--
EASE[41]	96.59±2.91	93.75±3.94	96.48±3.06	93.77±3.96	80.41±1.50	**57.06±2.63**	73.1±2.79	**57.49±2.70**
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	98.01±3.00	97.07±3.69	97.94±3.15	97.09±3.63	88.42±2.75	46.72±5.15	85.25±2.12	50.88±4.97
Imbalance-XGBoost[9]	94.50±3.94	92.81±4.90	94.24±4.26	92.86±4.78	71.90±1.69	47.27±3.08	56.40±3.49	49.19±3.18
DSENLG-IE	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**91.95±1.57**	51.85±3.22	**91.17±1.68**	56.87±2.91
Dataset	Yeast6				Winequality-white3vs7			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	88.40	--	--	--	--	--	--	--
HD-Ensemble[43]	94.19±3.80	--	86.59±6.10	--	--	--	--	--
EASE[41]	91.65±7.97	42.11±9.21	91.46±8.29	41.90±9.53	86.08±2.12	**50.00±20.2**	85.36±3.00	**51.61±21.0**
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	**96.21±5.68**	38.89±8.67	**96.13±6.07**	47.23±9.97	81.82±12.9	22.22±5.92	81.53±20.4	28.10±9.84
Imbalance-XGBoost[9]	84.51±9.89	**52.63±8.82**	83.49±10.3	**53.17±8.34**	74.43±9.61	23.79±22.9	70.31±9.07	25.32±24.8
DSENLG-IE	96.01±2.03	30.30±4.05	95.92±3.47	40.54±3.30	**92.63±6.79**	35.39±22.7	**91.99±8.05**	46.85±20.3
Dataset	Winequality-red8vs67				krvsk0vs8			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	--	--	--	--
HD-Ensemble[43]	--	--	--	--	**100.0±0.00**	--	**99.57±0.20**	--
EASE[41]	61.96±1.11	9.560±5.26	49.52±2.58	9.770±8.48	86.35±1.09	**70.42±1.80**	84.24±1.39	**70.75±1.81**
HOEC[42]	68.09±3.80	--	--	--	--	--	--	--
SPE[40]	58.27±1.09	5.330±1.87	56.57±1.02	4.740±6.23	93.97±6.99	53.39±9.04	93.57±8.00	57.71±8.77
Imbalance-XGBoost[9]	52.86±6.10	8.730±1.78	10.92±2.19	9.610±2.07	71.73±1.71	51.59±1.06	63.21±1.93	54.08±1.01
DSENLG-IE	**76.50±8.75**	**10.18±2.75**	**75.24±8.72**	**16.19±5.53**	98.17±2.02	58.30±3.89	98.14±2.06	64.55±3.31
Dataset	Shuttle-2vs5				kddbufferoverflowvsback			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	--	--	--	--
HD-Ensemble[43]	**100.0±0.00**	**--**	99.86±0.10	--	**100.0±0.00**	--	**100.0±0.00**	--

EASE[41]	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	99.69±1.51	**100.0±0.00**	99.70±1.47
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	99.85±1.08	**100.0±0.00**	99.85±1.05
Imbalance-XGBoost[9]	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
DSENLG-IE	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Dataset	krvsk0vs15				kddrootkitback			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	--	--	--	--
HD-Ensemble[43]	**100.0±0.00**	--	**100.0±0.00**	--	**100.0±0.00**	--	**100.0±0.00**	--
EASE[41]	98.42±3.75	97.07±5.33	98.32±4.01	97.14±5.25	97.75±4.25	85.71±4.74	97.62±4.50	86.50±4.54
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	99.98±0.04	98.63±3.15	99.98±0.04	98.67±3.07	95.40±7.49	**94.64±10.2**	95.02±8.59	**94.98±9.48**
Imbalance-XGBoost[9]	91.89±8.95	87.38±12.8	90.92±10.6	88.17±11.6	94.25±6.64	93.34±7.95	93.79±7.30	93.74±7.35
DSENLG-IE	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	98.76±5.04	87.19±2.95	98.58±5.93	84.53±2.64
Dataset	skinnonskin				cod			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
CBIS[26]	--	--	--	--	--	--	--	--
HD-Ensemble[43]	**100.0±0.00**	--	99.93±0.00	--	96.23±5.60	--	83.06±16.7	--
EASE[41]	**100.0±0.00**	**98.67±2.67**	**100.0±0.00**	**98.71±2.59**	90.29±7.36	63.47±9.91	89.38±8.32	64.22±9.50
HOEC[42]	--	--	--	--	--	--	--	--
SPE[40]	98.52±2.96	96.08±5.05	98.46±3.08	96.20±4.89	92.74±7.83	75.15±11.3	92.02±8.92	76.69±10.6
Imbalance-XGBoost[9]	96.31±6.24	93.76±9.07	95.97±7.10	94.10±8.33	86.26±11.1	**76.57±18.1**	83.93±14.4	**77.76±18.1**
DSENLG-IE	99.29±0.86	78.32±3.93	99.11±0.86	82.18±3.83	**98.62±0.19**	54.67±1.64	**98.61±0.19**	61.48±1.97

3) Comparison with Deep Learning based Imbalanced Methods

Six DL based imbalanced classification methods are chosen for comparison. Table X records comparison results in this section. The best results are shown in boldface. It can be seen the performance of DSENLG-IE is superior to the other deep learning based imbalanced methods on all four criteria.

TABLE X

COMPARISON WITH DEEP LEARNING BASED IMBALANCED CLASSIFICATION METHODS

Datasets	Measure	CNN+SMOTE [14]	CNN+AE+GAN [15]	BED [16]	RVGAN-TL [18]	EAL-GAN [47]	DLE-ISMOTE [49]	DSENLG-IE
Ecoli1	AUC	65.22±3.81	83.76±5.41	84.95±2.51	81.23±5.10	92.26±4.41	76.63±5.99	**92.47±4.39**
	F-M	46.68±5.09	43.03±6.90	75.84±2.68	72.52±6.54	69.68±9.60	58.26±7.10	**80.42±7.52**
	G-M	64.05±3.99	82.95±5.56	84.67±2.69	79.91±5.83	86.24±5.18	74.63±9.10	**92.09±4.84**
	Mcc	28.24±7.33	43.10±6.71	68.23±3.49	65.86±7.84	60.68±12.4	45.96±9.19	**80.48±9.12**
Musk	AUC	87.58±3.12	91.59±0.86	93.66±0.53	87.97±3.10	89.49±0.84	95.39±0.43	**98.56±0.76**
	F-M	77.16±6.51	83.41±0.33	85.47±1.20	84.03±4.04	67.98±1.17	86.43±1.25	**92.59±4.20**
	G-M	87.21±3.23	91.48±0.92	93.63±0.54	87.21±3.56	80.36±1.22	95.39±0.43	**98.55±0.77**
	Mcc	73.04±7.89	80.37±0.42	82.89±1.37	82.04±4.18	62.16±1.38	84.22±1.43	**91.50±4.82**
Ecoli3	AUC	82.88±8.31	83.25±1.29	91.97±2.12	74.43±8.83	92.00±5.74	84.52±1.83	**95.70±4.69**
	F-M	48.10±6.36	49.44±3.05	59.41±6.79	56.21±15.6	60.86±15.3	52.27±2.27	**73.37±6.77**
	G-M	82.09±8.51	83.21±1.34	91.59±2.31	70.31±11.8	86.50±6.64	84.51±1.85	**95.50±4.98**
	Mcc	45.76±9.45	56.65±3.09	59.67±6.42	52.39±17.3	56.30±17.1	49.63±2.26	**74.30±6.93**
Glass016 vs2	AUC	60.25±7.65	60.65±9.32	71.33±7.75	59.35±16.0	63.89±12.9	66.98±12.1	**89.39±11.6**
	F-M	21.51±6.01	23.14±8.72	24.88±4.16	19.67±24.1	**37.04±12.5**	22.69±7.69	22.22±10.9
	G-M	56.29±8.42	59.52±10.7	68.87±6.82	32.69±15.6	59.92±9.97	61.43±14.0	**88.76±12.5**
	Mcc	12.93±9.58	15.23±8.73	23.36±8.30	14.06±25.6	31.01±13.9	19.47±12.6	**31.38±12.9**
Shuttle-c 0-vs-c4	AUC	99.57±0.88	99.97±0.07	**100.0±0.00**	**100.0±0.00**	99.60±1.20	97.91±0.22	**100.0±0.00**
	F-M	99.18±1.12	99.59±0.91	**100.0±0.00**	**100.0±0.00**	99.40±1.43	97.87±0.54	**100.0±0.00**
	G-M	99.57±0.89	99.97±0.07	**100.0±0.00**	**100.0±0.00**	99.05±2.34	97.89±0.28	**100.0±0.00**
	Mcc	99.14±1.18	99.56±0.96	**100.0±0.00**	**100.0±0.00**	99.35±4.53	97.75±0.61	**100.0±0.00**
Dermatol ogy-6	AUC	**100.0±0.00**	**100.0±0.00**	92.35±6.65	97.35±7.46	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
	F-M	**100.0±0.00**	**100.0±0.00**	89.21±6.19	94.44±9.24	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
	G-M	**100.0±0.00**	**100.0±0.00**	91.81±7.14	96.92±8.74	99.77±0.82	**100.0±0.00**	**100.0±0.00**
	Mcc	**100.0±0.00**	**100.0±0.00**	89.34±6.08	94.72±9.45	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Yeast4	AUC	82.79±3.25	79.70±3.35	85.73±0.80	63.52±7.55	87.64±6.04	85.52±1.79	**87.71±4.70**
	F-M	29.63±2.04	29.83±5.38	25.08±1.55	33.28±7.16	30.45±11.3	29.10±2.52	**43.34±6.42**
	G-M	82.50±3.49	79.07±3.80	**85.62±0.84**	49.48±9.37	45.33±11.3	85.45±1.81	85.19±4.89
	Mcc	33.81±2.29	32.50±5.17	31.79±1.54	32.56±8.99	27.98±11.7	34.71±2.55	**47.68±6.85**
Abalone3 vs11	AUC	99.38±0.45	99.90±0.23	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
	F-M	77.33±5.96	96.00±8.94	**100.0±0.00**	**100.0±0.00**	98.77±1.67	**100.0±0.00**	**100.0±0.00**
	G-M	99.38±0.23	99.90±0.23	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
	Mcc	78.98±5.03	96.25±8.39	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Yeast5	AUC	92.42±5.13	91.83±3.98	**97.85±0.16**	79.91±7.21	97.15±3.91	96.87±0.86	97.55±5.15
	F-M	49.22±11.2	43.35±5.60	59.25±1.68	**66.38±8.78**	55.56±2.42	48.10±7.07	63.43±9.52
	G-M	92.28±5.60	91.68±4.08	**97.82±0.16**	76.85±9.77	80.94±2.64	96.82±0.89	97.52±5.95
	Mcc	55.20±11.3	48.60±4.56	63.47±1.37	**67.46±7.17**	54.17±2.47	54.52±5.79	66.92±8.83
krvsk3vs 11	AUC	92.06±2.42	87.60±2.39	98.47±1.78	99.39±1.21	99.53±0.09	98.07±1.41	**100.0±0.00**
	F-M	32.74±2.48	26.54±1.14	89.82±5.37	99.37±1.25	93.75±2.40	59.26±2.63	**100.0±0.00**
	G-M	91.98±2.36	87.56±2.37	98.45±1.80	99.38±1.23	95.14±1.60	98.05±1.42	**100.0±0.00**

	Mcc	40.62±2.57	33.86±1.79	89.86±5.27	99.37±1.27	93.57±2.48	63.63±2.60	**100.0±0.00**
Yeast6	AUC	87.39±5.17	86.63±7.44	88.29±2.91	70.98±6.78	93.36±3.55	93.45±1.86	**96.01±2.03**
	F-M	27.53±5.67	24.85±5.50	25.86±1.47	48.21±15.4	**54.76±9.82**	27.17±2.61	30.30±4.05
	G-M	87.24±5.32	86.39±7.54	88.23±2.82	64.15±11.6	70.20±4.96	93.21±1.92	**95.92±3.47**
	Mcc	34.59±6.23	32.17±7.29	33.70±2.11	48.53±16.3	**53.76±10.1**	36.95±2.42	40.54±3.30
Winequality-red 8vs67	AUC	64.34±7.62	60.26±3.15	66.13±6.21	64.70±1.93	52.94±16.9	57.22±8.10	**76.50±8.75**
	F-M	8.96±2.88	5.500±0.41	8.010±1.42	**38.00±6.53**	4.000±10.0	9.57±7.91	10.18±2.75
	G-M	62.50±9.34	60.02±3.27	65.87±6.19	54.47±3.72	0.000±0.00	57.14±8.65	**75.24±8.72**
	Mcc	10.27±5.50	5.67±1.30	10.01±3.87	**41.11±10.4**	1.938±10.3	5.810±7.54	16.19±5.53
Shuttle-2 vs5	AUC	99.94±0.08	99.89±0.04	99.91±0.08	**100.0±0.00**	**100.0±0.00**	99.92±0.08	**100.0±0.00**
	F-M	96.36±4.98	93.51±2.37	94.53±4.71	**100.0±0.00**	**100.0±0.00**	95.45±4.55	**100.0±0.00**
	G-M	99.94±0.08	99.89±0.04	99.91±0.08	**100.0±0.00**	**100.0±0.00**	99.92±0.08	**100.0±0.00**
	Mcc	96.46±4.85	93.62±2.26	94.66±4.50	**100.0±0.00**	**100.0±0.00**	95.57±4.43	**100.0±0.00**
kddrootki tback	AUC	99.93±0.06	90.50±10.2	**100.0±0.00**	**100.0±0.00**	95.38±0.92	93.75±6.25	98.76±5.04
	F-M	94.14±5.41	85.32±13.8	**100.0±0.00**	**100.0±0.00**	91.90±1.74	92.86±7.14	87.19±2.95
	G-M	99.93±0.06	89.35±12.1	**100.0±0.00**	**100.0±0.00**	92.98±1.61	93.30±6.70	98.58±5.93
	Mcc	94.34±5.22	89.28±12.1	**100.0±0.00**	**100.0±0.00**	91.82±1.76	93.25±6.75	84.53±2.64
cod	AUC	94.63±5.37	93.24±4.84	89.62±0.01	87.49±7.64	**99.26±2.15**	97.54±4.28	98.62±0.19
	F-M	8.04±0.85	37.68±2.35	20.76±1.92	**78.27±9.22**	46.33±3.09	27.74±1.42	54.67±1.64
	G-M	94.44±5.59	93.11±4.95	89.11±0.01	86.16±8.68	95.92±9.24	97.43±4.52	**98.61±0.19**
	Mcc	19.33±2.02	24.57±10.7	30.69±1.64	**79.14±9.08**	46.26±3.09	38.56±1.09	61.48±1.97

D. Robust Analysis

Robustness checking of the proposed model is conducted with three groups of experiments. In 1st group of experiment, the stability of the accuracies on all datasets and four evaluation criteria are shown in Fig.9. More stable the accuracy is, more robust the method is. In 2nd group of experiment, different methods are compared when the data has noise (noise rate 10%) as shown in Table XI. Higher the accuracy is, more robust the method is. In 3rd group of experiment, different methods are compared when the class label has noise (noise rate 10%) as shown in Table XII. Higher the accuracy is, more robust the method is. From the Fig.9, it can be seen that the performance of the proposed algorithm is most stable, i.e., the overall performance of the proposed algorithm tends to be better as the IR increases, indicating its good robustness. In the Tables XI- XII, it can be observed that the performance of the proposed DSENLG-IE algorithm is optimal on four evaluation criteria in most cases. For data with noise, the proposed method provided the best performance on 15,7,15 and 9 datasets for AUC, F-M, G-M and Mcc respectively. For class label with noise, the proposed method provided the best performance on 13,11,10 and 9 datasets for AUC, F-M, G-M and Mcc respectively. This indicate the proposed DSENLG-IE algorithm has a strong robustness.

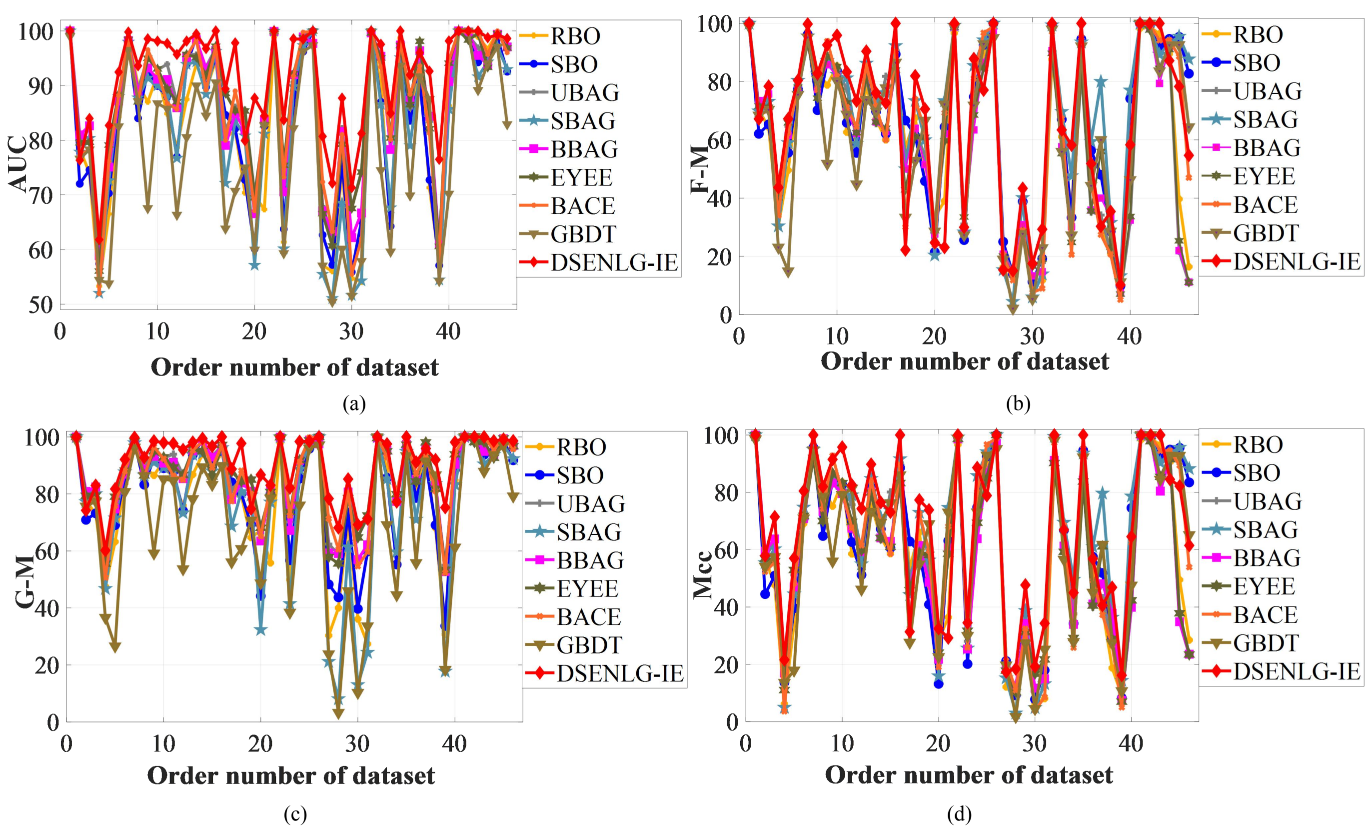

Fig.9. Stability of classification accuracy on different datasets: (a) AUC, (b) F-M, (c) G-M, (d) Mcc

TABLE XI
COMPARISON RESULTS WHEN DATA WITH NOISE (NOISE RATE 10%)

Dataset	Ecoli1				Musk			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	80.23±3.55	67.02±4.54	79.93±3.77	56.60±6.00	91.99±1.18	**81.53±1.94**	91.95±1.21	78.27±2.30
SPE[40]	82.00±5.36	69.48±7.69	81.66±5.65	60.12±10.3	90.06±1.48	79.21±2.28	89.94±1.55	75.41±2.72
Imbalance-XGBoost[9]	80.87±5.91	70.36±8.93	79.89±6.82	62.19±11.4	88.97±1.35	85.25±1.85	88.41±1.50	**83.18±2.08**
DSENLG-IE	**87.58±6.23**	**74.01±10.4**	**86.93±6.88**	**67.21±13.4**	**92.33±5.78**	77.42±1.47	**92.15±5.88**	74.68±1.65
Dataset	Ecoli3				Glass016vs2			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	81.57±7.52	57.20±10.3	80.48±8.76	53.21±11.6	60.36±12.9	**23.02±14.5**	50.63±25.1	**14.71±18.5**
SPE[40]	77.54±8.46	56.38±13.1	75.03±10.9	51.95±14.8	57.81±12.7	19.73±12.5	47.54±25.9	10.05±16.6
Imbalance-XGBoost[9]	73.21±9.90	53.54±17.7	68.11±14.6	49.82±19.5	50.57±4.99	4.970±12.6	7.190±17.9	1.580±13.7
DSENLG-IE	**95.51±3.06**	**75.34±14.3**	**95.35±3.22**	**75.04±14.0**	**61.42±15.4**	22.62±9.64	**58.55±15.7**	13.46±19.1
Dataset	Shuttle-c0-vs-c4				Dermatology-6			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	98.90±1.71	98.23±2.00	98.88±1.76	98.14±2.10	97.09±5.78	94.34±8.48	96.85±6.38	94.33±8.49
SPE[40]	98.83±1.57	98.35±1.81	98.81±1.61	98.26±1.90	96.38±5.58	94.23±7.04	96.13±5.98	94.25±7.06
Imbalance-XGBoost[9]	99.31±1.18	98.32±2.14	99.30±1.20	98.22±2.28	93.88±8.35	90.85±11.6	93.16±9.97	91.15±10.6
DSENLG-IE	**99.99±0.03**	**99.92±0.40**	**99.99±0.03**	**99.92±0.42**	**99.90±0.39**	**98.61±5.14**	**99.90±0.40**	**98.64±4.99**
Dataset	Yeast4				Abalone3vs11			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	76.12±6.51	37.03±8.74	73.34±8.94	36.74±9.41	92.08±10.1	83.66±15.5	90.99±12.0	84.30±14.8
SPE[40]	77.78±6.12	36.07±5.89	75.63±8.26	36.66±6.68	95.03±8.82	86.00±14.1	94.34±10.5	86.54±13.5
Imbalance-XGBoost[9]	61.81±5.69	30.75±12.7	47.67±13.2	31.26±13.4	91.73±11.1	82.36±18.3	89.82±16.9	82.99±17.9
DSENLG-IE	**80.45±6.53**	**39.61±4.87**	**78.33±6.78**	**37.95±4.83**	**99.24±5.30**	**98.51±8.68**	**98.99±7.07**	**98.71±7.40**
Dataset	Yeast5				krvsk3vs11			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	84.25±4.79	65.03±5.99	82.77±6.14	47.14±12.4	93.92±3.78	87.10±5.59	93.66±4.04	86.89±5.72
SPE[40]	87.22±7.63	**66.71±11.3**	85.99±9.27	47.73±9.83	94.17±4.05	88.41±6.06	93.91±4.36	88.23±6.17
Imbalance-XGBoost[9]	75.99±8.33	56.64±14.4	71.25±12.8	48.61±18.3	88.88±5.82	81.66±8.18	87.97±6.79	81.61±8.09
DSENLG-IE	**92.64±9.30**	63.43±11.4	**91.82±10.8**	**65.95±9.95**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**	**100.0±0.00**
Dataset	Yeast6				Winequality-red8vs67			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	79.25±8.87	46.98±11.8	76.07±12.2	47.14±12.4	65.27±11.9	**11.61±6.52**	55.83±25.2	12.79±9.90
SPE[40]	84.01±8.16	46.00±9.10	82.43±9.94	47.73±9.83	62.28±12.5	7.190±3.86	55.81±23.3	7.800±8.14
Imbalance-XGBoost[9]	69.84±9.39	**47.21±18.2**	60.96±16.9	**48.61±18.3**	52.16±5.24	6.800±15.7	8.460±19.4	7.780±18.7
DSENLG-IE	**90.05±7.70**	32.39±8.86	**89.15±8.75**	39.52±7.60	**79.64±8.86**	10.53±2.05	**76.99±8.21**	**18.15±5.02**
Dataset	Shuttle-2vs5				kddrootkitback			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	97.92±3.12	97.77±3.40	97.85±3.26	97.82±3.30	95.38±6.35	82.80±8.74	95.02±6.91	83.07±8.47
SPE[40]	97.94±2.93	**97.81±3.17**	97.88±3.05	**97.85±3.09**	95.53±5.86	93.04±8.08	95.22±6.31	93.27±7.88
Imbalance-XGBoost[9]	97.62±2.98	97.47±3.22	97.54±3.10	97.51±3.14	95.09±5.94	**93.41±7.56**	94.75±6.39	**93.68±7.29**
DSENLG-IE	**99.94±0.23**	97.31±9.23	**99.94±0.23**	97.59±8.20	**99.68±0.10**	88.96±6.17	**99.68±0.10**	85.08±5.38
Dataset	cod							
Measure	AUC	F-M	G-M	Mcc				
EASE[41]	86.02±7.25	**72.36±11.4**	84.38±9.22	**73.24±10.8**				
SPE[40]	88.40±7.90	68.21±9.94	87.17±9.11	69.34±10.1				
Imbalance-XGBoost[9]	82.25±0.04	68.51±16.5	79.20±13.4	69.68±15.8				
DSENLG-IE	**92.33±1.16**	51.71±0.29	**92.00±1.26**	58.54±0.84				

TABLE XII
COMPARISON RESULTS WHEN CLASS LABEL WITH NOISE (NOISE RATE 10%)

Dataset	Ecoli1				Musk			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	85.24±6.59	74.28±8.85	84.98±6.89	66.44±12.0	68.59±1.26	49.39±1.51	68.55±1.25	31.84±2.32
SPE[40]	85.82±4.38	76.44±6.29	85.45±4.71	69.61±8.20	69.76±1.82	51.29±2.26	69.48±1.91	34.93±3.25
Imbalance-XGBoost[9]	85.53±6.08	77.42±8.29	84.85±6.78	71.42±10.3	72.68±1.67	**60.31±2.94**	68.85±2.34	**53.94±3.08**
DSENLG-IE	**88.16±8.19**	**79.09±13.9**	**87.37±9.35**	**73.44±17.7**	**74.41±8.60**	57.51±11.1	**72.10±9.49**	47.42±17.0
Dataset	Ecoli3				Glass016vs2			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	59.98±6.15	34.83±6.54	59.08±6.81	15.84±9.62	55.82±11.2	23.87±12.9	49.04±20.1	8.710±17.2
SPE[40]	56.84±6.80	29.61±10.6	49.94±10.3	13.26±13.1	56.79±9.64	24.39±12.7	47.13±19.2	11.29±15.6
Imbalance-XGBoost[9]	57.99±5.13	29.53±10.4	45.83±11.1	19.76±12.1	52.59±5.93	13.61±14.2	22.40±22.6	7.370±16.7
DSENLG-IE	**64.29±2.97**	**39.90±2.08**	**61.76±3.48**	**23.04±0.22**	**57.32±12.1**	**31.80±13.7**	**54.13±14.4**	**12.69±20.1**

Dataset	Shuttle-c0-vs-c4				Dermatology-6			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	64.43±2.96	37.62±3.54	63.15±3.53	17.05±9.80	61.12±6.31	31.58±7.95	58.94±9.07	17.05±9.80
SPE[40]	64.94±2.97	38.46±3.66	63.59±3.42	16.58±13.1	60.51±8.05	31.54±9.72	58.28±10.1	16.58±13.1
Imbalance-XGBoost[9]	69.07±2.07	**53.47±3.60**	62.40±3.62	35.87±16.0	63.92±7.47	39.38±16.1	53.54±14.4	35.87±16.0
DSENLG-IE	**69.66±6.37**	45.48±8.73	**67.63±7.92**	**36.24±21.6**	**73.63±13.04**	**45.19±15.6**	**70.59±15.9**	**36.24±21.6**
Dataset	Yeast4				Abalone3vs11			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	55.11±4.23	24.09±3.71	54.47±4.92	7.010±5.81	58.21±6.15	26.49±6.53	**56.06±8.33**	11.86±8.96
SPE[40]	54.82±3.48	22.82±4.47	49.62±5.61	7.630±5.56	59.29±5.72	28.12±7.27	54.03±8.55	15.47±9.04
Imbalance-XGBoost[9]	53.54±2.08	14.64±6.04	29.02±8.20	12.93±7.82	**60.85±5.47**	**33.36±12.6**	47.26±11.3	**32.64±13.2**
DSENLG-IE	**66.11±2.26**	**39.10±2.38**	**57.84±2.57**	**19.47±4.21**	53.06±3.23	24.02±1.42	29.17±6.13	7.500±7.17
Dataset	Yeast5				krvsk3vs11			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	52.65±3.98	21.54±2.79	52.42±3.98	3.490±5.24	56.24±2.09	23.70±2.16	53.94±2.89	8.950±2.99
SPE[40]	56.39±4.63	24.07±4.69	54.25±6.07	9.100±6.60	56.92±3.23	24.41±3.36	54.55±4.09	10.00±4.66
Imbalance-XGBoost[9]	55.52±2.68	20.34±7.16	36.19±7.71	17.11±6.73	58.79±2.17	29.25±5.81	42.82±5.23	**31.62±5.81**
DSENLG-IE	**60.89±3.56**	**31.85±9.14**	**55.43±7.16**	**18.43±5.36**	**62.21±4.93**	**30.47±5.53**	**60.44±5.86**	18.27±7.64
Dataset	Yeast6				Winequality-red8vs67			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	55.22±4.03	22.37±3.81	53.95±5.49	7.000±5.45	51.05±5.43	19.03±4.84	48.45±6.87	1.480±7.48
SPE[40]	54.79±4.36	21.95±4.00	52.77±5.59	6.610±5.99	51.16±5.64	19.27±5.01	**49.17±7.22**	1.550±7.67
Imbalance-XGBoost[9]	53.59±2.53	14.96±7.06	29.20±10.0	13.03±8.73	50.27±2.18	6.840±5.90	17.02±12.9	0.780±6.80
DSENLG-IE	**63.45±6.66**	**28.57±4.47**	**54.08±8.95**	**15.80±9.95**	**51.74±1.35**	**22.28±0.62**	20.86±3.83	**5.620±4.04**
Dataset	Shuttle-2vs5				kddrootkitback			
Measure	AUC	F-M	G-M	Mcc	AUC	F-M	G-M	Mcc
EASE[41]	54.32±1.74	20.64±1.58	**52.27±2.16**	5.860±2.37	**54.36±3.48**	**20.59±2.67**	**53.82±3.99**	5.530±4.42
SPE[40]	53.95±2.55	20.26±2.40	51.54±3.36	5.390±3.48	52.39±2.99	19.18±2.26	51.78±3.43	3.030±3.79
Imbalance-XGBoost[9]	55.73±1.68	20.54±5.15	34.46±5.06	**25.56±6.21**	54.11±1.90	15.64±5.89	29.69±6.52	**18.28±7.69**
DSENLG-IE	**56.30±4.13**	**22.44±1.95**	46.95±5.94	9.220±5.61	51.92±4.06	20.54±1.64	16.48±14.1	4.680±6.85
Dataset	cod							
Measure	AUC	F-M	G-M	Mcc				
EASE[41]	50.43±1.28	16.98±0.81	**50.35±1.31**	0.520±1.54				
SPE[40]	50.34±1.10	17.03±0.68	50.32±1.10	0.400±1.33				
Imbalance-XGBoost[9]	50.48±0.26	2.080±1.02	9.840±3.08	**6.510±2.90**				
DSENLG-IE	**50.49±0.55**	**18.52±0.18**	12.74±2.99	2.050±2.28				