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Influence of Metric on Classification Error of Distance-Based Classifiers

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Abstract

Five types of classifiers that use sample distances for class estimation of an unknown sample was tested. Each classifier was tested with fifteen different metrics on 24 classification tasks from the UCI Machine Learning Repository. The metrics were compared and the best of them was found for each classifier. Surprisingly, the best metrics for all five types of classifiers is the Hassanat metrics. Classifiers were also compared and ranked according to their classification ability. Wilcoxon Test and Friedman Aligned test were used for statistical evaluation.

Keywords:

Multidimensional data, Classifier, Distance, Metrics, Hassanat metrics, k-NN, IINC.

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Introduction

A standard distance measure is Euclidean (L2) metrics. Its main advantages are that it is a natural measure of distance in an everyday life, it is direction invariant, it can be easily computed, and it is a prototype of a measure for distance. Thus it is common that simple - nearest neighbor and nearest neighbors classifiers (Cover 1967) - as well as sophisticated distance-based classifiers, e.g. LWM according to Paredes (2006) use this metric.

Here we test 15 different metrics including L1, L2, and Hassanat metrics.

For evaluation we use data on classification errors for 24 data sets from UCI Machine Learning Repository (UCI MLR - Bache and Lichman, 2013) for each type of classifier and each metrics used. For comparing these data standard statistical tests were used.

We show that recently published Hassanat metrics can give the best results of the classification error in comparison to fourteen other relatively simple metrics and that IINC classifier with Hassanat metrics works best compared to four other distance-based classifiers. It was also found that famous Manhattan metrics can be often considered as the second best before Orloci (or Angular) and Euclidean metrics that can be ranked as the third and the fourth best, respectively.

In this report we summarize measurements and tests. First five relatively simple classifiers are introduced. Then fifteen metrics excerpted mostly from Deza (2006) are shown. After it, statistical evaluation by Friedman aligned test and Wilcoxon test are shortly described. In Results section detailed tests with 24 data sets from UCI MLR are presented. Appendices contain some materials for statistical tests used and raw data, i.e. classification errors and standard deviations of classification errors are given.

Classifiers compared

We compare influence of metrics chosen on the classification error of five classifiers and these classifiers among each other. Therefore, five relatively simple classifiers are introduced. These are 1-NN, 5-NN, distribution mapping-based classifier, correlation dimension-based classifier, and IINC. These classifiers have in common that they have no or nearly no learning phase, they are very simple, and they often show good results compared to much more complex and sophisticated systems.

Nearest Neighbors Classifiers

1-NN

This perhaps the simplest classifier uses rule that to a sample of unknown class (the query sample or query point) is assigned class to which the (first) nearest neighbor from the learning set belongs. A thorough theory of this classifier was published by Cover and Hart (1967). There one can find several important conclusions.

5-NN

This classifier belongs to class of k -NN classifiers, where parameter k is chosen by user according to his experience. The k is mostly odd to suppress indecisive cases when there are two classes only. The k lies usually between 1 and square root of number of samples of the learning set. For classification the majority rule is used, the sample belongs to class that has most of samples among k nearest to the query sample. A special selection of five nearest neighbors follows results of Hassanat (2014) where one can find that this number of nearest neighbors seems to be the best option among all others.

Classifiers that Use Scaling in Data

Distribution mapping-based classifier

The estimate of the probability that point x belongs to a class in the case of different a-priori probabilities we multiply each sum for a class by the a-priori probability as follows.

$$\hat{p}(c|x) = \frac{1/N_c \sum_{x_i \in U_c} 1/r_i^q}{\sum_{k=1}^C (1/N_k \sum_{x_i \in U_k} 1/r_i^q)}$$

Where N_c is the number of samples of the class c in the learning set. The sum in the numerator goes for all points of the learning set from class c . The q is the distribution mapping exponent. (Jiřina and Jiřina, 2013).

Correlation dimension-based classifier

In this method it is supposed that distribution mapping exponents for individual query points differ only slightly and that one can use the value of correlation dimension v instead. Computation has then two steps, in the first step the estimate of correlation dimension v is computed using any known suitable method and then one uses the same procedure as in the preceding Section where v instead of q is used. A relative advantage of this approach is that estimate of the correlation dimension is more exact than estimate of the distribution mapping exponent and that computation of the correlation dimension v is done once only in difference

of the distribution mapping exponent that must be computed for each query point anew (Jiřina and Jiřina, 2014).

IINC

This method uses formula

$$\hat{p}(c|x) = \frac{\sum_{x_i \in U_c} 1/i}{\sum_{i=1}^N 1/i}.$$

(The sum in the numerator goes for all points of the learning set from class c.)

Taking a-priori probabilities into account there is

$$\hat{p}(c|x) = \frac{1/N_c \sum_{x_i \in U_c} 1/i}{\sum_{k=1}^C (1/N_k \sum_{x_i \in U_k} 1/i)}$$

This simple method has the same theoretical basis as two previous methods, i.e. it is based on the phenomenon of scaling in data and its relation to fractals. In this method is used a consideration more. If there is linear dependence of probability or simply of neighbor's number i on $z_i = r_i^q$, $i \approx r_i^q$ then why not to use i instead of r_i^q directly getting simpler formulas as shown above (Jiřina and Jiřina, 2014b).

Metrics

Nine metrics are excerpted from Deza (2006). There are Angular, Bray-Curtis, Canberra, Cayley-Klein-Hilbert, Clark, Intersection, Lorentz, Orloci, and Weierstrass metrics. We added L1, L2, L10, Mahalanobis, Class Dependent Mahalanobis, and Hassanat (2014) metrics. The Hassanat metric is described below.

All these fifteen metrics are metrics in R_d , where d is data space dimensionality. Moreover all can be easily computed, some exceptions are popular Mahalanobis metrics that need computation of covariance matrix, and the Class Dependent Mahalanobis metrics where the covariance matrix must be computed for each class separately.

Hassanat metric

This new metrics was introduced recently by Hassanat (2014).

$$D(A_i, B_i) = \begin{cases} 1 - \frac{1 + \min(A_i, B_i)}{1 + \max(A_i, B_i)} & , \min(A_i, B_i) \geq 0 \\ 1 - \frac{1 + \min(A_i, B_i) + |\min(A_i, B_i)|}{1 + \max(A_i, B_i) + |\min(A_i, B_i)|} & , \min(A_i, B_i) < 0 \end{cases} \quad (2)$$

And for all the vectors dimensions we get:

$$D_{\text{proposed}}(A, B) = \sum_{i=1}^m (D(A_i, B_i)) \quad (3)$$

where A and B are both vectors with size m. A_i and B_i are real numbers.

Statistical evaluation

Wilcoxon Goodness of Fit Test

We use two versions of this test.

Simple Table Test

We use Wilcoxon's goodness of Fit test in simple version according to Hole (2005) where W gained is compared with tabulated values depending on the number of nonzero positive and negative differences. A simple and efficient test according to Hole (2005) is summarized here as follows.

R_i are order numbers from smallest to largest absolute value of the difference of data for one and the other compared possibilities (do not count zeroes). To each order number a sign of corresponding difference is assigned. W is the signed sum of all ranks. Then:

$$W = \sum_{i=1}^N [\text{sgn}(x_{2,i} - x_{1,i}) \cdot R_i], \text{ (assume } \text{sgn}(0) = 0)$$

Knowing W and the number of nonzero differences N , one can accept or reject the H_0 hypothesis (that there is a good fit, i.e. no significant difference) by inspection of a table, see Appendix 1.

Wilcoxon's z-Value Test

We also use standard Wilcoxon Test in form according to WikiWilZ (2014), specifically the alternative test given by equations as follows.

$$\text{Calculate } W = \sum_{i=1}^N [\text{sgn}(x_{2,i} - x_{1,i}) \cdot R_i], \text{ (assume } \text{sgn}(0) = 0)$$

$$\text{Calculate sampling probabilities } \pi^+ = P(x_{2,i} > x_{1,i}), \pi^- = P(x_{2,i} < x_{1,i}), \pi^0 = P(x_{2,i} = x_{1,i})$$

$$\text{For } N \geq 10 \text{ use normal approximation } Z = \frac{4W - N(N+1)}{\sqrt{\frac{2N(N+1)(2N+1)}{3}(\pi^+ + \pi^- - (\pi^+ - \pi^-)^2)}}$$

If $z > z_{\text{critical}}$ then reject H_0

Critical values follow from standard normal distribution for p_{critical} .

Friedman aligned test

We adopt procedure according to Derrac et al. (2011) as follows:

The starting point are classification errors for five classifiers with Hassanat metrics, see Appendix 3. Then order numbers for smallest to largest classification errors are assigned, see the upper part of Table 2 (with names of data sets) and average rank for each classifier is computed. The ranking differences $R_i - R_j$ are shown in the next part of Table 2 and then z -values that are computed using formula

$$z = (\hat{R}_i - \hat{R}_j) / \sqrt{\frac{k(n+1)}{6}}$$

Corresponding p -values are shown in the next part of Table 2. It is apparent that all percentages are rather high, above the 5 % significance level and then all entries say “reject” the H_0 hypothesis of a good fit, i.e. no significant difference. Comparisons for IINC as control for different significance levels are shown in the last part of Table 2.

Results

Here results of tests with 24 data sets from UCI MLR are shown and results of statistical tests are presented.

Statistical tests

Comparison of the first and the second best metrics for a classifier

We use two versions of the Wilcoxon’s Goodness of Fit Test as mentioned above for each classifier separately. Results are given in Table 1.

Classification Error

Method	iinc	Local	1-NN	Global	5-NN
meanError	0.156773	0.157604	0.164297	0.170339	0.174307
Std.dev.	0.074323	0.076323	0.070886	0.08065	0.077166
RelativeDev.	47.4%	48.4%	43.1%	47.3%	44.3%

Ranging metrics starting with the best

Metrics1 (best)	Hassanat	Hassanat	Hassanat	Hassanat	Hassanat
Metrics2	L1	L1	L1	Angular	L1
Metrics3	Orloci	L2	Angular	Orloci	Angular
Metrics4	Angular	Orloci	Orloci	L1	Orloci
Metrics5	L2	Angular	L2	L2	L2

Comparing the first and the second metrics.

WilcoxonTable test [WilcoxTable] H0 = Good Fit, i.e. not significantly different

Pluses	13	15	14	14	11
Minuses	9	8	9	10	10
Zeroes	2	1	1	0	3
Nr	22	23	23	24	21
W	75	90	68	81	25
Wcrit for 0.01/0.005	49 (reject)	55 (reject)	55 (reject)	61 (reject)	43
Wcrit for 0.02/0.01	56 (reject)	62 (reject)	62 (reject)	69 (reject)	49
Wcrit for 0.05/0.025	66 (reject)	73 (reject)	73	81 (reject)	59
Wcrit for 0.10/0.05	75 (reject)	83 (reject)	83	92	67

Wilcoxon z test H0=not significantly different

z-val	-1.29131	-0.97642	-1.3037	-0.9997	-2.33161
p-val	9.83%	16.44%	9.62%	15.87%	0.99%
0.05	reject	reject	reject	reject	
0.1		reject		reject	
0.15		reject		reject	

Table 1. Comparison of the best and the second best metrics for each of five classifiers separately.

Comparison of classifiers with Hassanat metrics

We use the Friedman Aligned Test for multiple comparisons described e.g. by Derrac et al. (2011). Results are given in Table 2. In summary, IINC with Hassanat metrics is better than other four classifiers tested on 5 % significance level. Note that RANK under the Average Rank is the same as the rank of the mean classification error. The target of the Friedman Aligned Test is to check the significance level. The hypothesis tested H0 is the Good Fit, i.e. no significant difference in classification ability.

Friedman Aligned Test

Data set	iinc	Local	1-NN	Global	5-NN
australian	56	57	69	66	58
balance	111	90	76	82	119
cancer	8	16	11	9	7
diabetes	92	87	112	89	110
DNA	95.5	95.5	84	92	103
german	102	92	109	104	113
glass	106	88	94	105	114
heart	71	72	85	79	74
ionosphere	40	47	43	46	40
iris	36	36	50	108	36
led17	1	4	53	33	19
letter	25	29	27.5	23	27.5
liver	116	120	115	117	118
monkey1	20	40	3	30	40
phoneme	65	60	52	61	59
satimage	51	54	48	55	49
segmen	12	13	6	14	10
sonar	77	78	73	81	86
vehicle	100	107	101	99	97
vote	44	45	31	32	34
vowel	5	22	2	18	38
waveform21	64	62	83	63	75
waveform40	70	68	98	67	80
wine	21	24	15	17	26

Average

Rank: 57.85417 58.60417 60.02083 62.08333 63.85417

RANK 1 2 3 4 5

Ranking differences

Ri-Rj	iinc	Local	1-NN	Global	5-NN
iinc	0	-0.75	-2.16667	-4.22917	-6
Local	0.75	0	-1.41667	-3.47917	-5.25
1-NN	2.16667	1.41667	0	-2.0625	-3.83333
Global	4.22917	3.47917	2.0625	0	-1.77083
5-NN	6	5.25	3.83333	1.77083	0

z-values	iinc	Local	1-NN	Global	5-NN
iinc	0	-0.18371	-0.53072	-1.03593	-1.46969
Local	0.183712	0	-0.34701	-0.85222	-1.28598
1-NN	0.530723	0.347011	0	-0.50521	-0.93897
Global	1.03593	0.852218	0.505207	0	-0.43376
5-NN	1.469694	1.285982	0.938971	0.433764	0

p-value	iinc	Local	1-NN	Global	5-NN
iinc		42.71%	29.78%	15.01%	7.08%
Local	42.71%		36.43%	19.70%	9.92%
1-NN	29.78%	36.43%		30.67%	17.39%

Global	15.01%	19.70%	30.67%	33.22%
5-NN	7.08%	9.92%	17.39%	33.22%

H0: A Good Fit					
SignLevel	iinc	Local	1-NN	Global	5-NN
5%	Control	reject	reject	reject	reject
22%	Control	reject	reject		
40%	Control	reject			

Table 2. The Friedman Aligned Test for comparing classifiers with IINC as Control.

Summary

Our results say that without doubt the Hassanat metrics is the best among others studied in this report. On the other hand we have to use rather elaborated statistical tests because simple tests, e.g. signed test, cannot affirm apparent differences in raw data in favor of any metrics or any classifier. When inspecting the second part of Table 1, it is seen that best four metrics can be ranked starting with the best: Hassanat, L1, Orloci or Angular, and L2. There is surprising finding that Hassanat metrics is the best in all cases. It is also strange that commonly used Euclidean (L2) metrics is the third best not considering Hassanat metrics.

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Appendices

Appendix 1. The Table test Based on Wilcoxon Test

According to Hole (2005).

Table of critical values for the Wilcoxon test:

To use this table: compare your obtained value of Wilcoxon's test statistic to the critical value in the table (taking into account N, the number of subjects). Your obtained value is statistically significant if it is equal to or SMALLER than the value in the table.

e.g.: suppose my obtained value is 22, and I had 15 participants. The critical value in the table is 25: my obtained value is *smaller* than this, and so I would conclude that the difference between the two conditions in my study was unlikely to occur by chance ($p < .05$ two-tailed test, or $p < .025$, one-tailed test).

One Tailed Significance levels:			
	0.025	0.01	0.005
Two Tailed significance levels:			
N	0.05	0.02	0.01
6	0	-	-
7	2	0	-
8	4	2	0
9	6	3	2
10	8	5	3
11	11	7	5
12	14	10	7
13	17	13	10
14	21	16	13
15	25	20	16
16	30	24	20
17	35	28	23
18	40	33	28
19	46	38	32
20	52	43	38
21	59	49	43
22	66	56	49
23	73	62	55
24	81	69	61
25	89	77	68

Appendix 2. The c++ functions for computing the Mahalanobis distance

According to Benzi, Collum and Tuma (2000) and Tuma (2014).

```
//      function [Z,D] = ainvl(A,tol);      norm(inv(A)-Z*Z')-->0
void ainvl(double z[],double d[],double a[],long n,double tol){
//
// left-looking ainvl decomposition
//
// purpose:
//  Computes the factorization
//   $ZD^{-1}Z^T \approx \text{inv}(A)$ 
//  of the symmetric and positive definite matrix A.
//  simple dense code,
//  where D is diagonal matrix of squares of eigenvalues
//
// input:
//  A:  matrix to be factored;
//  tol: drop tolerance for elements in U and V factors;
//
// output:
//  Z,D: AINV factors.
// returns 1 if OK else 0 if pivot is lesser than 1.0e=30.
//
// history:
//  Matlab code by Mirek Tuma, 2003.
//  FORTRAN code by Marcel Jirina, 2014. Needs subroutines myrow, mycol, scas.
//  c++ code by Marcel Jirina, 2014. No own externals.
//
//      basic initializations
//
long i,j,k,l;
double pi,pj,pp,ajnk,zknj,xinvpp;
double* dd = new double [n];
//
// unit matrices
//
for(i=0;i<n;i++){
    for(j=0;j<n;j++) z[i*n+j]=0;
    d[i,i]=z[i*n+i]=1;
}
//
// the loop
//
for(i=0;i<n;i++){
    //
    // pivoting
    //
    for(j=0;j<i;j++){
        //
        // find the multipliers
        //
        pi=pj=pp=0;
        for(k=0;k<n;k++){
            pi+=(ajnk=a[j*n+k])*z[k*n+i];
            pj+=a[i*n+k]*(zknj=z[k*n+j]);
            pp+=ajnk*zknj;
        }
        //
        // update the remaining columns
        //
        if(fabs(pp)<1.0e-30) goto nic;
        xinvpp=1/pp;
        //change the i-th column of z:
        //Z(:,i) = Z(:,i) - Z(:,j)*inv(pp)*pj;
        for(k=0;k<n;k++){ //do k=1,n
```

```

        z[k*n+i]=z[k*n+i]-z[k*n+j]*xinvpp*pj;
    }
    //
    // dropping
    //
    for(k=0;k<n;k++){
    if(fabs(z[k*n+i]) < tol) z[k*n+i]=0.0;
    }
}

pp=0;
for(k=0;k<n;k++){ pp+=a[i*n+k]*z[k*n+i];
d[i*n+i]=pp; //D(i,i) = pp;
dd[i]=sqrt(1/pp);
//
}
//
//Z=Z*sqrt(inv(D)); D is diagonal
//
for(k=0;k<n;k++){
    for(l=0;l<n;l++){
        z[k*n+l]=z[k*n+l]*dd[l];
    }
}
//case of singular matrix A --> z and d are then unit matrices
if(fabs(pp)<1.0e-30){
    for(i=0;i<n;i++){
        for(j=0;j<n;j++) z[i*n+j]=0;
        d[i,i]=z[i*n+i]=1;
    }
}
//return 1;
// norm(inv(A)-Z*Z')
} // of ainvl //////////////////////////////////////

```

```

double mahala(double u[], double v[], double z[], long n){
//
    v*=inv(a)*u;
    double vysledek;
    double* dd = new double [n];
    double* ls = new double [n];
    long i,j;
    for(i=0;i<n;i++) dd[i]=u[i]-v[i];
    for(i=0;i<n;i++) {
        ls[i]=0;
        for(j=0;j<n;j++) ls[i]+=z[i*n+j]*dd[j];
    }
    //scalar product
    vysledek=0;
    for(i=0;i<n;i++) vysledek+=ls[i]*ls[i];
    delete ls;
    delete dd;
    return sqrt(vysledek);
} // end of mahala //////////////////////////////////////

```

Appendix 3. Classification errors of five classifiers with Hassanat metrics

Summary of raw data (Appendix 4) used for statistical tests.

mean	0.156773	0.157604	0.164297	0.170339	0.174307
Metrics	Hassanat	Hassanat	Hassanat	Hassanat	Hassanat
Method	iinc	Local	1-NN	Global	5-NN
Task					
australian	0.129013	0.12974	0.17699	0.167888	0.141188
balance	0.314418	0.265925	0.196774	0.24424	0.389539
cancer	0.032496	0.038217	0.036739	0.035578	0.030156
diabetes	0.270575	0.260427	0.318489	0.262781	0.309251
DNA	0.274874	0.274874	0.246206	0.267285	0.298482
german	0.2954	0.2726	0.3078	0.2996	0.3236
glass	0.303937	0.261115	0.273264	0.300412	0.325494
heart	0.178889	0.182593	0.246296	0.218148	0.194074
ionosphere	0.085726	0.097964	0.088	0.094262	0.08173
iris	0.079091	0.079091	0.108182	0.307273	0.079091
led17	0.004608	0.021518	0.118597	0.074131	0.047766
letter	0.051	0.0625	0.058	0.04925	0.058
liver	0.369855	0.397681	0.366087	0.375362	0.377681
monkey1	0.047903	0.084214	0.020299	0.062506	0.083575
phoneme	0.167265	0.151028	0.11527	0.153694	0.142646
satimage	0.113	0.1245	0.1055	0.127	0.1065
segmen	0.036797	0.037359	0.028918	0.037749	0.036061
sonar	0.209352	0.213354	0.184574	0.234032	0.256162
vehicle	0.288335	0.30429	0.295095	0.284518	0.275175
vote	0.088647	0.092582	0.071729	0.073497	0.077876
vowel	0.028444	0.049152	0.016061	0.045152	0.080101
waveform21	0.166834	0.160313	0.245275	0.165594	0.194556
waveform40	0.177281	0.171721	0.280917	0.168201	0.220638
wine	0.048808	0.049732	0.038058	0.039976	0.054033

Appendix 4. Classification errors – raw data.

1-NN classifier

mean	0.164297	0.168857	0.173039	0.173039	0.173729	0.187004	0.198592	0.228548	0.234505	0.2497	0.293743	0.324354	0.327547	0.337463	0.34674
Metrics	Hassanat	L1	Orloci	Angular	L2	L10	CDMah	Weierstras	Mahala	Lorentz	Canberra	BrayCurtis	Intersection	Clark	CayleyKleinHilber
Method	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN
												X	X	X	X
australian	0.17699	0.188716	0.206124	0.206124	0.207279	0.251308	0.224803	0.202647	0.346635	0.19048	0.195128	0.400337	0.448983	0.447244	0.442752
balance	0.196774	0.249619	0.191669	0.191669	0.249774	0.248663	0.237223	0.296369	0.260629	0.176142	0.271946	0.157392	0.155611	0.477462	0.262564
cancer	0.036739	0.039228	0.038658	0.038658	0.050668	0.058754	0.048469	0.08759	0.046442	0.083975	0.083075	0.141013	0.348454	0.257677	0.455728
diabetes	0.318489	0.314582	0.308194	0.308194	0.294784	0.305197	0.303266	0.378369	0.306115	0.39697	0.341852	0.46109	0.375994	0.427454	0.447255
DNA	0.246206	0.245363	0.214165	0.214165	0.257167	0.273187	0.278246	0.254637	0.342327	0.243676	0.252951	0.48398	0.491568	0.491568	0.436762
german	0.3078	0.3212	0.3324	0.3324	0.3276	0.3261	0.3362	0.3166	0.3555	0.3141	0.3203	0.4431	0.4622	0.372	0.3701
glass	0.273264	0.309865	0.306574	0.306574	0.327181	0.361211	0.379167	0.459961	0.436695	0.466624	0.490155	0.3779	0.327642	0.330806	0.366857
heart	0.246296	0.25037	0.255556	0.255556	0.251111	0.262963	0.257778	0.255926	0.42037	0.238519	0.26963	0.405926	0.467037	0.466667	0.472593
ionosphere	0.088	0.098777	0.125594	0.125594	0.140467	0.129903	0.140467	0.332161	0.14072	0.148318	0.160563	0.43338	0.416097	0.416097	0.398918
iris	0.108182	0.088182	0.059091	0.059091	0.059091	0.059091	0.05	0.04	0.06	0.099091	0.248182	0.275455	0.485455	0.238182	0.287273
led17	0.118597	0.118597	0.154011	0.154011	0.114998	0.044803	0.108601	0.113743	0.100016	0.121752	0.213421	0.063421	0.118674	0.108601	0.108601
letter	0.058	0.0515	0.05325	0.05325	0.048	0.0685	0.067	0.138	0.0675	0.392	0.47075	0.03975	0.03775	0.034	0.12925
liver	0.366087	0.387826	0.389275	0.389275	0.395942	0.414493	0.368986	0.486957	0.428406	0.516812	0.469565	0.489855	0.463478	0.468986	0.444348
monkey1	0.020299	0.020844	0.022289	0.022289	0.020666	0.019756	0.079208	0.067247	0.35113	0.065932	0.06575	0.495893	0.493455	0.5	0.406049
phoneme	0.11527	0.117347	0.127788	0.127788	0.118385	0.121389	0.119385	0.328732	0.124578	0.322802	0.414102	0.29358	0.293486	0.371704	0.408107
satimage	0.1055	0.1	0.105	0.105	0.1065	0.119	0.124	0.1865	0.1285	0.3535	0.4735	0.2255	0.1245	0.267	0.2065
segmen	0.028918	0.032771	0.038485	0.038485	0.038095	0.049134	0.038095	0.159784	0.042987	0.264545	0.345758	0.205931	0.142857	0.142857	0.313766
sonar	0.184574	0.174728	0.180938	0.180938	0.183713	0.290921	0.364831	0.184233	0.206606	0.184122	0.216972	0.49256	0.46631	0.485628	0.46631
vehicle	0.295095	0.301124	0.293609	0.293609	0.305121	0.321442	0.371926	0.323526	0.444102	0.406936	0.483119	0.280644	0.240137	0.246224	0.233092
vote	0.071729	0.073343	0.090153	0.090153	0.087389	0.081329	0.099054	0.087989	0.09718	0.080146	0.137705	0.484681	0.419756	0.405893	0.475865
vowel	0.016061	0.016606	0.017374	0.017374	0.011859	0.023051	0.087293	0.171051	0.026384	0.302485	0.446949	0.16202	0.088121	0.099434	0.209758
waveform2	0.245275	0.239557	0.258561	0.258561	0.237298	0.240763	0.302517	0.254738	0.296434	0.26056	0.277381	0.337039	0.3378	0.341419	0.334161
waveform4	0.280917	0.276023	0.314702	0.314702	0.282164	0.342199	0.328386	0.282745	0.318684	0.296662	0.311479	0.325057	0.324298	0.336842	0.3323
wine	0.038058	0.036405	0.069478	0.069478	0.054234	0.074935	0.051319	0.075638	0.28017	0.066654	0.089598	0.308988	0.331476	0.365367	0.312854

5-NN classifier

mean	0.174307	0.175814	0.176771	0.176771	0.183601	0.198158	0.21954	0.239224	0.240598	0.240752	0.286886	0.306963	0.323888	0.327547	0.335214	
Metrics	Hassanat	L1	Orloci	Angular	L2	L10	Weierstras	Lorentz	CDMah	Mahala	Canberra	Clark	BrayCurtis	Intersection	CayleyKleinHilb	
Method	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	
												X	X	X	X	
australian	0.141188	0.153237	0.17348	0.17348	0.171608	0.239992	0.176818	0.160597	0.201458	0.323173	0.173084	0.453813	0.39642	0.448983	0.467718	
balance	0.389539	0.392493	0.265671	0.265671	0.37513	0.375784	0.296369	0.176142	0.342308	0.371358	0.271946	0.307167	0.157392	0.155611	0.237772	
cancer	0.030156	0.030009	0.03234	0.03234	0.035277	0.042005	0.046005	0.060388	0.03731	0.036009	0.079849	0.348454	0.140721	0.348454	0.483664	
diabetes	0.309251	0.299866	0.28239	0.28239	0.291916	0.292448	0.367825	0.387852	0.294652	0.325122	0.337161	0.432388	0.46109	0.375994	0.499837	
DNA	0.298482	0.298482	0.220067	0.220067	0.323777	0.318718	0.317032	0.27403	0.247049	0.44941	0.278246	0.236088	0.48398	0.491568	0.265599	
german	0.3236	0.3431	0.3368	0.3368	0.3368	0.3377	0.3277	0.3313	0.3679	0.3832	0.3354	0.3	0.4431	0.4622	0.2989	
glass	0.325494	0.352438	0.361761	0.361761	0.391645	0.437231	0.473818	0.471808	0.485265	0.685139	0.49458	0.135418	0.370001	0.327642	0.243812	
heart	0.194074	0.193333	0.202222	0.202222	0.193333	0.231111	0.205926	0.199259	0.197407	0.343704	0.228148	0.451111	0.414815	0.467037	0.45	
ionosphere	0.08173	0.09196	0.117915	0.117915	0.125614	0.115099	0.316225	0.124145	0.125614	0.123638	0.134946	0.358954	0.43338	0.416097	0.362942	
iris	0.079091	0.079091	0.049091	0.049091	0.069091	0.039091	0.04	0.099091	0.05	0.04	0.248182	0.296364	0.275455	0.485455	0.491818	
led17	0.047766	0.047766	0.098453	0.098453	0.047115	0.017814	0.038168	0.038857	0.893659	0.031116	0.107704	0.106341	0.063421	0.118674	0.106341	
letter	0.058	0.05225	0.0615	0.0615	0.05275	0.0795	0.127	0.3895	0.0725	0.07975	0.4705	0.0355	0.03975	0.03775	0.1295	
liver	0.377681	0.373043	0.352174	0.352174	0.408986	0.403188	0.491014	0.502899	0.36	0.361449	0.527826	0.467826	0.486087	0.463478	0.455362	
monkey1	0.083575	0.083578	0.105341	0.105341	0.083396	0.071753	0.104877	0.084205	0.127435	0.135604	0.077214	0.5	0.498078	0.493455	0.406049	
phoneme	0.142646	0.147706	0.156694	0.156694	0.148197	0.153938	0.328732	0.322727	0.149994	0.150407	0.414083	0.437034	0.29358	0.293486	0.413213	
satimage	0.1065	0.105	0.1145	0.1145	0.1045	0.122	0.157	0.353	0.1195	0.1205	0.474	0.2	0.2255	0.1245	0.157	
segmen	0.036061	0.041255	0.055974	0.055974	0.057056	0.074805	0.157922	0.26368	0.057056	0.066753	0.342814	0.142857	0.204892	0.142857	0.290519	
sonar	0.256162	0.250584	0.245326	0.245326	0.270286	0.322552	0.262357	0.247533	0.342712	0.274269	0.270571	0.46631	0.492072	0.46631	0.46631	
vehicle	0.275175	0.278407	0.291715	0.291715	0.288588	0.312577	0.31278	0.405752	0.378646	0.451059	0.482525	0.242324	0.280056	0.240137	0.233311	
vote	0.077876	0.080608	0.089794	0.089794	0.083848	0.09144	0.091226	0.082899	0.128697	0.128937	0.129923	0.386427	0.480778	0.419756	0.45498	
vowel	0.080101	0.088808	0.113576	0.113576	0.095596	0.116889	0.17398	0.301899	0.22002	0.112202	0.446949	0.126081	0.161657	0.088121	0.211051	
waveform2	0.194556	0.187818	0.207515	0.207515	0.186672	0.196456	0.187535	0.205817	0.242456	0.235474	0.24322	0.33202	0.337039	0.3378	0.326181	
waveform4	0.220638	0.211179	0.261841	0.261841	0.227079	0.282962	0.21366	0.20178	0.267102	0.2539	0.237721	0.3351	0.325057	0.324298	0.3351	
wine	0.054033	0.037526	0.046361	0.046361	0.038166	0.080726	0.054995	0.056221	0.06561	0.295886	0.078662	0.269535	0.308988	0.331476	0.258149	

DME-based (local) classifier

mean	0.157604	0.162566	0.170403	0.175413	0.176549	0.200087	0.216326	0.228472	0.230899	0.232421	0.27925	0.323383	0.326693	0.327547	0.343873
Metrics	Hassanat	L1	L2	Orloci	Angular	L10	Weierstras	CDMah	Mahala	Lorentz	Canberra	BrayCurtis	Clark	Intersectio	CayleyKleinHilbe
Method	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local
												X	X	X	X
australian	0.12974	0.132486	0.151748	0.156251	0.155518	0.261297	0.159147	0.173774	0.31081	0.150327	0.182809	0.397723	0.447244	0.448983	0.443041
balance	0.265925	0.26727	0.244014	0.232487	0.229937	0.228794	0.296369	0.233284	0.241086	0.176142	0.176142	0.157392	0.167295	0.155611	0.233378
cancer	0.038217	0.039102	0.035436	0.043476	0.043327	0.03763	0.048057	0.040274	0.045839	0.060672	0.056698	0.140721	0.344055	0.348454	0.383889
diabetes	0.260427	0.248441	0.249221	0.258579	0.262216	0.264453	0.36678	0.253529	0.286725	0.387985	0.393069	0.46109	0.403227	0.375994	0.430353
DNA	0.274874	0.302698	0.342327	0.159359	0.157673	0.39629	0.366779	0.13828	0.526981	0.27403	0.363406	0.48398	0.491568	0.491568	0.436762
german	0.2726	0.2782	0.2758	0.2973	0.2976	0.2946	0.2757	0.2932	0.3231	0.2808	0.263	0.4433	0.372	0.4622	0.3701
glass	0.261115	0.295799	0.332523	0.313496	0.311469	0.439913	0.472981	0.481943	0.654147	0.466406	0.490112	0.371972	0.327642	0.327642	0.34932
heart	0.182593	0.182593	0.18	0.189259	0.188519	0.222963	0.194074	0.187407	0.344444	0.183333	0.347407	0.411481	0.466667	0.467037	0.472593
ionosphere	0.097964	0.13701	0.187734	0.133911	0.132217	0.1686	0.320499	0.187734	0.172913	0.174877	0.096507	0.43338	0.416097	0.416097	0.39037
iris	0.079091	0.069091	0.059091	0.069091	0.069091	0.039091	0.04	0.04	0.03	0.099091	0.099091	0.275455	0.445455	0.485455	0.485455
led17	0.021518	0.016375	0.012013	0.01491	0.01166	0.130303	0.007903	0.891399	0.006112	0.006702	0.201298	0.063421	0.108601	0.118674	0.108601
letter	0.0625	0.05975	0.06925	0.1245	0.133	0.09775	0.12725	0.095	0.09975	0.3895	0.3915	0.03975	0.03775	0.03775	0.129
liver	0.397681	0.402609	0.405217	0.364348	0.365797	0.411304	0.505797	0.361159	0.362319	0.496812	0.498551	0.483768	0.452174	0.463478	0.447826
monkey1	0.084214	0.08601	0.090136	0.221672	0.225818	0.101753	0.129562	0.132003	0.115867	0.069312	0.213445	0.479903	0.5	0.493455	0.406049
phoneme	0.151028	0.165095	0.1657	0.175517	0.178406	0.170156	0.328713	0.162943	0.166963	0.322765	0.322689	0.29358	0.293109	0.293486	0.305951
satimage	0.1245	0.136	0.1385	0.1205	0.1285	0.1525	0.158	0.161	0.149	0.353	0.353	0.2255	0.2255	0.1245	0.2065
segmen	0.037359	0.040649	0.052511	0.119437	0.11987	0.07303	0.160693	0.052511	0.066061	0.264242	0.267403	0.205628	0.142857	0.142857	0.296147
sonar	0.213354	0.226844	0.254475	0.239668	0.242061	0.310088	0.258614	0.338884	0.281225	0.213563	0.429263	0.493535	0.46631	0.46631	0.46631
vehicle	0.30429	0.317413	0.326319	0.320193	0.3247	0.333986	0.310877	0.438091	0.463924	0.406573	0.41038	0.279819	0.237019	0.240137	0.227559
vote	0.092582	0.094427	0.095325	0.14897	0.147808	0.15823	0.126804	0.146114	0.152996	0.096028	0.189453	0.488145	0.404051	0.419756	0.4754
vowel	0.049152	0.046586	0.054283	0.072202	0.075091	0.075212	0.171697	0.204889	0.074202	0.301899	0.302081	0.160566	0.090909	0.088121	0.209576
waveform2	0.160313	0.152853	0.150653	0.175153	0.174692	0.161514	0.157214	0.199438	0.196215	0.184557	0.258646	0.337039	0.33732	0.3378	0.334161
waveform4	0.171721	0.161321	0.165941	0.204061	0.206102	0.20344	0.158479	0.203103	0.192383	0.163281	0.238698	0.325057	0.3323	0.324298	0.3323
wine	0.049732	0.042976	0.051451	0.055563	0.056104	0.06919	0.04983	0.067362	0.278513	0.056221	0.157349	0.308988	0.331476	0.331476	0.312313

Correlation dimension-based (global) classifier

mean	0.170339	0.17587	0.176	0.196015	0.205432	0.216868	0.239048	0.240516	0.255824	0.281366	0.290069	0.323383	0.326693	0.327547	0.343873	
Metrics	Hassanat	Angular	Orloci	L1	L2	Weierstras	Mahala	Lorentz	CDMaha	Canberra	L10	BrayCurtis	Clark	Intersectio	CayleyKleinHilb	
Method	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	
												X	X	X	X	
australian	0.167888	0.154347	0.157401	0.165978	0.179453	0.167554	0.358262	0.16614	0.200607	0.176243	0.257117	0.397723	0.447244	0.448983	0.443041	
balance	0.24424	0.229459	0.228181	0.268804	0.257292	0.296369	0.260616	0.176142	0.206909	0.271946	0.233893	0.157392	0.167292	0.155611	0.233378	
cancer	0.035578	0.045817	0.04523	0.043792	0.038376	0.048057	0.046576	0.060672	0.043788	0.080876	0.041302	0.140721	0.344055	0.348454	0.383889	
diabetes	0.262781	0.25844	0.255187	0.256527	0.258986	0.366911	0.278121	0.389155	0.256259	0.33365	0.269266	0.46109	0.403227	0.375994	0.430353	
DNA	0.267285	0.167791	0.17032	0.256324	0.322091	0.394604	0.548061	0.258853	0.158516	0.267285	0.526138	0.48398	0.491568	0.491568	0.436762	
german	0.2996	0.2944	0.2954	0.3113	0.2984	0.2852	0.3363	0.3014	0.3214	0.3055	0.3289	0.4433	0.372	0.4622	0.3701	
glass	0.300412	0.311954	0.312534	0.73063	0.68662	0.462258	0.797419	0.469685	0.822329	0.490594	0.648035	0.371972	0.327642	0.327642	0.34932	
heart	0.218148	0.191111	0.191852	0.205926	0.201111	0.191481	0.355185	0.205185	0.208148	0.23963	0.234815	0.411481	0.466667	0.467037	0.472593	
ionosphere	0.094262	0.134813	0.134813	0.128427	0.173481	0.319074	0.194559	0.168648	0.173481	0.179984	0.255497	0.43338	0.416097	0.416097	0.39037	
iris	0.307273	0.059091	0.069091	0.069091	0.059091	0.04	0.05	0.099091	0.04	0.248182	0.049091	0.275455	0.445455	0.485455	0.485455	
led17	0.074131	0.017566	0.021914	0.060329	0.038729	0.020971	0.020516	0.038062	0.891399	0.070499	0.915695	0.063421	0.108601	0.118674	0.108601	
letter	0.04925	0.1145	0.1085	0.048	0.04875	0.12525	0.07325	0.3895	0.07175	0.4705	0.07025	0.03975	0.03775	0.03775	0.129	
liver	0.375362	0.371304	0.370145	0.381159	0.396232	0.494493	0.370435	0.50087	0.370435	0.527246	0.4	0.483768	0.452174	0.463478	0.447826	
monkey1	0.062506	0.223295	0.220221	0.063763	0.068107	0.119834	0.105932	0.059484	0.113958	0.056792	0.126156	0.479903	0.5	0.493455	0.406049	
phoneme	0.153694	0.176501	0.170421	0.12809	0.130922	0.328713	0.133924	0.322765	0.132641	0.414102	0.139289	0.29358	0.293109	0.293486	0.305951	
satimage	0.127	0.148	0.1385	0.0935	0.098	0.155	0.122	0.3535	0.1275	0.4735	0.1095	0.2255	0.2255	0.1245	0.2065	
segmen	0.037749	0.135065	0.147186	0.062424	0.293117	0.160736	0.055238	0.264026	0.293117	0.341688	0.724156	0.205628	0.142857	0.142857	0.296147	
sonar	0.234032	0.218388	0.219329	0.67457	0.576704	0.240294	0.257334	0.332365	0.53369	0.250218	0.645809	0.493535	0.46631	0.46631	0.46631	
vehicle	0.284518	0.310736	0.306846	0.288517	0.29002	0.307816	0.452236	0.406456	0.378351	0.483469	0.309106	0.279819	0.237019	0.240137	0.227559	
vote	0.073497	0.156077	0.155168	0.076488	0.090502	0.125659	0.15831	0.079482	0.141511	0.122544	0.17694	0.488145	0.404051	0.419756	0.4754	
vowel	0.045152	0.066949	0.063717	0.040141	0.048242	0.171697	0.068687	0.302081	0.187535	0.446586	0.060788	0.160566	0.090909	0.088121	0.209576	
waveform21	0.165594	0.176933	0.180753	0.156114	0.159094	0.169652	0.196455	0.198896	0.199558	0.23974	0.164895	0.337039	0.33732	0.3378	0.334161	
waveform40	0.168201	0.202801	0.2046	0.15856	0.164939	0.1617	0.192902	0.17524	0.202823	0.184841	0.207279	0.325057	0.3323	0.324298	0.3323	
wine	0.039976	0.055548	0.056692	0.035907	0.052102	0.051498	0.304827	0.054694	0.064074	0.077172	0.067736	0.308988	0.331476	0.331476	0.312313	

IINC - Inverted Indexes of Neighbors Classifier

mean	0.156773	0.159764	0.161295	0.161295	0.165494	0.185766	0.192172	0.211102	0.231566	0.233068	0.283367	0.315862	0.323965	0.327547	0.33568	
Metrics	Hassanat	L1	Orloci	Angular	L2	L10	CDMaha	Weierstras	Lorentz	Mahala	Canberra	Clark	BrayCurtis	Intersectio	CayleyKleinHilbe	
Method	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	
												X	X	X	X	
australian	0.129013	0.133073	0.15175	0.15175	0.147538	0.222751	0.179562	0.159005	0.150882	0.314464	0.167277	0.447115	0.396861	0.448983	0.461309	
balance	0.314418	0.325484	0.237052	0.237052	0.304992	0.301766	0.30012	0.296369	0.176142	0.30592	0.176142	0.419576	0.157392	0.155611	0.249505	
cancer	0.032496	0.032795	0.028832	0.028832	0.034847	0.039382	0.040118	0.045712	0.061994	0.03984	0.056414	0.348454	0.140721	0.348454	0.482928	
diabetes	0.270575	0.262096	0.268334	0.268334	0.255189	0.270561	0.25965	0.368476	0.387988	0.285407	0.390983	0.498838	0.46109	0.375994	0.477224	
DNA	0.274874	0.278246	0.166105	0.166105	0.310287	0.348229	0.176223	0.309444	0.269815	0.468803	0.268971	0.236088	0.48398	0.491568	0.265599	
german	0.2954	0.3091	0.3269	0.3269	0.3113	0.3119	0.3338	0.2969	0.3126	0.3644	0.2933	0.364	0.4431	0.4622	0.3625	
glass	0.303937	0.330125	0.32575	0.32575	0.351761	0.378976	0.469267	0.469734	0.462214	0.654798	0.491462	0.135418	0.36997	0.327642	0.243812	
heart	0.178889	0.17963	0.184815	0.184815	0.179259	0.218889	0.186667	0.192593	0.187778	0.352222	0.200741	0.477778	0.411111	0.467037	0.482593	
ionosphere	0.085726	0.108185	0.123899	0.123899	0.148149	0.140467	0.148149	0.323646	0.14241	0.14672	0.096507	0.358954	0.43338	0.416097	0.362942	
iris	0.079091	0.079091	0.049091	0.049091	0.049091	0.049091	0.04	0.04	0.099091	0.04	0.099091	0.227273	0.275455	0.485455	0.448182	
led17	0.004608	0.004608	0.050701	0.050701	0.004458	0.000751	0.104301	0.005251	0.007556	0.005656	0.798702	0.104301	0.063421	0.118674	0.104301	
letter	0.051	0.0485	0.062	0.062	0.04975	0.07225	0.0715	0.12675	0.389	0.07325	0.39	0.036	0.03975	0.03775	0.1295	
liver	0.369855	0.382899	0.365217	0.365217	0.391304	0.41942	0.357391	0.508116	0.505217	0.386667	0.508986	0.490435	0.488696	0.463478	0.432174	
monkey1	0.047903	0.048084	0.056393	0.056393	0.047903	0.063919	0.095731	0.079916	0.048588	0.209266	0.214172	0.5	0.492256	0.493455	0.406049	
phoneme	0.167265	0.176027	0.1863	0.1863	0.180577	0.183996	0.186508	0.328713	0.322765	0.181541	0.322689	0.433222	0.29358	0.293486	0.409228	
satimage	0.113	0.11	0.116	0.116	0.1155	0.1345	0.133	0.1595	0.353	0.125	0.354	0.1945	0.2255	0.1245	0.157	
segmen	0.036797	0.041212	0.052944	0.052944	0.050476	0.067186	0.050476	0.159913	0.264545	0.059784	0.265195	0.142857	0.205801	0.142857	0.291082	
sonar	0.209352	0.198937	0.22738	0.22738	0.228487	0.292775	0.346918	0.222291	0.201889	0.246865	0.359456	0.46631	0.49256	0.46631	0.46631	
vehicle	0.288335	0.294006	0.296801	0.296801	0.293449	0.309738	0.365088	0.31229	0.404327	0.444075	0.408482	0.242672	0.280176	0.240137	0.232839	
vote	0.088647	0.085201	0.096506	0.096506	0.08889	0.104532	0.13853	0.089339	0.088428	0.140377	0.083114	0.390735	0.487429	0.419756	0.458162	
vowel	0.028444	0.027253	0.038202	0.038202	0.027394	0.041838	0.129859	0.172323	0.301899	0.043091	0.302081	0.126061	0.161838	0.088121	0.211414	
waveform21	0.166834	0.161493	0.182556	0.182556	0.163814	0.168837	0.210013	0.160354	0.181838	0.204733	0.193799	0.33338	0.337039	0.3378	0.326341	
waveform40	0.177281	0.175862	0.213042	0.213042	0.180839	0.233758	0.220103	0.175619	0.179762	0.210582	0.277997	0.33718	0.325057	0.324298	0.33718	
wine	0.048808	0.042436	0.064521	0.064521	0.056611	0.082879	0.069156	0.062217	0.057857	0.290173	0.081259	0.269535	0.308988	0.331476	0.258149	

Appendix 5. Standard deviations of the classification errors – raw data.

1-NN classifier

mean	0.070886	0.071562	0.069937	0.069937	0.071884	0.07588	0.083393	0.083336	0.081264	0.097553	0.101635	0.09631	0.081928	0.091846	0.091806068
Metrics	Hassanat	L1	Orloci	Angular	L2	L10	CDMah	Weierstras	Mahala	Lorentz	Canberra	BrayCurtis	Intersectio	Clark	CayleyKleinHilb
Method	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN	1-NN
australian	0.02779	0.033124	0.03118	0.03118	0.029657	0.028325	0.07142	0.029506	0.040238	0.029472	0.028794	0.040107	0.028313	0.016044	0.018149853
balance	0.0526	0.063248	0.06708	0.06708	0.063993	0.063191	0.053002	0.076175	0.063735	0.105128	0.131826	0.158423	0.154787	0.043155	0.104066733
cancer	0.01443	0.016372	0.012568	0.012568	0.016101	0.020991	0.015736	0.027073	0.019245	0.033625	0.02731	0.033462	0.002364	0.070827	0.06212897
diabetes	0.030072	0.027815	0.03149	0.03149	0.03017	0.02975	0.02845	0.033727	0.038963	0.045479	0.047237	0.106726	0.134662	0.110517	0.076008874
DNA	0.430982	0.430483	0.410415	0.410415	0.437257	0.445784	0.448324	0.435841	0.474689	0.429481	0.434887	0.499954	0.50014	0.50014	0.496194095
german	0.023193	0.029581	0.029001	0.029001	0.026788	0.023437	0.030699	0.035347	0.03408	0.029497	0.030961	0.0823	0.132508	0.155235	0.153790508
glass	0.067124	0.077287	0.074654	0.074654	0.081118	0.08456	0.079839	0.07982	0.062834	0.069549	0.072114	0.02579	0.013547	0.026614	0.033523816
heart	0.048673	0.045705	0.051841	0.051841	0.053979	0.05157	0.068868	0.050012	0.078679	0.051927	0.053457	0.086362	0.067994	0.044896	0.044305654
ionosphere	0.032442	0.036523	0.034097	0.034097	0.03849	0.046615	0.03849	0.031762	0.040414	0.05127	0.045768	0.103832	0.114586	0.114586	0.054763125
iris	0.097767	0.108165	0.083896	0.083896	0.096233	0.096233	0.084984	0.05164	0.084327	0.094325	0.072354	0.162569	0.057687	0.097612	0.099512125
led17	0.016351	0.016351	0.015526	0.015526	0.015841	0.008977	0.002026	0.018654	0.016391	0.018981	0.022841	0.014585	0.008903	0.002026	0.002025846
letter	0.233773	0.221043	0.22456	0.22456	0.213793	0.252634	0.250053	0.344943	0.250917	0.488258	0.499206	0.195396	0.190615	0.181252	0.335518376
liver	0.057883	0.057044	0.047485	0.047485	0.059679	0.063814	0.054164	0.05391	0.06874	0.052753	0.073608	0.059359	0.067819	0.068214	0.049222269
monkey1	0.038382	0.038413	0.041083	0.041083	0.03849	0.037587	0.17217	0.062976	0.057081	0.062004	0.062078	0.09548	0.023162	0	0.043330161
phoneme	0.012435	0.012876	0.014453	0.014453	0.013192	0.012909	0.01412	0.021385	0.01386	0.021773	0.017933	0.000467	0.000245	0.079516	0.040075106
satimage	0.307273	0.300075	0.30663	0.30663	0.308554	0.323869	0.329664	0.389607	0.334729	0.478176	0.499422	0.418016	0.330234	0.442503	0.404894702
segmen	0.008306	0.010339	0.011793	0.011793	0.012322	0.013565	0.012322	0.038132	0.011361	0.037065	0.031192	0.019101	4.49E-16	4.49E-16	0.02517379
sonar	0.074475	0.063658	0.064553	0.064553	0.069544	0.066975	0.091936	0.059937	0.071154	0.06091	0.074391	0.043938	0.005035	0.04344	0.005034538
vehicle	0.027298	0.031142	0.025067	0.025067	0.02627	0.026822	0.035233	0.028879	0.031583	0.035386	0.041911	0.022059	0.024449	0.029793	0.021547601
vote	0.025221	0.026454	0.029032	0.029032	0.026897	0.02716	0.033869	0.025545	0.035721	0.029731	0.053328	0.055013	0.074811	0.061132	0.075927562
vowel	0.010826	0.012163	0.01165	0.01165	0.010654	0.013501	0.029509	0.029585	0.014724	0.043807	0.043596	0.029792	0.009754	0.020787	0.031945204
waveform2	0.011452	0.012259	0.012247	0.012247	0.012495	0.013625	0.013541	0.011591	0.013966	0.011809	0.012161	0.008562	0.005817	0.010175	0.004468282
waveform4	0.010909	0.012705	0.012812	0.012812	0.014655	0.01306	0.013832	0.015434	0.014495	0.014134	0.010905	0.012238	0.011701	0.009615	0.002872038
wine	0.041604	0.034654	0.035367	0.035367	0.029043	0.05616	0.029174	0.04858	0.078401	0.046727	0.051957	0.037898	0.007153	0.076238	0.018866409

5-NN classifier

mean	0.077166	0.075776	0.07526	0.07526	0.076529	0.079939	0.082576	0.096872	0.087428	0.088365	0.10012	0.068151	0.096395	0.081928	0.081266
Metrics	Hassanat	L1	Orloci	Angular	L2	L10	Weierstras	Lorentz	CDMah	Mahala	Canberra	Clark	BrayCurtis	Intersectio	CayleyKleinHill
Method	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN	5-NN
australian	0.021134	0.025085	0.027679	0.027679	0.026192	0.027485	0.024714	0.026172	0.108188	0.056894	0.024866	0.030342	0.04049	0.028313	0.028728
balance	0.089329	0.082789	0.085153	0.085153	0.089599	0.089409	0.076175	0.105128	0.090035	0.118763	0.131826	0.086749	0.158423	0.154787	0.108036
cancer	0.012758	0.012893	0.012845	0.012845	0.013106	0.014271	0.018518	0.026329	0.013085	0.012413	0.026671	0.002364	0.033868	0.002364	0.043136
diabetes	0.035911	0.036256	0.031939	0.031939	0.032628	0.031682	0.033768	0.046004	0.032926	0.035778	0.048219	0.145781	0.106726	0.134662	0.083589
DNA	0.457785	0.457785	0.414467	0.414467	0.468114	0.466176	0.465516	0.446213	0.431477	0.497644	0.448324	0.424856	0.499954	0.50014	0.441838
german	0.032246	0.026475	0.033239	0.033239	0.026855	0.031723	0.028771	0.030065	0.032184	0.027475	0.029672	2.8E-16	0.0823	0.132508	0.002092
glass	0.061468	0.064544	0.079274	0.079274	0.082625	0.084398	0.077421	0.066744	0.080069	0.096033	0.061137	0.006162	0.025712	0.013547	0.069335
heart	0.053206	0.049797	0.050865	0.050865	0.0524	0.047947	0.055321	0.048285	0.063006	0.069407	0.051358	0.026655	0.085724	0.067994	0.024887
ionosphere	0.038649	0.036701	0.0324	0.0324	0.038074	0.046459	0.030425	0.043612	0.038074	0.033742	0.039495	0.003659	0.103832	0.114586	0.014285
iris	0.103124	0.103124	0.070052	0.070052	0.082009	0.069108	0.05164	0.094325	0.097183	0.069921	0.072354	0.102153	0.162569	0.057687	0.170154
led17	0.009352	0.009352	0.012092	0.012092	0.009243	0.007395	0.009718	0.012785	0.003242	0.007988	0.019501	0.003242	0.014585	0.008903	0.003242
letter	0.233773	0.222559	0.240275	0.240275	0.223562	0.270551	0.333015	0.487698	0.259346	0.27094	0.499191	0.185063	0.195396	0.190615	0.335794
liver	0.06602	0.068342	0.058211	0.058211	0.057844	0.050007	0.046355	0.054483	0.062206	0.057853	0.070338	0.056552	0.060377	0.067819	0.060934
monkey1	0.073061	0.073319	0.078235	0.078235	0.073035	0.059398	0.080483	0.040449	0.16022	0.115803	0.04421	0	0.0998	0.023162	0.04333
phoneme	0.018113	0.016848	0.017892	0.017892	0.016329	0.015078	0.021385	0.021838	0.014894	0.01528	0.01798	0.106861	0.000467	0.000245	0.019073
satimage	0.308554	0.30663	0.318497	0.318497	0.305985	0.327368	0.363892	0.478022	0.324457	0.325627	0.499448	0.4001	0.418016	0.330234	0.363892
segmen	0.011248	0.013202	0.017144	0.017144	0.018034	0.02072	0.038012	0.036779	0.018034	0.02024	0.032377	4.49E-16	0.019918	4.49E-16	0.018269
sonar	0.081954	0.072735	0.076016	0.076016	0.078271	0.08322	0.073972	0.070981	0.087432	0.077029	0.069921	0.005035	0.042444	0.005035	0.005035
vehicle	0.027776	0.026564	0.024505	0.024505	0.024042	0.031227	0.028013	0.035461	0.028683	0.029494	0.042265	0.013043	0.021995	0.024449	0.021386
vote	0.029269	0.032416	0.030357	0.030357	0.030288	0.030584	0.031845	0.032038	0.040519	0.044276	0.050391	0.003728	0.052418	0.074811	0.033964
vowel	0.027541	0.032966	0.037109	0.037109	0.0342	0.041208	0.03102	0.043299	0.042971	0.033582	0.043403	0.018898	0.029769	0.009754	0.032726
waveform2	0.010671	0.011336	0.012576	0.012576	0.013355	0.011887	0.011076	0.012945	0.014439	0.012709	0.011464	0.002634	0.008562	0.005817	0.001749
waveform4	0.011359	0.010126	0.012756	0.012756	0.014071	0.013925	0.011779	0.026897	0.012808	0.012675	0.01314	0.003762	0.012238	0.011701	0.003762
wine	0.037692	0.026767	0.03265	0.03265	0.026843	0.047309	0.038989	0.038368	0.042788	0.079204	0.055329	0.007996	0.037898	0.007153	0.021159

DME-based (local) classifier

mean	0.076323	0.077318	0.078658	0.078361	0.079132	0.084055	0.082896	0.083104	0.089409	0.097714	0.09993	0.095871	0.081647	0.081928	0.09016	
Metrics	Hassanat	L1	L2	Orloci	Angular	L10	Weierstras	CDMah	Mahala	Lorentz	Canberra	BrayCurtis	Clark	Intersectio	CayleyKleinHilb	
Method	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	Local	
australian	0.023386	0.021712	0.024623	0.026797	0.026284	0.030007	0.023735	0.084441	0.040462	0.0237	0.038845	0.039663	0.016044	0.028313	0.017692	
balance	0.061819	0.067656	0.071524	0.081106	0.082049	0.078375	0.076175	0.046659	0.07696	0.105128	0.105128	0.158423	0.159068	0.154787	0.114054	
cancer	0.014906	0.01682	0.012937	0.014339	0.014285	0.013306	0.020183	0.013918	0.016247	0.025786	0.018801	0.033868	0.006017	0.002364	0.072185	
diabetes	0.037449	0.036287	0.036954	0.035543	0.036976	0.03326	0.034365	0.029159	0.030412	0.045671	0.045622	0.106726	0.117173	0.134662	0.071479	
DNA	0.446639	0.45962	0.474689	0.366165	0.364588	0.489332	0.482129	0.345339	0.499482	0.446213	0.481183	0.499954	0.50014	0.50014	0.496194	
german	0.02818	0.02766	0.02715	0.029385	0.029264	0.026913	0.025635	0.029255	0.03656	0.0282	0.024928	0.082168	0.155235	0.132508	0.153791	
glass	0.07408	0.06783	0.076962	0.081066	0.079318	0.084416	0.072597	0.065345	0.082869	0.061474	0.064981	0.0267	0.013547	0.013547	0.02489	
heart	0.044427	0.04643	0.0502	0.054125	0.053527	0.056611	0.052809	0.073089	0.075848	0.044622	0.036764	0.086963	0.044896	0.067994	0.044306	
ionosphere	0.037043	0.039703	0.039297	0.033826	0.033389	0.050665	0.028496	0.039297	0.034665	0.047996	0.033221	0.103832	0.114586	0.114586	0.057315	
iris	0.103124	0.094592	0.0694	0.067106	0.067106	0.069108	0.05164	0.069921	0.067495	0.094325	0.094325	0.162569	0.068568	0.057687	0.08816	
led17	0.007645	0.007034	0.005175	0.006087	0.005673	0.007535	0.003603	0.002026	0.00407	0.004402	0.001901	0.014585	0.002026	0.008903	0.002026	
letter	0.242092	0.237053	0.253911	0.330192	0.339617	0.297013	0.333294	0.293252	0.299704	0.487698	0.488147	0.195396	0.190615	0.190615	0.335242	
liver	0.063353	0.067171	0.061205	0.061209	0.062494	0.053981	0.049452	0.062376	0.061348	0.053434	0.051469	0.058625	0.064416	0.067819	0.054719	
monkey1	0.086125	0.085982	0.082917	0.088272	0.089281	0.075033	0.086286	0.161998	0.142779	0.087374	0.064485	0.079001	0	0.023162	0.04333	
phoneme	0.018765	0.01976	0.01902	0.020729	0.021235	0.018674	0.021372	0.01904	0.021051	0.021829	0.021885	0.000467	0.001038	0.000245	0.009612	
satimage	0.330234	0.342874	0.34551	0.325627	0.334729	0.359595	0.364832	0.367623	0.356178	0.478022	0.478022	0.418016	0.418016	0.330234	0.404895	
segmen	0.010429	0.01227	0.016279	0.02743	0.027045	0.019453	0.038389	0.016279	0.021761	0.037693	0.038735	0.019066	4.49E-16	4.49E-16	0.015668	
sonar	0.068087	0.076639	0.078677	0.082028	0.08249	0.096507	0.073752	0.095423	0.078717	0.078601	0.031056	0.045983	0.005035	0.005035	0.005035	
vehicle	0.025761	0.024725	0.03073	0.027224	0.027467	0.027567	0.027788	0.027837	0.027358	0.035958	0.034171	0.022208	0.006455	0.024449	0.020121	
vote	0.034943	0.035468	0.038147	0.041855	0.042534	0.041969	0.036316	0.042675	0.044348	0.035334	0.066597	0.057523	0.062806	0.074811	0.075811	
vowel	0.018378	0.017261	0.019835	0.025305	0.024045	0.025457	0.031464	0.040785	0.026568	0.043104	0.04366	0.03046	5.61E-16	0.009754	0.031869	
waveform2	0.010365	0.011554	0.011548	0.011071	0.011067	0.010663	0.011504	0.011339	0.011544	0.011737	0.021394	0.008562	0.003822	0.005817	0.004468	
waveform4	0.00866	0.008542	0.009035	0.011075	0.010955	0.009041	0.00849	0.012309	0.010758	0.008461	0.03662	0.012238	0.002872	0.011701	0.002872	
wine	0.035856	0.030983	0.032058	0.033106	0.033746	0.042847	0.035196	0.045123	0.078646	0.038368	0.076377	0.037898	0.007153	0.007153	0.018113	

Correlation dimension-based (global) classifier

mean	0.08065	0.079324	0.078412	0.073667	0.074784	0.083136	0.086514	0.097376	0.079517	0.100902	0.086944	0.095871	0.081647	0.081928	0.09016
Metrics	Hassanat	Angular	Orloci	L1	L2	Weierstras	Mahala	Lorentz	CDMaha	Canberra	L10	BrayCurtis	Clark	Intersectio	CayleyKleinHilb
Method	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global	Global
australian	0.024985	0.026455	0.026666	0.029058	0.027441	0.025286	0.038484	0.030283	0.07783	0.026357	0.029733	0.039663	0.016044	0.028313	0.017692
balance	0.064107	0.083117	0.082984	0.070337	0.071059	0.076175	0.072772	0.105128	0.043252	0.131826	0.079365	0.158423	0.159076	0.154787	0.114054
cancer	0.015023	0.014052	0.013961	0.019718	0.017286	0.020183	0.017745	0.025786	0.015663	0.027079	0.015467	0.033868	0.006017	0.002364	0.072185
diabetes	0.036595	0.039071	0.036901	0.035408	0.033455	0.034548	0.032713	0.047198	0.028963	0.04683	0.035143	0.106726	0.117173	0.134662	0.071479
DNA	0.442729	0.373838	0.376073	0.436787	0.467475	0.488972	0.497895	0.43819	0.365378	0.442729	0.499527	0.499954	0.50014	0.50014	0.496194
german	0.025671	0.027933	0.027102	0.022964	0.028184	0.028338	0.028622	0.026439	0.02875	0.030644	0.03466	0.082168	0.155235	0.132508	0.153791
glass	0.08516	0.083443	0.084381	0.071008	0.061681	0.077819	0.084596	0.06108	0.057989	0.059433	0.070563	0.0267	0.013547	0.013547	0.02489
heart	0.052283	0.053755	0.054955	0.05494	0.051842	0.052058	0.078718	0.056843	0.072117	0.050806	0.054015	0.086963	0.044896	0.067994	0.044306
ionosphere	0.037978	0.035357	0.035357	0.040866	0.038071	0.028596	0.030638	0.047129	0.038071	0.039476	0.194703	0.103832	0.114586	0.114586	0.057315
iris	0.213493	0.0694	0.067106	0.105688	0.083896	0.05164	0.084984	0.094325	0.069921	0.072354	0.070052	0.162569	0.068568	0.057687	0.08816
led17	0.014315	0.006177	0.007109	0.011952	0.01045	0.007397	0.007255	0.010456	0.002026	0.017264	0.001784	0.014585	0.002026	0.008903	0.002026
letter	0.216417	0.318457	0.31105	0.213793	0.215372	0.331044	0.260579	0.487698	0.258106	0.499191	0.2556	0.195396	0.190615	0.190615	0.335242
liver	0.061015	0.063537	0.061711	0.061575	0.062154	0.0487	0.061499	0.054946	0.069237	0.071893	0.054699	0.058625	0.064416	0.067819	0.054719
monkey1	0.06978	0.090058	0.088692	0.069513	0.073419	0.083544	0.140885	0.074236	0.165408	0.075633	0.089025	0.079001	0	0.023162	0.04333
phoneme	0.016382	0.018532	0.018327	0.013647	0.013174	0.021372	0.014673	0.021829	0.013749	0.017933	0.012643	0.000467	0.001038	0.000245	0.009612
satimage	0.333056	0.355189	0.34551	0.291205	0.297389	0.361995	0.327368	0.478176	0.333616	0.499422	0.312344	0.418016	0.418016	0.330234	0.404895
segmen	0.01065	0.023988	0.023908	0.009124	0.071122	0.038558	0.018074	0.037591	0.071122	0.032042	0.023956	0.019066	4.49E-16	4.49E-16	0.015668
sonar	0.086936	0.070564	0.072343	0.08342	0.037178	0.067024	0.072247	0.074749	0.005035	0.073663	0.084036	0.045983	0.005035	0.005035	0.005035
vehicle	0.025291	0.028194	0.025857	0.031817	0.026941	0.027394	0.032751	0.035293	0.037619	0.042404	0.033544	0.022208	0.006455	0.024449	0.020121
vote	0.02749	0.042679	0.041855	0.029358	0.033317	0.035905	0.043658	0.02825	0.046073	0.048585	0.04403	0.057523	0.062806	0.074811	0.075811
vowel	0.017763	0.024068	0.023041	0.018194	0.019253	0.031464	0.024385	0.042919	0.040391	0.042945	0.023318	0.03046	5.61E-16	0.009754	0.031869
waveform2	0.011293	0.011196	0.011887	0.012619	0.012164	0.012422	0.012647	0.01159	0.011452	0.012314	0.010445	0.008562	0.003822	0.005817	0.004468
waveform4	0.008701	0.011188	0.010538	0.008392	0.009914	0.008767	0.011129	0.010469	0.012921	0.011295	0.011943	0.012238	0.002872	0.011701	0.002872
wine	0.038487	0.033516	0.034564	0.026634	0.032585	0.036071	0.082009	0.036415	0.04371	0.049524	0.046074	0.037898	0.007153	0.007153	0.018113

IINC - Inverted Indexes of Neighbors Classifier

mean	0.074323	0.075037	0.072045	0.072045	0.075767	0.080841	0.084774	0.081762	0.096226	0.087846	0.098675	0.075807	0.096118	0.081928	0.085256	
Metrics	Hassanat	L1	Orloci	Angular	L2	L10	CDMaha	Weierstras	Lorentz	Mahala	Canberra	Clark	BrayCurtis	Intersectio	CayleyKleinHilb	
Method	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	iinc	
australian	0.023679	0.022687	0.027163	0.027163	0.024466	0.027362	0.114226	0.026135	0.022773	0.056329	0.033329	0.015604	0.040548	0.028313	0.018126	
balance	0.070918	0.081386	0.087581	0.087581	0.080529	0.082692	0.068688	0.076175	0.105128	0.097824	0.105128	0.079651	0.158423	0.154787	0.104845	
cancer	0.013141	0.012655	0.010563	0.010563	0.011598	0.011704	0.012124	0.018252	0.025328	0.012968	0.020314	0.002364	0.033868	0.002364	0.043674	
diabetes	0.033718	0.033096	0.036815	0.036815	0.031423	0.036325	0.029407	0.034161	0.045833	0.034043	0.045442	0.162998	0.106726	0.134662	0.077977	
DNA	0.446639	0.448324	0.372331	0.372331	0.462806	0.47661	0.38117	0.462459	0.444051	0.499236	0.443612	0.424856	0.499954	0.50014	0.441838	
german	0.026551	0.031048	0.028694	0.028694	0.031587	0.026743	0.031161	0.029639	0.030191	0.03013	0.029322	0.148131	0.0823	0.132508	0.147158	
glass	0.066202	0.076967	0.085636	0.085636	0.086362	0.08863	0.098277	0.074175	0.062955	0.084603	0.064399	0.006162	0.024404	0.013547	0.069335	
heart	0.048001	0.045399	0.047691	0.047691	0.046041	0.04888	0.070376	0.046277	0.046279	0.075709	0.044952	0.051434	0.088377	0.067994	0.049409	
ionosphere	0.035842	0.038933	0.032573	0.032573	0.038112	0.05045	0.038112	0.02743	0.042838	0.03808	0.033221	0.003659	0.103832	0.114586	0.014285	
iris	0.103124	0.103124	0.051817	0.051817	0.070052	0.070052	0.069921	0.05164	0.094325	0.069921	0.094325	0.114432	0.162569	0.057687	0.139199	
led17	0.003703	0.003703	0.010193	0.010193	0.003631	0.001159	0.002339	0.003788	0.005078	0.00395	0.001901	0.002339	0.014585	0.008903	0.002339	
letter	0.220025	0.214847	0.241186	0.241186	0.217455	0.258934	0.25769	0.332734	0.487584	0.260579	0.487811	0.186313	0.195396	0.190615	0.335794	
liver	0.060379	0.064355	0.051635	0.051635	0.069289	0.071745	0.051769	0.049811	0.053751	0.073401	0.051854	0.05612	0.058782	0.067819	0.02894	
monkey1	0.072574	0.072533	0.076913	0.076913	0.072574	0.072701	0.170274	0.086197	0.066074	0.116309	0.084213	0	0.091288	0.023162	0.04333	
phoneme	0.021859	0.020804	0.019755	0.019755	0.02079	0.020173	0.020733	0.021372	0.02181	0.020977	0.021885	0.082342	0.000467	0.000245	0.018255	
satimage	0.316672	0.312968	0.320305	0.320305	0.319704	0.341274	0.33966	0.366233	0.478022	0.330802	0.478329	0.395914	0.418016	0.330234	0.363892	
segmen	0.013801	0.01419	0.017455	0.017455	0.017776	0.021663	0.017776	0.036107	0.037684	0.023887	0.038443	4.49E-16	0.019025	4.49E-16	0.018326	
sonar	0.076273	0.076324	0.076722	0.076722	0.08785	0.078055	0.087324	0.069445	0.064949	0.075173	0.061913	0.005035	0.043938	0.005035	0.005035	
vehicle	0.023613	0.027063	0.022056	0.022056	0.023253	0.027368	0.029945	0.028435	0.035214	0.028626	0.0346	0.016279	0.022053	0.024449	0.02158	
vote	0.034911	0.034638	0.036034	0.036034	0.03458	0.030884	0.043166	0.034038	0.034957	0.043947	0.035787	0.032461	0.05405	0.074811	0.044182	
vowel	0.015124	0.014347	0.018462	0.018462	0.015113	0.020549	0.033159	0.030219	0.043533	0.023811	0.04366	0.017402	0.029525	0.009754	0.032745	
waveform2	0.010981	0.01104	0.01117	0.01117	0.012859	0.011394	0.013063	0.0106	0.011075	0.0151	0.010725	0.005056	0.008562	0.005817	0.001922	
waveform4	0.008335	0.009442	0.010974	0.010974	0.010275	0.012115	0.011865	0.010034	0.009655	0.011123	0.020691	0.002811	0.012238	0.011701	0.002811	
wine	0.03769	0.031021	0.035344	0.035344	0.030289	0.052727	0.042342	0.036926	0.040336	0.081771	0.082353	0.007996	0.037898	0.007153	0.021159	