ISSN 1726-5479

SENSORS & TRANSDUCERS

1 vol. 124
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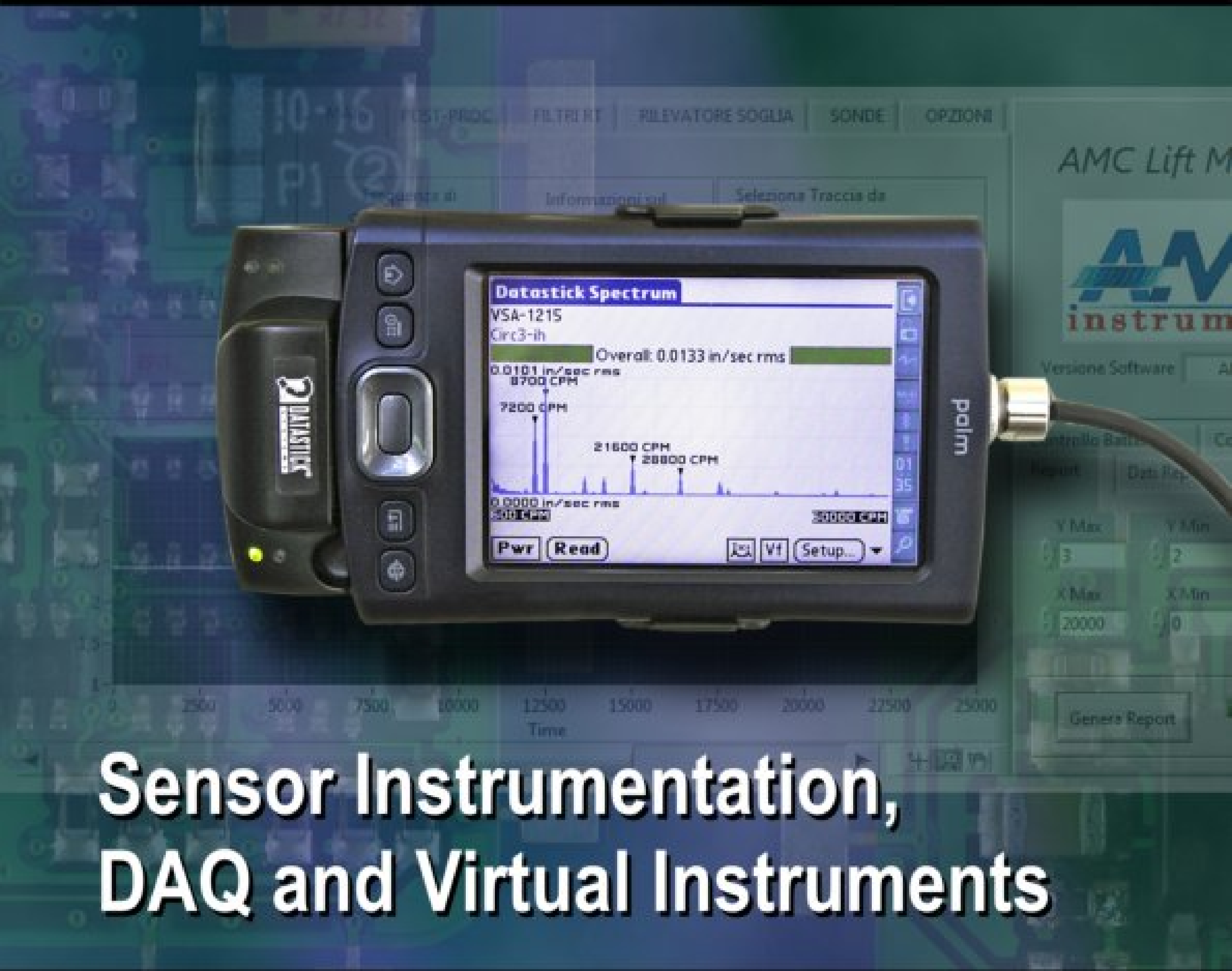

Sensor Instrumentation, DAQ and Virtual Instruments

International Frequency Sensor Association Publishing

IFSA

Sensors & Transducers

Volume 124, Issue 1,
January 2011

www.sensorsportal.com

ISSN 1726-5479

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Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
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Sensors & Transducers Journal

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January 2011

www.sensorsportal.com

ISSN 1726-5479

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Sensors & Transducers Journal, Vol. 124, Issue 1, January 2011, pp. 11-18

Sensors & Transducers

ISSN 1726-5479

http://www.sensorsportal.com

Classification of Unknown Thermocouple Types Using Similarity Factor Measurement

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Received: 20 November 2010 /Accepted: 24 January 2011 /Published: 28 January 2011

Abstract: In contrast to classification using PCA method, a new methodology is proposed for type identification of unknown thermocouple. The new methodology is based on calculating the degree of similarity between two multivariate datasets using two types of similarity factors. One similarity factor is based on principle component analysis and the angles between the principle component subspaces while the other is based on the Mahalanobis distance between the datasets. Datasets containing thermo-emfs against given temperature ranges are formed for each type of thermocouple (e.g. J, K, S, T, R, E, B and N type) by experimentation are considered as reference datasets. Datasets corresponding to unknown type are captured. Similarity factor between the datasets one of which being the unknown type and the other being each known type are compared. When maximum similarity factor occurs, then the class of unknown type is allocated to that of known type. *Copyright © 2011 IFSA.*

Keywords: PCA based similarity, Distance based similarity, Similarity Factor

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1. Introduction

The classification of thermocouple sensor is required for various purposes such as operating temperature range selection in process control and measurement, sensitivity of temperature measurement and response time of measurement. The conventional method is to perform thermocouple calibration process with the help of calibrator, which is a time consuming task. The classification is based on the material composition of thermocouple and is designated by the type letter (e.g. J, K, R, B etc.). A Novel method may be devised for type identification of a given thermocouple, whose type is unknown. The thermo e.m.f.s of all standard types of thermocouple for selected temperature ranges are collected from standard thermocouple database. Thermo e.m.f. dataset actually represent the typical features of different types of thermocouple, which can be best observed by its corresponding thermo e.m.f. vs. temperature plot. Pattern matching has often been applied to classify these datasets with similar features. Similarity measures emphasizing difference between statistical properties between the datasets. These measures are defined by making use of norms or weighted norms of Fourier or wavelet transformed data. Kundu and Sarkar used probabilistic neural networks and PCA for identification of unknown thermocouple [1, 2]. Several methods of finding the similarity have been reported in the literature. These are i) PCA based similarity as proposed by Krzanowski, ii) weighted PCA –similarity and, iii) Distance based similarity as proposed by Singhal and Seborg [3]. Kano introduced a dissimilarity measure based on eigen-decomposition of data sets, which is very effective for finding the variance/covariance changes from two data sets [4]. Huang et al. used parameter similarity measures for multiple multiplicative fault diagnosis of dynamic processes [5]. In the present work, several combined similarity measures (e.g. linear combination of indices) to a single similarity factor because most of the aforesaid similarity measures are scaled to range from zero to unity.

2. Similarity Factor

Similarity factors can be used to access the degree of similarity between two multivariate datasets, one of which is the data set of interest and the other is the template data set. Normally PCA is used to discriminate among two or several multivariate datasets. In PCA, the multivariate datasets are transformed into reduced dimension space. The orthonormal projecting matrix consists of loading vectors. These principle loading vectors stand for the most important directions of variability of the data. Mathematically, PCA can be expressed by the following equations.

$$X = TP^T + E \tag{1}$$

$$Cov(T) = \Lambda = diag(\lambda_1, \lambda_2, ...\lambda_n), \tag{2}$$

where X and T are the matrices of the original and the transformed variables respectively, P is the corresponding loading matrix, Λ is a diagonal and semi-positive-definite matrix, which is the estimated covariance matrix of the variables in the transformed space. Usually, only n PCs are selected to represent the variability of the original data set.

2.1. PCA Based Similarity Measures

Krzanowski first introduced the idea of PCA based similarity measure for assessing the similarity between two data sets X_1, X_2 .They contain the same number of variables but not the same no. of observations. It has been assumed that in each data set k; PCs which describes at least 95% of the total variance is selected. Consequently, the corresponding loading matrices span the reduced spaces of the two original data sets. PCA based similarity measure is calculated from the squared cosine values of angles between the loadings, that is,

$$S_{PCA} = \frac{1}{k}\sum_{i=1}^{k}\sum_{j=1}^{k} Cos^2\theta_{ij}, \tag{3}$$

where k is the number of selected PCs in both data sets, θ_{ij} is the angle between the ith PC of X_1 and the jth PC of X_2. The value of k can be chosen such that they describe at least 95% variance in each dataset. Since the amount of variance described by each of the k PCs varies significantly. S_{PCA} weights all the PCs equally and it may not capture the degree of similarity between the datasets when only one or two PCs explain most of the variance. A modified PCA similarity as introduced by Singhal and Seborg [3] weights for each PC by its explained variance. The Modified PCA similarity is defines as,

$$S_{PCA}^{\lambda} = \frac{\sum\sum(\lambda_i^{(1)}\lambda_j^{(2)})Cos^2\theta_{ij}}{\sum_{i=1}^{k}\sum_{j=1}^{k}\lambda_i^{(1)}\lambda_j^{(2)}}, \tag{4}$$

where $\lambda_i^{(1)}, \lambda_i^{(2)}$ are the ith eigenvalues of the 1st and 2nd datasets respectively.

2.2. Distance –Based Similarity Measures

The distance similarity measure compares two data sets that may have similar spatial orientation but are located far apart. This similarity measure is particularly useful when two datasets have similar principle components but the values of the variables may be different due to different operating conditions. The distance similarity measure can be used to distinguish between these cases. The distance similarity measure is expressed as:

$$S_{dist} = 2\times\frac{1}{\sqrt{2\pi}}\int_{\phi}^{\infty} e^{\frac{-z^2}{2}}dz = 2\times[1-\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\phi} e^{\frac{-z^2}{2}}dz \tag{5}$$

,

where $\phi = \sqrt{(\overline{X}_2 - \overline{X}_1)\sum_1^{*-1}(\overline{X}_2 - \overline{X}_1)^T}$, $\overline{X}_1$ and $\overline{X}_2$ are sample mean row vectors and $\sum_1^{*-1}$ is the pseudo-inverse of X_1 calculated using singular value decomposition. K-singular values used to calculate the pseudo-inverse such that k PCs describes at least 95% of the variance in each dataset. The dataset X_1 is assumed to be the reference data set.

2.3. Combination of Similarity Measures

When more than one similarity factor is used to calculate the similarity between datasets, a key issue is to decide how the similarity factors should be combined to produce a single measure of the degree of similarity. It is convenient to combine $S_{PCA}{}^{\lambda}$ and S_{dist} into a single similarity factor, SF, using a weighted average of the two quantities

$$SF = \alpha_1 S_{PCA}^{\lambda} + \alpha_2 S_{dist} \tag{6}$$

where $\alpha_1 + \alpha_2 = 1$

The weighted average SF can be used as a similarity measure between datasets and is also used for clustering. It is up to the user to choose the weighting factors $\{\alpha_i\}$, to give relative importance of each similarity for given application. Good pattern matching can be obtained for a wide range of $\{\alpha_i\}$.

3. Measurement & Data Analysis

3.1. Case Studies

The experiments are performed taking eight types of standard thermocouples (e.g. J, K, S, T, R, N, E and B types). The plot (thermo e.m.f. vs. temperature) for all standard thermocouples is shown in Fig. 1.Using thermocouple calibrator, the temperature are varied in the range 0 to 400^0 C in intervals of 1^0 C. Thermo e.m.f is measured for each type within this range. For each type three runs are repeated. For each type of thermocouple (e.g. J, K, R, T etc.) observations consisting of thermo e.m.f vs. temperature are taken three times within the temperature range 0 to $+400^0$ C. Thus the individual datasets for each type are formed as $X_1, X_2......X_8$. The dimensions of each dataset are 410×3 as shown in Tables 2(a), 2(b) and 2(c). The thermo e.m.f. for all types is corrected to 0^0 C using cold junction temperature compensation. Also test data are formed by taking the observation from any one from $X_1, X_2......X_8$ at a time. While forming the test data set only two subsamples are taken randomly. Thus the dimension of the test data becomes 401×2. The no of test datasets is 8 as because each type of thermocouple is considered. PCA-based similarity and distance based similarity between the test data set and each known data set are calculated. Similarity factor using the formula (equation 6) is also calculated.

Table 1. Thermocouple Types.

Type	Composition	Temp. Range($^\circ$C)
B	Pt-30% Rh vs. Pt-6% , Rh	0 to 1820
E	Ni-Cr Alloy vs. Cu-Ni alloy	-270 to 1000
J	Fe vs. Cu-Ni alloy	-210 to 1200
K	Ni-Cr alloy vs. Ni-Al alloy	-270 to 1372
N	Ni-Cr-Si alloy vs. Ni-Si-Mg alloy	-270 to 1300
R	Pt-13% , Rh vs. Pt	-50 to 1768
S	Pt-10% , Rh vs. Pt	-50 to 1768
T	Cu vs. Cu-Ni alloy	-270 to 400

4. Results

The normalized data sets corresponding to each standard thermocouple has the dimension of 401×3. Thus dataset for each type consists of three populations, each having 401 observations. The test dataset for each unknown type of thermocouple are formed taking two populations out of three randomly. Thus the test data set has the dimension 401×2. PCA based similarity, distance based and the combined similarity factor are computed between each test sample and the all standard samples. PCA based, distance based and combined similarity factors among the different known types and unknown types are tabulated in Tables 3(a), 3(b) and 3(c), respectively. It can be seen that when match occurs between the test data set and data set of known type, the similarity factor reaches at maximum value close to unity. The unknown types are classified into one of the eight known types according the maximum value of similarity factors as determined. However, in contrast, when classifying the test dataset using distance parameter, the distance becomes minimum between the two data sets.

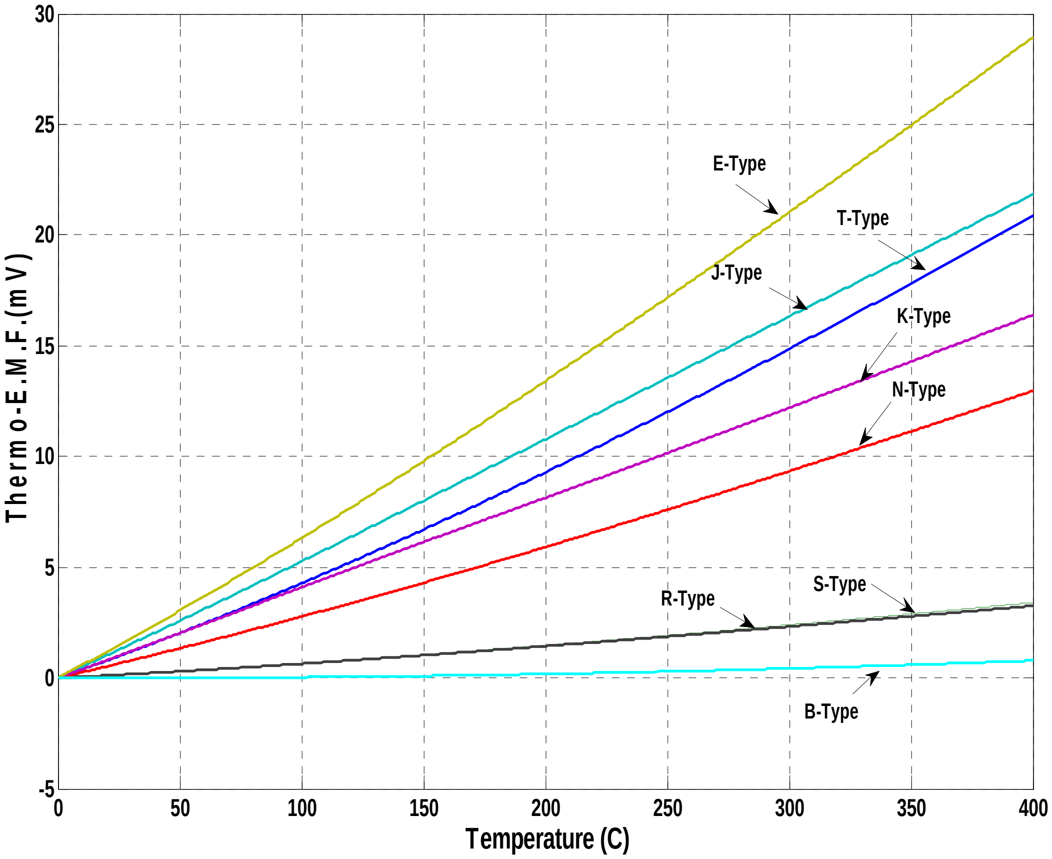

Fig. 1. Thermo e.m.f. vs. temperature plot of all types of thermocouple.

Table 2 (a). Thermocouple Data Base.

Temp (◦C).	**Thermo E. M. F. (mv)**								
	X1 (J Type)			**X2 (K Type)**			**X3 (R Type)**		
0	0.00E+00	2.50E-02	-2.50E-02	0.00E+00	2.50E-02	-2.50E-02	0.00E+00	2.50E-02	-2.50E-02
1	5.00E-02	7.50E-02	2.50E-02	3.90E-02	6.40E-02	1.40E-02	5.00E-03	3.00E-02	-2.00E-02
2	1.01E-01	1.26E-01	7.60E-02	7.90E-02	1.04E-01	5.40E-02	1.10E-02	3.60E-02	-1.40E-02
3	1.51E-01	1.76E-01	1.26E-01	1.19E-01	1.44E-01	9.40E-02	1.60E-02	4.10E-02	-9.00E-03
4	2.02E-01	2.27E-01	1.77E-01	1.58E-01	1.83E-01	1.33E-01	2.10E-02	4.60E-02	-4.00E-03
5	2.53E-01	2.78E-01	2.28E-01	1.98E-01	2.23E-01	1.73E-01	2.70E-02	5.20E-02	2.00E-03
6	3.03E-01	3.28E-01	2.78E-01	2.38E-01	2.63E-01	2.13E-01	3.20E-02	5.70E-02	7.00E-03
7	3.54E-01	3.79E-01	3.29E-01	2.77E-01	3.02E-01	2.52E-01	3.80E-02	6.30E-02	1.30E-02
8	4.05E-01	4.30E-01	3.80E-01	3.17E-01	3.42E-01	2.92E-01	4.30E-02	6.80E-02	1.80E-02
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	---------	---------	---------	---------	---------	---------	---------	---------	---------
390	2.13E+01	2.13E+01	2.13E+01	1.60E+01	1.60E+01	1.60E+01	3.30E+00	3.33E+00	3.28E+00
391	2.14E+01	2.14E+01	2.13E+01	1.60E+01	1.60E+01	1.60E+01	3.32E+00	3.34E+00	3.29E+00
392	2.14E+01	2.14E+01	2.14E+01	1.61E+01	1.61E+01	1.60E+01	3.33E+00	3.35E+00	3.30E+00
393	2.15E+01	2.15E+01	2.14E+01	1.61E+01	1.61E+01	1.61E+01	3.34E+00	3.36E+00	3.31E+00
394	2.15E+01	2.15E+01	2.15E+01	1.61E+01	1.62E+01	1.61E+01	3.35E+00	3.37E+00	3.32E+00
395	2.16E+01	2.16E+01	2.15E+01	1.62E+01	1.62E+01	1.62E+01	3.36E+00	3.38E+00	3.33E+00
396	2.16E+01	2.17E+01	2.16E+01	1.62E+01	1.63E+01	1.62E+01	3.37E+00	3.39E+00	3.34E+00
397	2.17E+01	2.17E+01	2.17E+01	1.63E+01	1.63E+01	1.62E+01	3.38E+00	3.40E+00	3.35E+00
398	2.17E+01	2.18E+01	2.17E+01	1.63E+01	1.63E+01	1.63E+01	3.39E+00	3.41E+00	3.36E+00
399	2.18E+01	2.18E+01	2.18E+01	1.64E+01	1.64E+01	1.63E+01	3.40E+00	3.42E+00	3.37E+00
400	2.18E+01	2.19E+01	2.18E+01	1.64E+01	1.64E+01	1.64E+01	3.41E+00	3.43E+00	3.38E+00

Table 2 (b). Thermocouple Data Base.

Temp (◦C).	**Thermo E. M. F. (mv)**								
	X4 (T Type)			**X5 (S Type)**			**X6 (N Type)**		
0	0.00E+00	2.50E-02	-2.50E-02	0.00E+00	2.50E-01	-2.50E-01	0.00E+00	2.50E-01	-2.50E-01
1	3.90E-02	6.40E-02	1.40E-02	5.00E-03	2.55E-01	-2.45E-01	2.60E-02	2.76E-01	-2.24E-01
2	7.80E-02	1.03E-01	5.30E-02	1.10E-02	2.61E-01	-2.39E-01	5.20E-02	3.02E-01	-1.98E-01
3	1.17E-01	1.42E-01	9.20E-02	1.60E-02	2.66E-01	-2.34E-01	7.80E-02	3.28E-01	-1.72E-01
4	1.56E-01	1.81E-01	1.31E-01	2.20E-02	2.72E-01	-2.28E-01	1.04E-01	3.54E-01	-1.46E-01
5	1.95E-01	2.20E-01	1.70E-01	2.70E-02	2.77E-01	-2.23E-01	1.30E-01	3.80E-01	-1.20E-01
6	2.34E-01	2.59E-01	2.09E-01	3.30E-02	2.83E-01	-2.17E-01	1.56E-01	4.06E-01	-9.40E-02
7	2.73E-01	2.98E-01	2.48E-01	3.80E-02	2.88E-01	-2.12E-01	1.82E-01	4.32E-01	-6.80E-02
8	3.12E-01	3.37E-01	2.87E-01	4.40E-02	2.94E-01	-2.06E-01	2.08E-01	4.58E-01	-4.20E-02
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390	2.03E+01	2.03E+01	2.02E+01	3.16E+00	3.41E+00	2.91E+00	1.26E+01	1.29E+01	1.24E+01
391	2.03E+01	2.03E+01	2.03E+01	3.17E+00	3.42E+00	2.92E+00	1.26E+01	1.29E+01	1.24E+01
392	2.04E+01	2.04E+01	2.04E+01	3.18E+00	3.43E+00	2.93E+00	1.27E+01	1.29E+01	1.24E+01
393	2.04E+01	2.05E+01	2.04E+01	3.19E+00	3.44E+00	2.94E+00	1.27E+01	1.30E+01	1.25E+01
394	2.05E+01	2.05E+01	2.05E+01	3.20E+00	3.45E+00	2.95E+00	1.28E+01	1.30E+01	1.25E+01
395	2.06E+01	2.06E+01	2.05E+01	3.21E+00	3.46E+00	2.96E+00	1.28E+01	1.30E+01	1.25E+01
396	2.06E+01	2.07E+01	2.06E+01	3.22E+00	3.47E+00	2.97E+00	1.28E+01	1.31E+01	1.26E+01
397	2.07E+01	2.07E+01	2.07E+01	3.23E+00	3.48E+00	2.98E+00	1.29E+01	1.31E+01	1.26E+01
398	2.07E+01	2.08E+01	2.07E+01	3.24E+00	3.49E+00	2.99E+00	1.29E+01	1.31E+01	1.26E+01
399	2.08E+01	2.08E+01	2.08E+01	3.25E+00	3.50E+00	3.00E+00	1.29E+01	1.32E+01	1.27E+01
400	2.09E+01	2.09E+01	2.08E+01	3.26E+00	3.51E+00	3.01E+00	1.30E+01	1.32E+01	1.27E+01

Table 2(c). Thermocouple Data Base.

Temp (˚C).	**Thermo E. M. F. (mv)**					
	X7 (E Type)			**X8 (B Type)**		
0	0.00E+00	2.50E-02	-2.50E-02	0.00E+00	2.50E-02	-2.50E-02
1	5.90E-02	8.40E-02	3.40E-02	0.00E+00	2.50E-02	-2.50E-02
2	1.18E-01	1.43E-01	9.30E-02	0.00E+00	2.50E-02	-2.50E-02
3	1.76E-01	2.01E-01	1.51E-01	-1.00E-03	2.40E-02	-2.60E-02
4	2.35E-01	2.60E-01	2.10E-01	-1.00E-03	2.40E-02	-2.60E-02
5	2.94E-01	3.19E-01	2.69E-01	-1.00E-03	2.40E-02	-2.60E-02
6	3.54E-01	3.79E-01	3.29E-01	-1.00E-03	2.40E-02	-2.60E-02
7	4.13E-01	4.38E-01	3.88E-01	-1.00E-03	2.40E-02	-2.60E-02
8	4.72E-01	4.97E-01	4.47E-01	-2.00E-03	2.30E-02	-2.70E-02
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390	2.81E+01	2.82E+01	2.81E+01	7.46E-01	7.71E-01	7.21E-01
391	2.82E+01	2.83E+01	2.82E+01	7.50E-01	7.75E-01	7.25E-01
392	2.83E+01	2.83E+01	2.83E+01	7.54E-01	7.79E-01	7.29E-01
393	2.84E+01	2.84E+01	2.84E+01	7.58E-01	7.83E-01	7.33E-01
394	2.85E+01	2.85E+01	2.84E+01	7.62E-01	7.87E-01	7.37E-01
395	2.85E+01	2.86E+01	2.85E+01	7.66E-01	7.91E-01	7.41E-01
396	2.86E+01	2.87E+01	2.86E+01	7.70E-01	7.95E-01	7.45E-01
397	2.87E+01	2.87E+01	2.87E+01	7.74E-01	7.99E-01	7.49E-01
398	2.88E+01	2.88E+01	2.88E+01	7.78E-01	8.03E-01	7.53E-01
399	2.89E+01	2.89E+01	2.88E+01	7.82E-01	8.07E-01	7.57E-01
400	2.89E+01	2.90E+01	2.89E+01	7.87E-01	8.12E-01	7.62E-01

Table 3(a). PCA based similarity between unknown thermocouple type and known type.

S^{λ}_{PCA}		*Unknown type*							
		J -Type	K -Type	S -Type	T -Type	R -Type	E -Type	B -Type	N-Type
Known type	J -Type	1.00E+00	5.04E-01	9.39E-01	8.47E-01	7.85E-01	5.05E-01	1.00E+00	6.30E-01
	K- Type	5.04E-01	1.00E+00	5.94E-01	6.13E-01	7.61E-01	1.00E+00	5.04E-01	9.08E-01
	S -Type	9.39E-01	5.94E-01	1.00E+00	6.72E-01	9.39E-01	5.97E-01	9.39E-01	8.03E-01
	T -Type	8.47E-01	6.13E-01	6.72E-01	1.00E+00	5.35E-01	6.10E-01	8.47E-01	5.01E-01
	R -Type	7.85E-01	7.61E-01	9.39E-01	5.35E-01	1.00E+00	7.63E-01	7.85E-01	9.50E-01
	E -Type	5.05E-01	1.00E+00	5.97E-01	6.10E-01	7.63E-01	1.00E+00	5.05E-01	9.10E-01
	B- Type	1.00E+00	5.04E-01	9.39E-01	8.47E-01	7.85E-01	5.05E-01	1.00E+00	6.30E-01
	N-Type	6.30E-01	9.08E-01	8.03E-01	5.01E-01	9.50E-01	9.10E-01	6.30E-01	1.00E+00

Table 3(b). Distance based similarity between unknown thermocouple type and known type.

S_{dist}		*Unknown type*							
		J -Type	K -Type	S -Type	T -Type	R -Type	E -Type	B -Type	N-Type
Known type	J -Type	1.00E+00	5.92E-01	7.81E-01	9.21E-01	9.01E-01	5.01E-01	5.90E-01	5.58E-01
	K- Type	5.01E-01	1.00E+00	5.01E-01	5.01E-01	5.01E-01	5.01E-01	9.72E-01	5.01E-01
	S -Type	6.71E-01	5.01E-01	1.00E+00	5.01E-01	7.95E-01	5.21E-01	5.01E-01	5.01E-01
	T -Type	9.21E-01	5.01E-01	5.01E-01	1.00E+00	8.37E-01	8.23E-01	5.01E-01	5.01E-01
	R -Type	5.01E-01	5.01E-01	8.34E-01	7.88E-01	1.00E+00	5.01E-01	5.01E-01	5.44E-01
	E -Type	8.16E-01	5.01E-01	6.84E-01	5.01E-01	5.01E-01	1.00E+00	5.01E-01	5.01E-01
	B- Type	5.01E-01	9.72E-01	5.01E-01	5.01E-01	5.01E-01	5.01E-01	1.00E+00	5.65E-01
	N-Type	5.01E-01	5.01E-01	5.01E-01	5.01E-01	5.01E-01	5.01E-01	5.01E-01	1.00E+00

Table 3(c). Combined similarity between unknown thermocouple type and known type.

SF		*Unknown type*							
		J -Type	K -Type	S -Type	T -Type	R -Type	E -Type	B -Type	N-Type
Known type	J -Type	1.00E+00	1.84E-01	5.62E-01	8.41E-01	8.03E-01	2.20E-03	1.80E-01	1.16E-01
	K- Type	2.40E-03	1.00E+00	2.60E-03	2.20E-03	2.40E-03	2.00E-03	9.44E-01	2.00E-03
	S -Type	3.42E-01	2.60E-03	1.00E+00	2.20E-03	5.89E-01	4.14E-02	2.40E-03	2.60E-03
	T -Type	8.41E-01	2.20E-03	2.40E-03	1.00E+00	6.74E-01	6.46E-01	2.20E-03	2.00E-03
	R -Type	2.40E-03	2.60E-03	6.67E-01	5.75E-01	1.00E+00	2.60E-03	2.60E-03	8.72E-02
	E -Type	6.31E-01	2.40E-03	3.68E-01	2.20E-03	2.20E-03	1.00E+00	2.40E-03	2.60E-03
	B- Type	2.60E-03	9.44E-01	2.60E-03	2.60E-03	2.40E-03	2.00E-03	1.00E+00	1.31E-01
	N-Type	2.40E-03	2.20E-03	2.40E-03	2.20E-03	2.00E-03	2.60E-03	2.20E-03	1.00E+00

5. Discussion

In the present work, an attempt has been made to classify the unknown data set based on calculated similarity factor which tends to become unity. In doing so, decision boundaries among the datasets have not been estimated. Sometimes it may occur that unknown datasets may have almost equal similarity factors with respect to any two or more known data sets. Better inference could be derived when decision boundaries based discriminate analysis (Fischer discriminate analysis) are made because calculation of prior and posterior probabilities and cost of misclassification would provide better guideline for better prediction.

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- SECSED: Sensor circuits and sensor devices
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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

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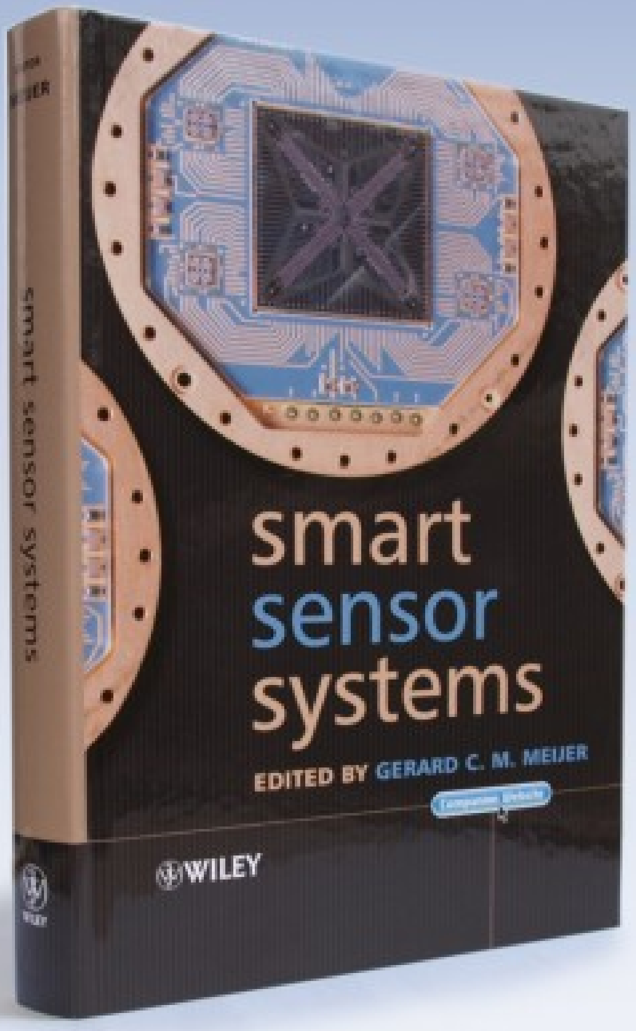
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