Problem-dependent Designs for Error Correcting Output Codes

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ABSTRACT

Error correcting output codes (ECOC) represent a successful extension of binary classifiers to address the multiclass problem. In this paper, we propose a novel technique called ECOCONE (Optimal Node Embedding) to improve an initial ECOC configuration defining a strategy to create new dichotomies and improve optimally the performance. The process of searching for new dichotomies is guided by the confusion matrices over two exclusive training subsets. A weighted methodology is proposed to take into account the different relevance between dichotomies. We validate our extension technique on well-known UCI databases. The results show significant improvement to the traditional coding techniques with far few extra cost.

Keywords. Error Correcting Output Codes, Multiclass classification

1.ECOC

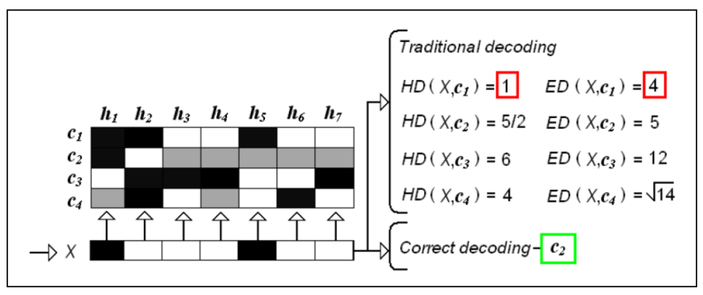


Figure 1: Example of ternary matrix M for a 4-class problem. A new test codeword is misclassified when using the traditional decoding strategies.

Coding strategy → Coding matrix

Decoding strategy → Similarity metrics

2.ECOC-ONE

Given N_c classes and a coding matrix M (see fig. 1):

for $t = 1$ to T iterations:

1) Compute the optimal partition $\wp_i$ of the subset of classes
2) Test accuracy on the training and validation subsets.
3) Select the pair of classes $\{C_i, C_j\}$ with the highest error analyzing the confusion matrices from the training and validation subsets.
4) Find the partition $\wp_i$ containing $\{C_i, C_j\}$ that minimizes the error rate in the training and validation subsets.
5) Compute the weight for the dichotomy of partition $\wp_i$ based on the error.

Update the matrix M.

Table 1. ECOC-ONE extension algorithm

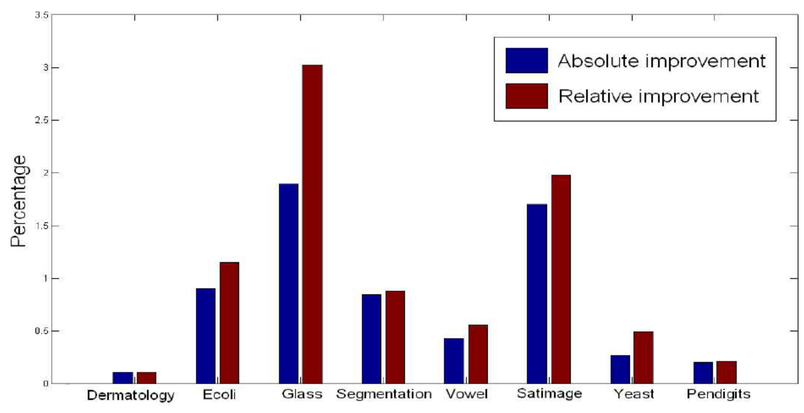
4.RESULTS

Problem	one-versus-all		one-versus-all-ONE		one-versus-all-dense	
	Hit	#D	Hit	#D	Hit	#D
Ecoli	77.00±1.14	8	**80.60±0.75**	11	77.75±1.02	11
Yeast	51.28±0.99	10	**55.84±1.08**	13	**54.76±1.06**	13
Glass	62.34±2.17	7	**65.17±1.80**	10	**65.52±2.07**	10
Dermathology	93.17±0.82	6	**95.43±0.72**	9	**94.70±0.69**	9
Vowel	73.97±1.73	11	**83.63±0.81**	14	78.43±1.41	14
Rank	4.00		**1.00**		1.40	

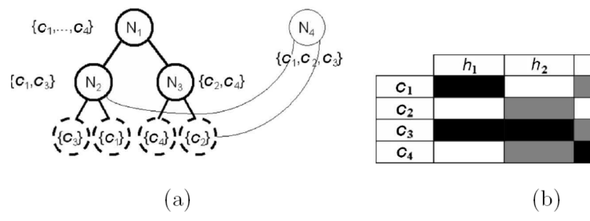
Table 2: Results of coding extensions of one-versus-all for UCI repository database.

Problem	one-versus-one		one-versus-one-ONE		one-versus-one-dense	
	Hit	#D	Hit	#D	Hit	#D
Ecoli	80.35±1.61	28	**80.65±1.59**	31	**81.20±1.29**	31
Yeast	54.58±1.10	45	**56.83±0.89**	48	54.48±0.94	48
Glass	67.38±1.98	21	**68.97±1.99**	24	**67.79±1.88**	24
Dermathology	95.48±0.80	15	**96.95±0.67**	18	**95.83±0.82**	18
Vowel	86.00±1.16	55	**88.96±1.07**	58	81.33±1.24	58
Rank	2.00		**1.00**		1.80	

Table 3: Results of coding extensions of one-versus-one for UCI repository database.



Absolute and relative percentage improvement comparison between Euclidean distance and weighted Euclidean distance



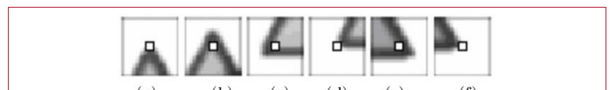
(a) (b)

(left) ECOC-ONE with initial optimal tree and first optimal node embedding. (right) Comparison between ECOC-ONE with SVM and multiclass SVM with RBF

Problem	ECOC-ONE	Multiclass SVM
Dermathology	**95.83±0.94**	**96.52±0.61**
Ecoli	**75.68±1.28**	69.74±0.76
Glass	**57.83±1.93**	**59.93±1.99**
Segmentation	**97.84±1.12**	95.23±0.59
Vowel	69.14±3.01	**77.55±0.96**
Satimage	**89.04±0.63**	85.60±0.40
Yeast	**52.58±1.73**	**52.57±0.92**
Pendigits	**98.43±0.99**	**98.72±0.17**
Rank	**1.12**	1.38

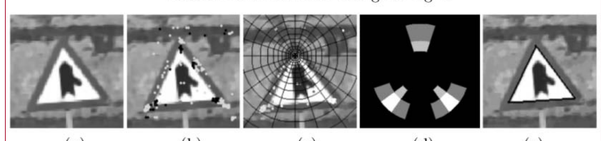
4.REAL APPLICATIONS

TRAFFIC SIGN RECOGNITION



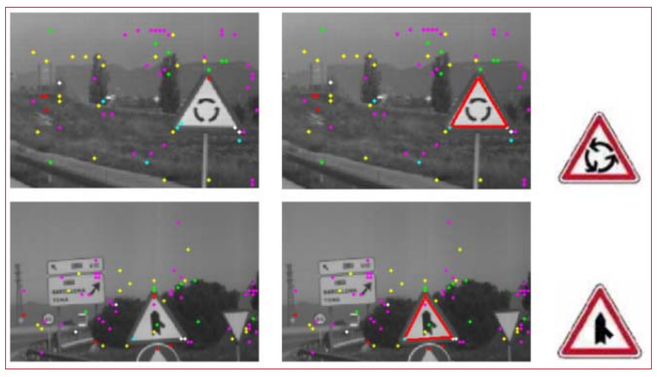
(a) (b) (c) (d) (e) (f)

Selected landmarks for triangular signs.

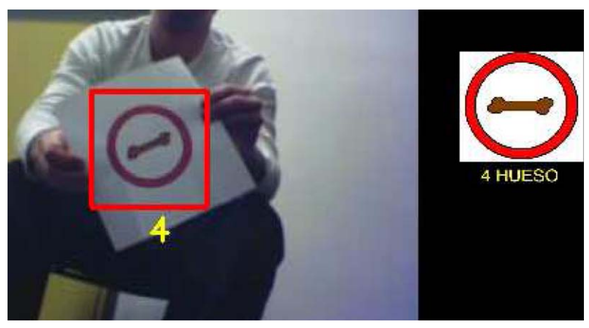


(a) (b) (c) (d) (e)

Input image. (b) Detected landmarks. (c) Contextual descriptors. (d) Resulting bins at feature selection of the correlogram of the landmark (e) Detected sign.



ROBOTICS



CONCLUSIONS

In most of the ECOC coding strategies, the ECOC matrix is pre-designed, using the same dichotomies in any type of problem. We introduced a new coding and decoding strategy called ECOC-ONE. The ECOC-ONE strategy can be seen as a general extension for any initial coding matrix. The procedure shares classifiers among classes in the ECOC-ONE matrix, and selects the best partitions weighed by their relevance. In this way, it reduces the overall error for a given problem. Moreover, using the validation subset the performance is increased and overfitting is avoided. We show that this technique improves in most cases the generalization performance of any initial code with few extra cost better than other distance maximization extensions. Besides, ECOC-ONE can generate an initial small code by itself. As a result, a compact - small number of classifiers – multiclass recognition technique with improved accuracy is presented with very promising results.