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Introducing Bidirectional Ordinal Classifier Cascades Based on a Pain Intensity Recognition Scenario

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ABSTRACT

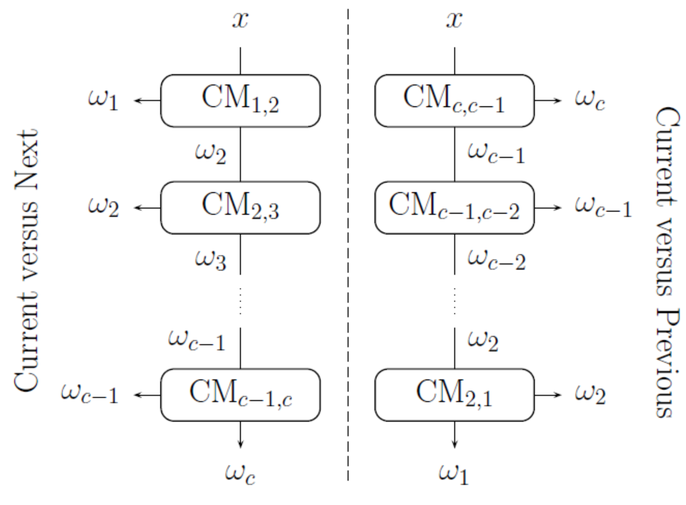
Ordinal classifier cascades (OCCs) are basic classification architectures that were invented for ordinal classification tasks, i.e. tasks in which the classes constitute an ordinal class structure. Due to strong performing alternatives, in general, OCC architectures are only used for the detection of ordinal class structures. In the current study, we propose a straightforward combination of OCCs, which we denote as bidirectional ordinal classifier cascades (bOCCs).

FORMALISATION

- $X \subset \mathbb{R}^d, d \in \mathbb{N}$ d-dimensional data set
- $\omega_1 \prec \cdots \prec \omega_c,\ c \geq 3$ ordered class labels (edge classes: ω_1, ω_c)
- $l(x)$ true label of data sample x
- $X_{i,j} \coloneqq \{x \in X | l(x) = \omega_i \vee l(x) = \omega_j\} \subset X$
- $CM_{i,j}$ classification model that is trained in combination with $X_{i,j}$
- $CM_{i,j} = CM_{j,i}\ \forall i, j \in \{1, \ldots, c\}$ (symmetric classification models)

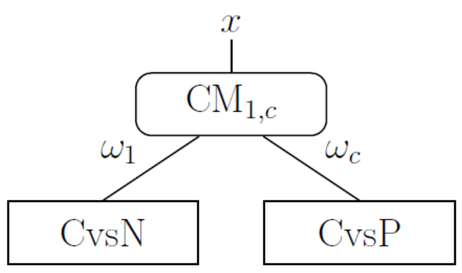
ORDINAL CLASSIFIER CASCADES (OCCs)

- OCCs consist of a sequence of classification models (CMs)
- Each CM provides the final decision or passes the current input
- Motivation: The direction of OCCs is important!
- Separate the pairwise OCCs into CvsN and CvsP:



BIDIRECTIONAL ORDINAL CLASSIFIER CASCADES (bOCCs)

- Simple idea: Combine the pairwise approaches, CvsN & CvsP
- Selector component: $CM_{1,c}$



- If the output of $CM_{1,c}$ is equal to ω_1, proceed with CvsN
- If the output of $CM_{1,c}$ is equal to ω_c, proceed with CvsP
- Study Question: Does this simple approach improve classification?

BIOVID HEAT PAIN DATABASE (PART A)

Number of participants	87 (43 f, 44 m)
Number of classes	5 (no pain $\prec \cdots \prec$ very strong pain)
Number of samples per class/person	20 (8700 samples in total)
Number of features (ECG+EDA+EMG)	194 (68+70+56)

COMPARISON TO ERROR CORRECTING OUTPUT CODES

- One versus All (1vsA), One versus One (1vs1)
- All Binary Combinations (ABC)

EXPERIMENTAL SETTINGS

- Models: Support Vector Machines with linear kernel
- Features: Concatenation of ECG, EDA, and EMG data
- Evaluation: Leave-One-Person-Out (LOPO) Cross Validation
- Performance Metrics: Accuracy, Mean Absolute Error (MAE)
- Test: Two-sided Wilcoxon signed-rank test at 5%-level

RESULTS (rows: true labels, columns: predicted labels)

- T_i indicates pain level i (T_0: no pain level)

	Current vs. Next					Current vs. Previous				
	T_0	T_1	T_2	T_3	T_4	T_0	T_1	T_2	T_3	T_4
T_0	**1035**	418	182	72	33	**573**	312	401	319	135
T_1	674	**551**	302	153	60	384	**397**	441	378	140
T_2	561	488	**352**	216	123	254	317	**470**	465	234
T_3	411	414	316	**291**	308	130	213	380	**532**	485
T_4	300	247	198	219	**776**	41	89	203	361	**1046**
$\sum$	2981	2118	1350	951	1300	1382	1328	1895	2055	2040

RESULTS (* indicates stat. significance with respect to bOCC)

Approach	Accuracy	MAE	#Classifiers
CvsN	$34.54 \pm 8.06^*$	$1.139 \pm 0.229^*$	4
CvsP	$34.69 \pm 9.31^*$	$1.063 \pm 0.258^*$	4
1vsA	$35.11 \pm 7.81^*$	$1.155 \pm 0.267^*$	5
bOCC	$\underline{37.01 \pm 8.97}$	1.040 ± 0.267	5
1vs1	36.95 ± 9.41	$\underline{1.002 \pm 0.259^*}$	10
ABC	36.29 ± 8.07	$1.098 \pm 0.279^*$	15

CONCLUSION

- The direction of an OCC sequence has a significant impact
- The addition of one CM significantly improves performance
- Only the 1vs1 ECOC approach outperformed bOCC (MAE)

FUTURE WORK

- Optimisation of the selector component
- Combination of 1vs1 and bOCC

Contact

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Recent Studies on the Detection of Ordinal Class Structures

- Lausser, L., Schäfer, L.M., Kühlwein, S.D. *et al*: Detecting Ordinal Subcascades, Neural Processing Letters **52**, pp. 2583–2605 (2020)
- Bellmann, P., Schwenker, F.: Ordinal Classification: Working Definition and Detection of Ordinal Structures, IEEE Access **8**, pp. 164380–164391 (2020)