Deep and Ordinal Ensemble Learning for Human Age Estimation From Facial Images

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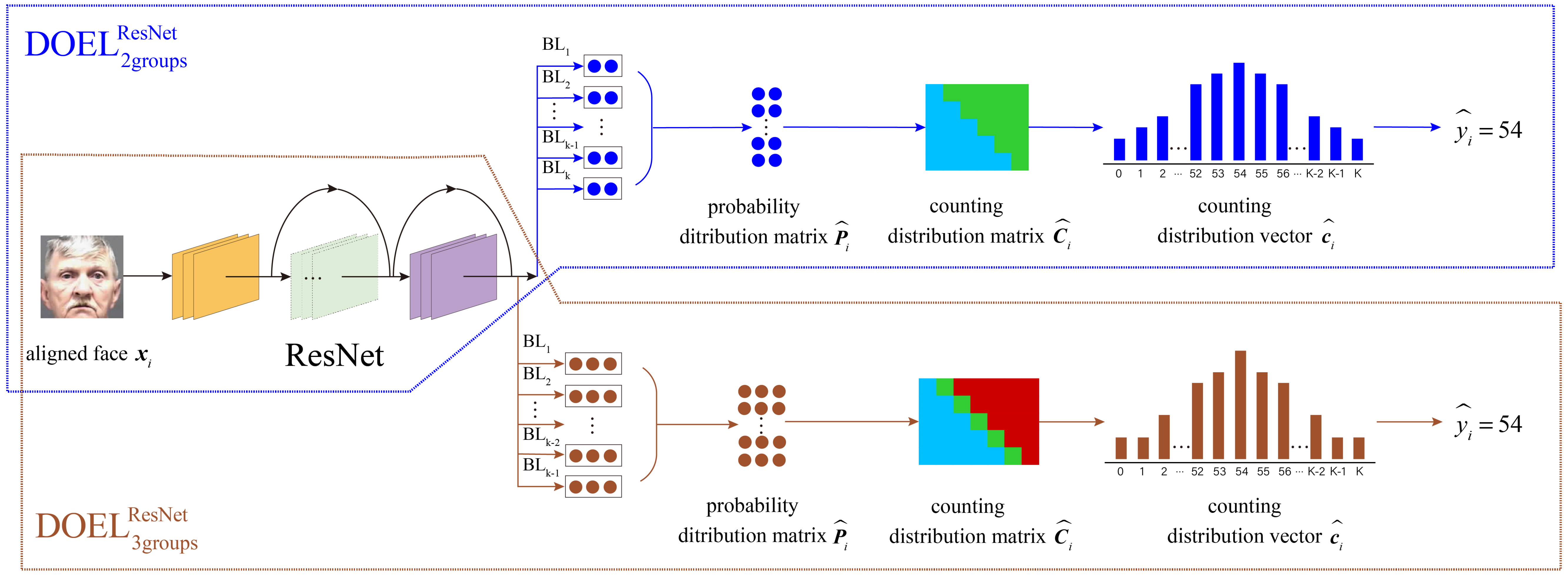
Framework of Two DOELs



Evaluation Results

Methods	Validation Set		Test Set		Num. of Networks
	MAE	ϵ-error	MAE	ϵ-error	
DEX [53]	3.25	0.28	-	0.265	20
Tan et al. [46]	3.21	0.28	2.94	0.264	8
DHAA [61]	3.052	0.265	-	0.252	1
BridgeNet [62]	2.98	0.26	2.87	0.255	1
$DOEL^{ResNet101}_{2groups}$	**2.933**	**0.258**	**2.713**	**0.247**	1
$DOEL^{ResNet101}_{3groups}$	2.965	0.259	2.726	0.249	1

Table 1. Evaluation Results on Chalearn LAP 2015 database

Methods	MAE	CS($l = 5$)	CS($l = 10$)
DEX [53]	4.63	-	-
Liu et al. [57]	3.93	76.0%	91.0%
LSDML [58]	3.92	75.0%	89.0%
ODFL [42]	3.89	80.0%	91.0%
Tan et al. [46]	4.34	76.0%	86.0%
Shen et al. [47]	3.85	80.6%	-
Pan et al. [40]	4.10	78.0%	88.0%
Xie et al. [32]	3.58	78.3%	92.3%
ODL [59]	3.71	81.0%	**96.0%**
SADAL [60]	3.68	-	-
DHAA [61]	3.72	-	-
$DOEL^{ResNet101}_{2groups}$	3.52	81.1%	92.6%
$DOEL^{ResNet101}_{3groups}$	**3.44**	**82.7%**	93.0%

Table 2. Evaluation Results on FG-NET database.

Link

[codes] https://github.com/Xiejiu/second_age_estimation

Highlights

- We modify the ordinal ranking method for age prediction from the perspective of ensemble learning.
- Our modification named $DOEL_{2groups}$ has better interpretability and lower prediction errors theoretically.
- We present a further modification called $DOEL_{3groups}$.
- Extensive evaluations validate the efficacy of our two approaches.

Limitations of $OR_{2groups}$ [1,2]

Binary classifier	Age group 1	Age group 2	Output
BC_1	0	1,2,…, K	$\hat{r}_1(x) = 0 \text{ if x } \in\ g_1^1\ else\ 1$
BC_2	0,1	2,3,…,K	$\hat{r}_2(x) = 0 \text{ if x } \in\ g_2^1\ else\ 1$
⋮	⋮	⋮	⋮
BC_k	0,1,…,k-1	k,k+1,…,K	$\hat{r}_{k-1}(x) = 0 \text{ if x } \in\ g_{k-1}^1\ else\ 1$
⋮	⋮	⋮	⋮
BC_{K-1}	0,1,…,K-2	K-1, K	$\hat{r}_{K-1}(x) = 0 \text{ if x } \in\ g_{K-1}^1\ else\ 1$
BC_K	0,1,…,k-1	K	$\hat{r}_K(x) = 0 \text{ if x } \in\ g_K^1\ else\ 1$

Predicted age: $\hat{y} = \sum_{k=1}^{K} \hat{r}_k(x)$ (1)

- Eq. (1) is logical only when we get the ranking predictions as the follows: $\hat{r}_1 = \hat{r}_2 = \cdots = \hat{r}_m = 1$, and $\hat{r}_{m+1} = \hat{r}_{m+2} = \cdots = \hat{r}_K = 0$
- The Conflicts may emerge in practice, such as $\hat{r}_m = 0$ whereas $\hat{r}_{m+1}$=1.

$DOEL_{2groups}$

Base learner	Age group 1	Age group 2
BL_k	0,1,…,k	k+1,k+2,…,K

Output

k+1 K-k

$$\hat{c}_k(x) = \begin{cases} (1,1,\ldots,1,0,0,\ldots,0) & if\ x \in g_k^1 \\ (0,0,\ldots,0,1,1,\ldots,1) & if\ x \in g_k^2 \end{cases}$$

- Counting distribution matrix: $\hat{C}(x) = [\hat{c}_1; \hat{c}_2; \ldots; \hat{c}_K]$
- Counting distribution vector: $\hat{c}(x) = [\sum_{k=1}^{K} \hat{C}_{k,1}, \sum_{k=1}^{K} \hat{C}_{k,2}, \ldots, \sum_{k=1}^{K} \hat{C}_{k,K+1}]$
- Estimated age: $\hat{y} = index\ (\max \hat{c}(x))$

$DOEL_{3groups}$

Base learner	Age group 1	Age group 2	Age group 3
BL_k	0,1,…,k-1	k	k+1,k+2,…,K

Output

k 1 K-k

$$\hat{c}_k(x) = \begin{cases} (1,1,\ldots,1,0,0,0,\ldots,0) & if\ x \in g_k^1 \\ (0,0,\ldots,0,1,0,0,\ldots,0) & if\ x \in g_k^2 \\ (0,0,\ldots,0,0,1,1,\ldots,1) & if\ x \in g_k^3 \end{cases}$$

- Counting distribution matrix: $\hat{C}(x) = [\hat{c}_1; \hat{c}_2; \ldots; \hat{c}_{K-1}]$
- Counting distribution vector: $\hat{c}(x) = [\sum_{k=1}^{K-1} \hat{C}_{k,1}, \sum_{k=1}^{K-1} \hat{C}_{k,2}, \ldots, \sum_{k=1}^{K-1} \hat{C}_{k,K+1}]$
- Estimated age: $\hat{y} = index(max\ \hat{c}(x))$

$OR_{2groups}$ vs. $DOEL_{2groups}$ vs. $DOEL_{3groups}$

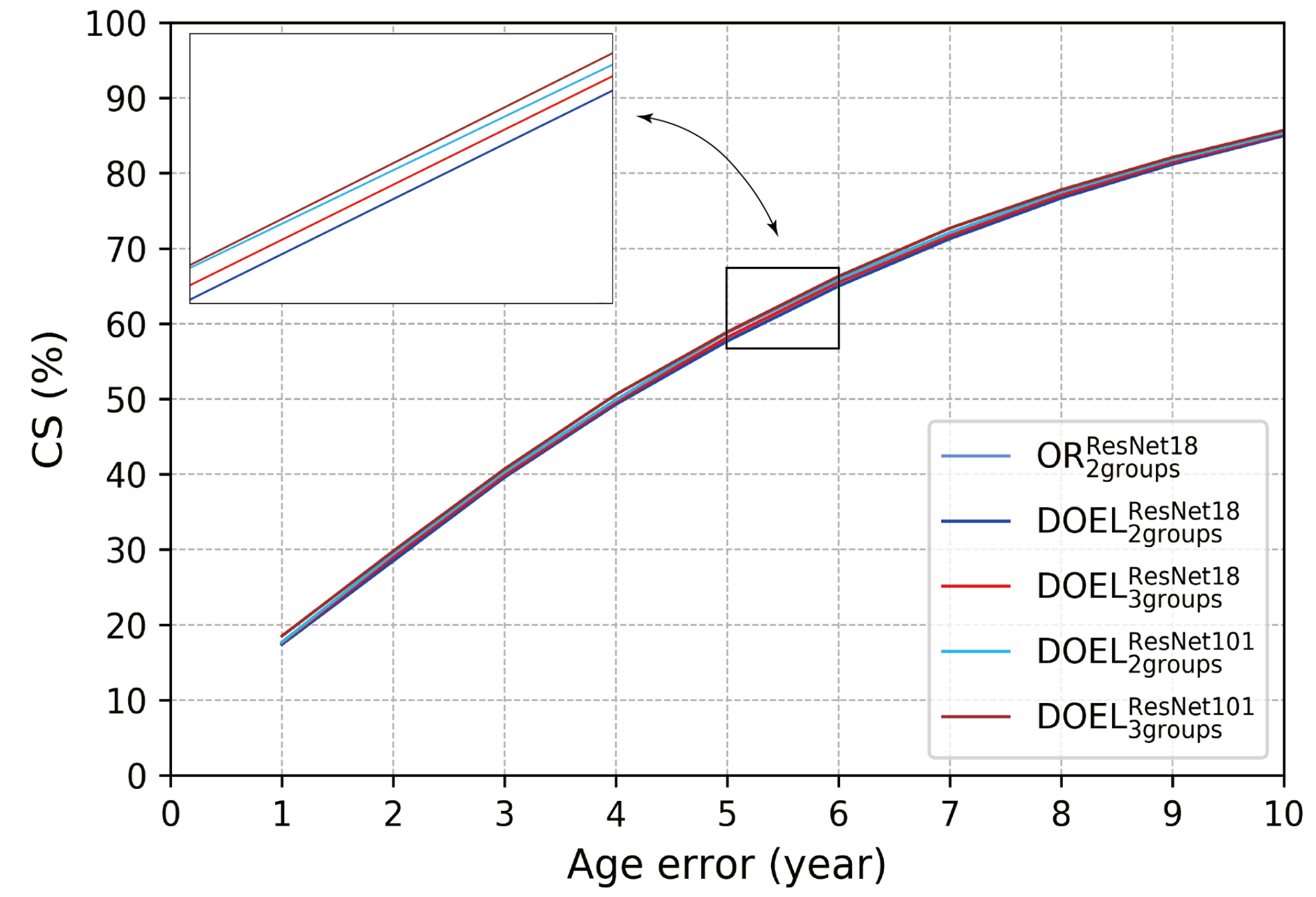


Figure 1. CS curves of different ordinal regression modellings.

Methods	on AgeDB	
	MAE	IR
$OR^{ResNet18}_{2groups}$	5.83422	30/16488
$DOEL^{ResNet18}_{2groups}$	5.83408	-
$DOEL^{ResNet18}_{3groups}$	**5.79756**	-
$DOEL^{ResNet101}_{2groups}$	5.73700	-
$DOEL^{ResNet101}_{3groups}$	**5.69204**	-

Table 3. Comparisons among different ordinal regression modellings.

References

[1] Z. Niu, M. Zhou, L. Wang, X. Gao, and G. Hua. Ordinal regression with multiple output CNN for age estimation. *CVPR*, 2016.
[2] S. Chen, C. Zhang, M. Dong, J. Le, and M. Rao. Using ranking-CNN for age estimation. *CVPR*, 2017.