Geometric Order Learning for Rank Estimation

Seon-Ho Lee, Nyeong-Ho Shin, Chang-Su Kim

NeurIPS 2022

KOREA UNIVERSITY

MCL Media Communications Lab

Order Learning (순서학습)

- Related Work
  - **[ICLR 2020]** Order Learning and Its Application to Age Estimation
  - **[ICLR 2021]** Deep Repulsive Clustering of Ordered Data Based on Order-Identity Decomposition
  - **[CVPR 2022]** Moving Window Regression: A Novel Approach to Ordinal Regression
  - **[ECCV 2022]** Order Learning Using Partially Ordered Data via Chainization
  - **[NeurIPS 2022]** Geometric Order Learning for Rank Estimation

Order Learning

[ICLR 2020] Order Learning and Its Application to Age Estimation

Rank Estimation

- Estimate the rank of an object instance
  - Depth
  - Aesthetic score
  - Facial age

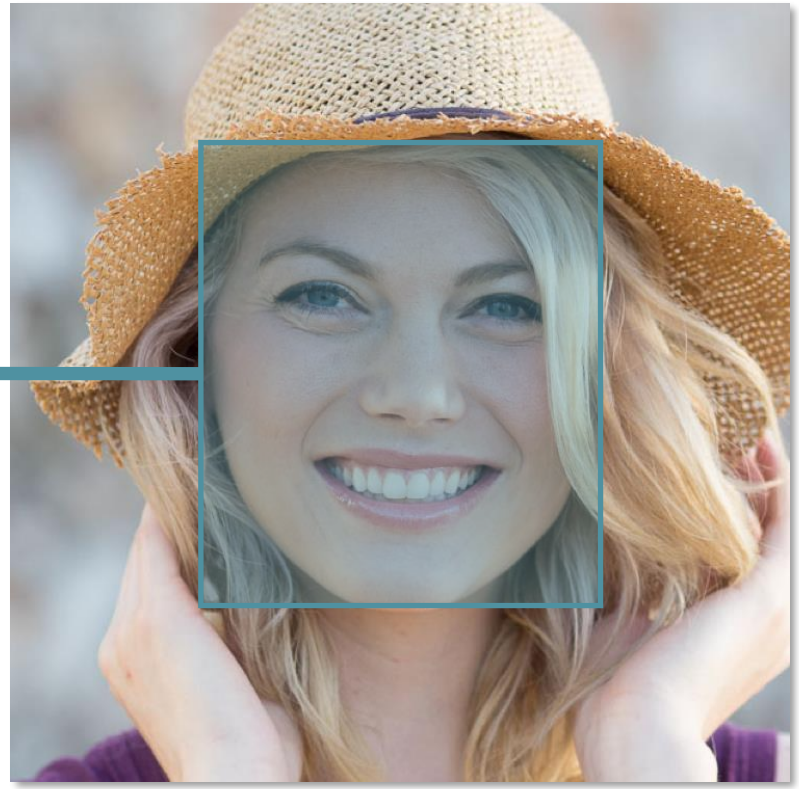
How far the region is?

How beautiful the image is?

How old is she?

Direct Estimation is Difficult

How old is she?



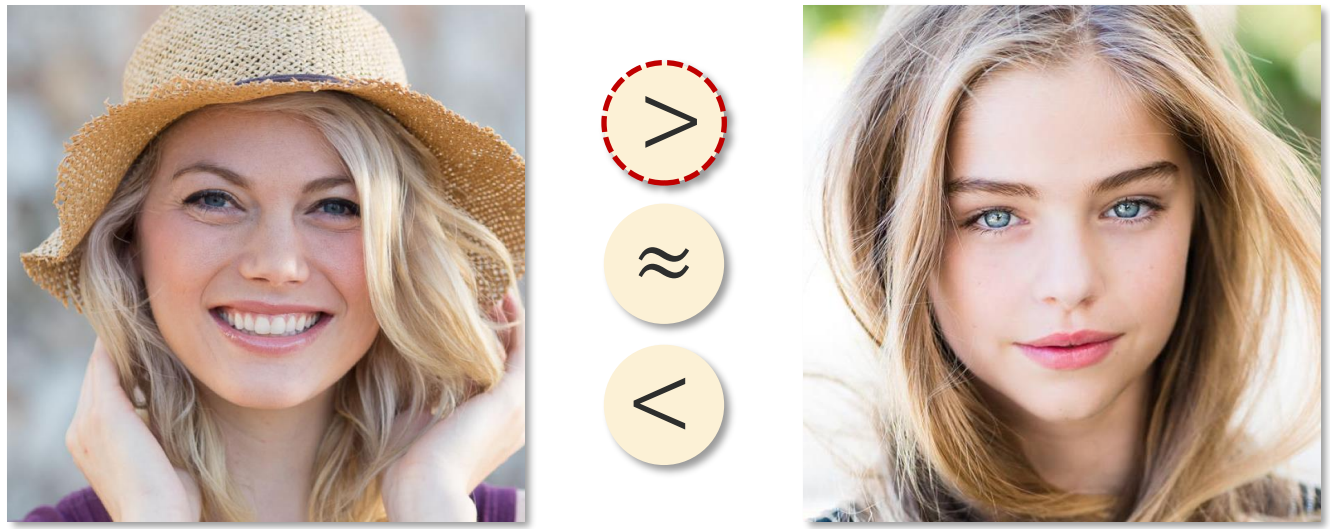
Order Learning

- Rank estimation via relative assessment

How old is she?

Order Learning

- Rank estimation via relative assessment

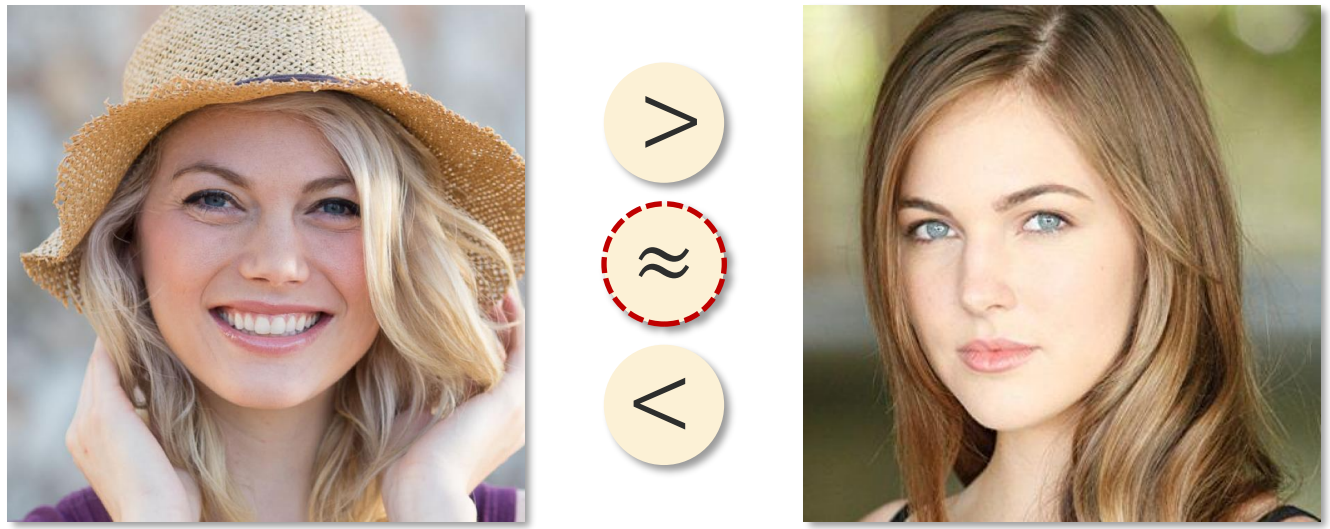


target

reference

Order Learning

- Rank estimation via relative assessment



target

reference

Order Learning

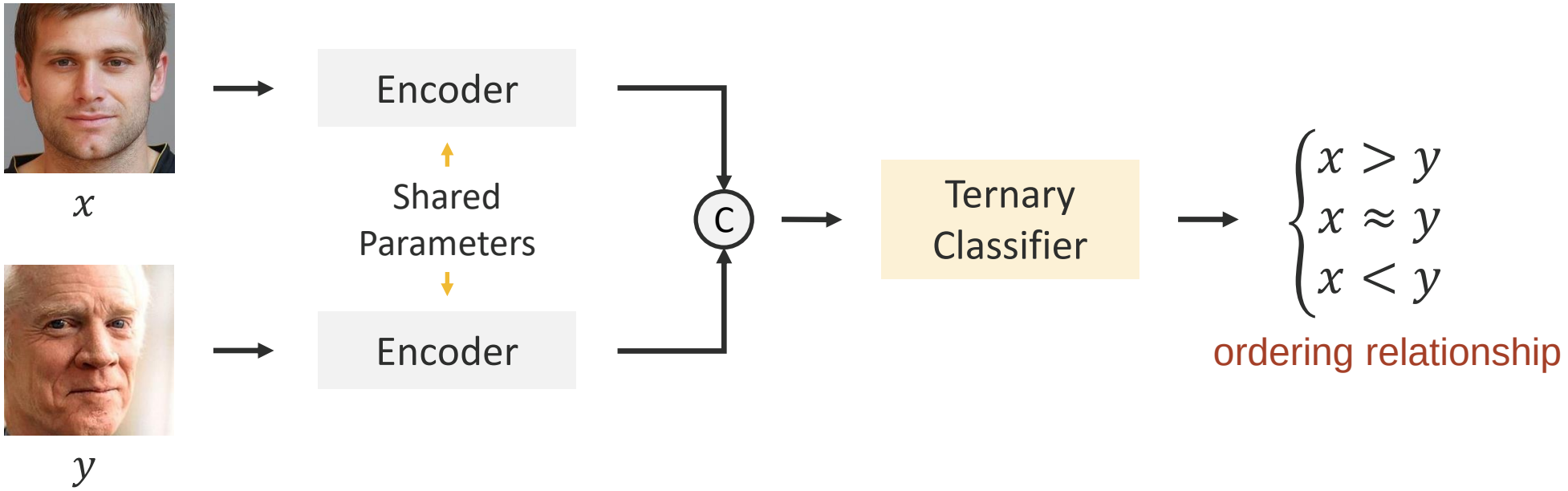
- Rank estimation via relative assessment

target

reference

Pairwise Comparator

- It consists of a Siamese network and a ternary classifier



Age Estimation Example

- Test image : x
- Reference image : y

: $x \succ y$: $x \approx y$: $x \prec y$

Test image

22
Male
Asian

Reference images

15 16 17 18 19 20 21 **22** 23 24 25 26 27 28 29 30 31 32 33

DRC-ORID

[ICLR 2021] Deep Repulsive Clustering of Ordered Data Based on Order-Identity Decomposition

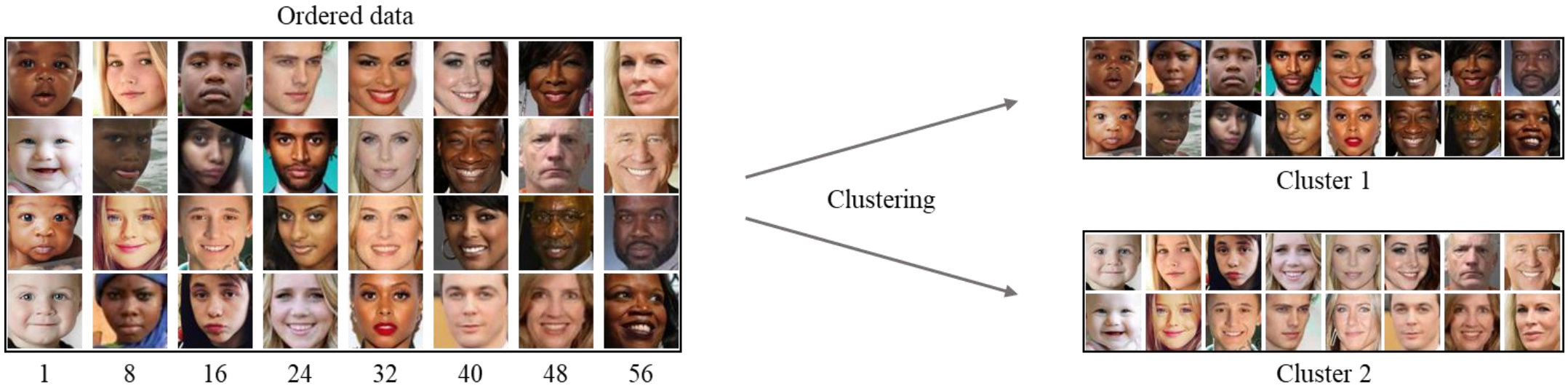
Order-Identity Decomposition

- Order feature : order related information
- Identity feature : characteristics unrelated to ranks

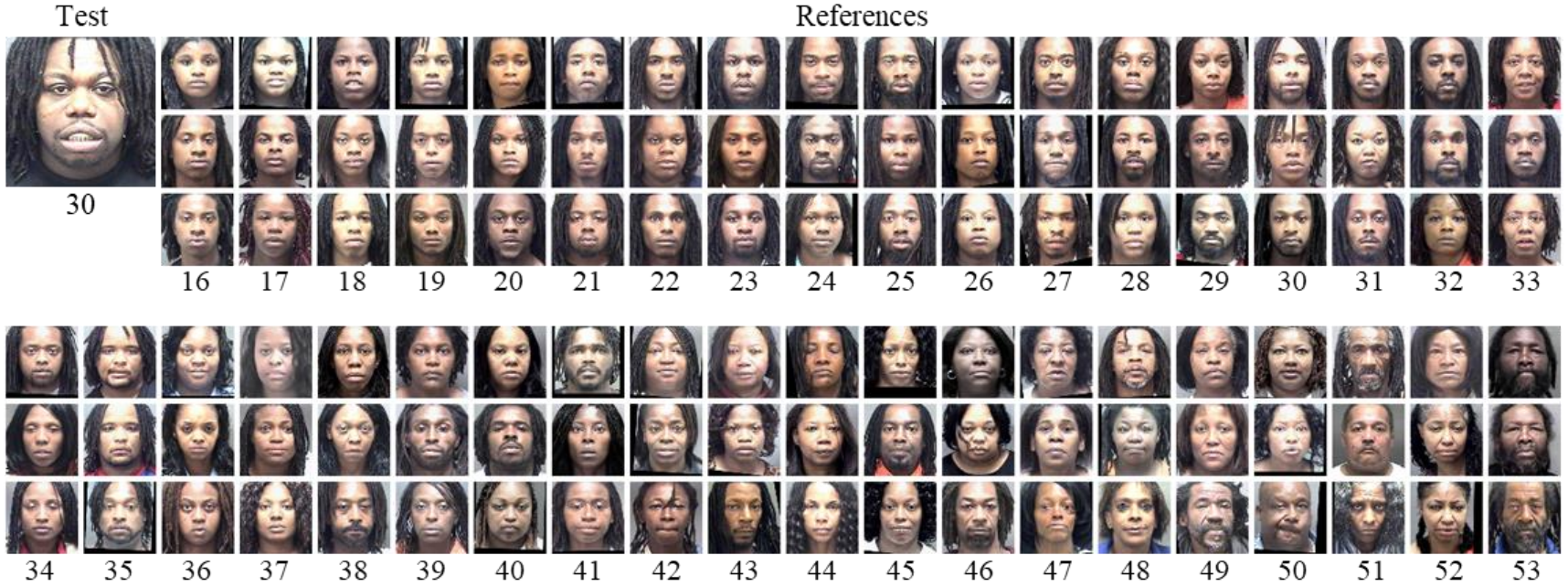
Order feature : skin texture, wrinkles, …

Identity feature : race, gender, …

Clustering of Ordered Data



Reference Selection Based on Identity Feature



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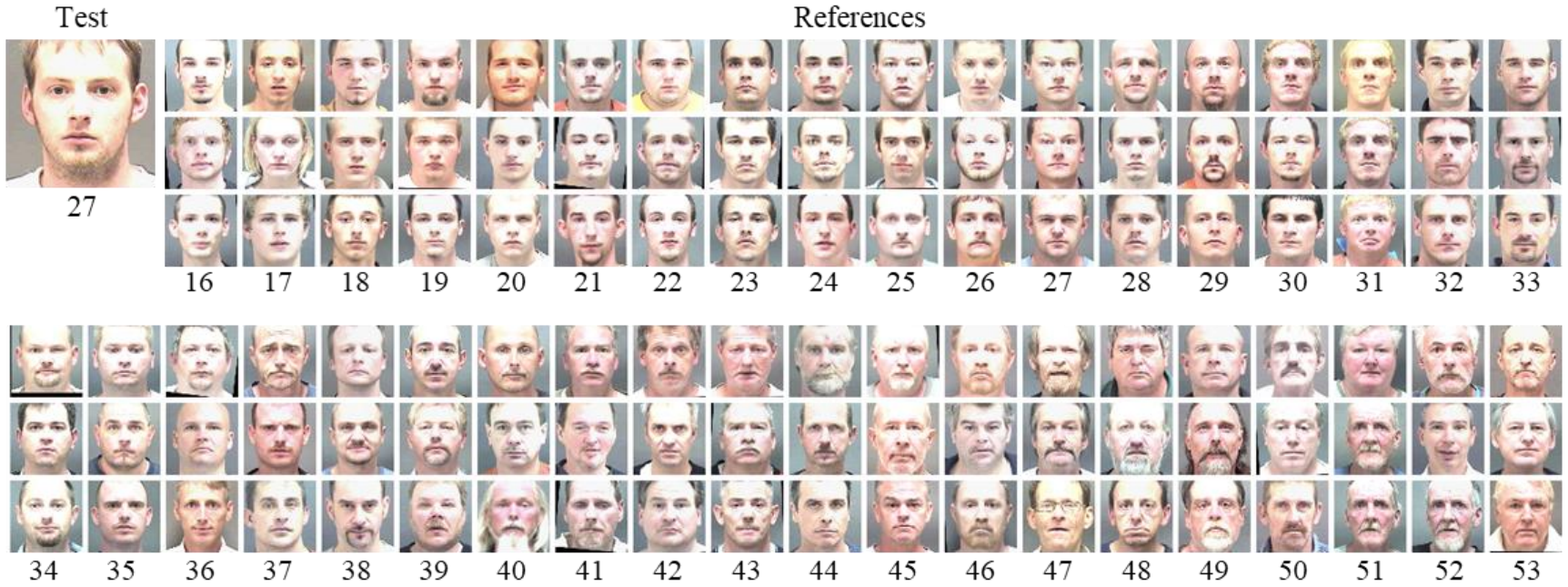

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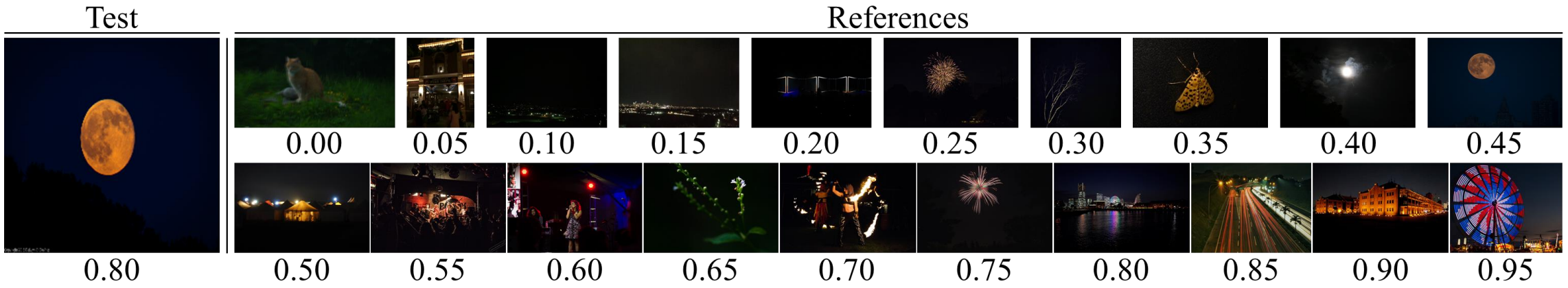


Moving Window Regression

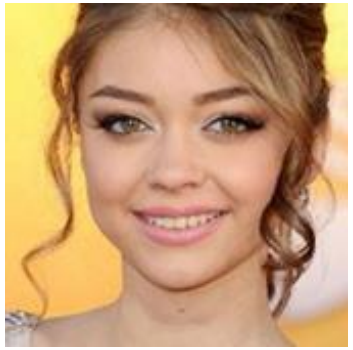
[CVPR 2022] Moving Window Regression: A Novel Approach to Ordinal Regression

ρ-rank

- How much greater or smaller the input is than the references

ρ-rank	-1	-0.4	1
Age	20	22	30

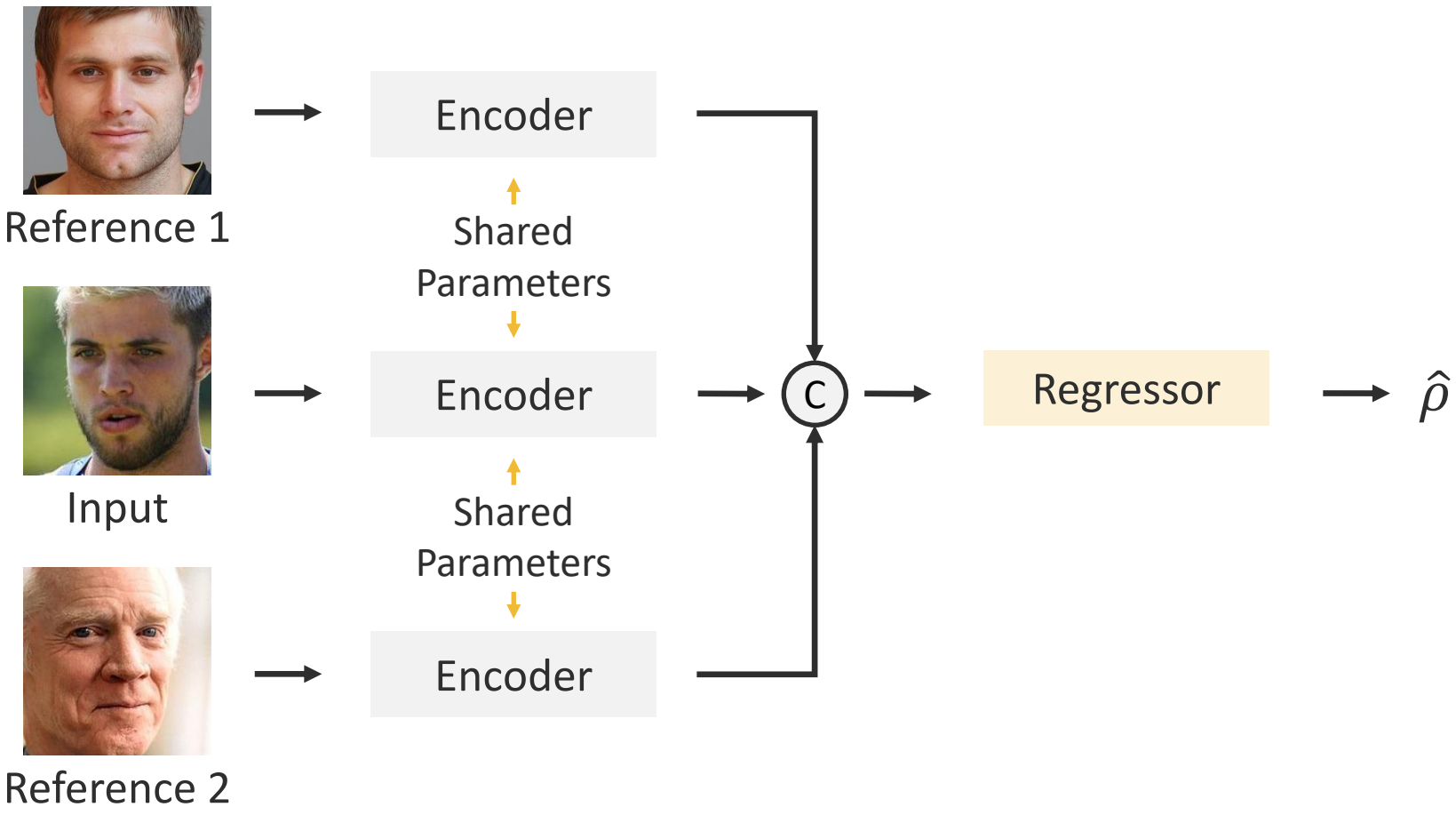
2 years older



8 years younger

Reference 1 | Target | Reference 2

ρ-regressor



CVPR 2022

Moving Window Regression: A Novel Approach to Ordinal Regression

Nyeong-Ho Shin, Seon-Ho Lee, Chang-Su Kim

Age Estimation Results

- MORPH Ⅱ & FG-NET

	Setting A		Setting B		Setting C		Setting D		FG-NET	
	MAE	CS (%)	MAE	CS (%)	MAE	CS (%)	MAE	CS (%)	MAE	CS (%)
MV	-	-	-	-	2.79	-	2.16	-	-	-
BridgeNet	2.38	91.0	2.63	86.0	-	-	-	-	2.56	86.0
AVDL	2.37	-	2.53	-	-	-	**1.94**	-	2.32	-
OL	2.41	91.7	2.75	88.2	2.68	88.8	2.22	93.3	-	-
DRC-ORID	2.26	93.8	**2.51**	89.7	2.58	89.5	2.16	93.5	-	-
MWR	**2.13**	**94.2**	2.53	**90.4**	**2.53**	**90.5**	2.00	**95.0**	**2.23**	**91.1**

GOL

[NeurIPS 2022] Geometric Order Learning for Rank Estimation

Rank Estimation Methods

- Ordinal regression
  - Predict the rank of an object directly via a regressor or a classifier

- Comparison based approaches
  - **Metric learning**
    - How different x is from y
  - **Order learning**
    - x is greater than y
    - x is similar to y
    - x is smaller than y

Rank Estimation Methods

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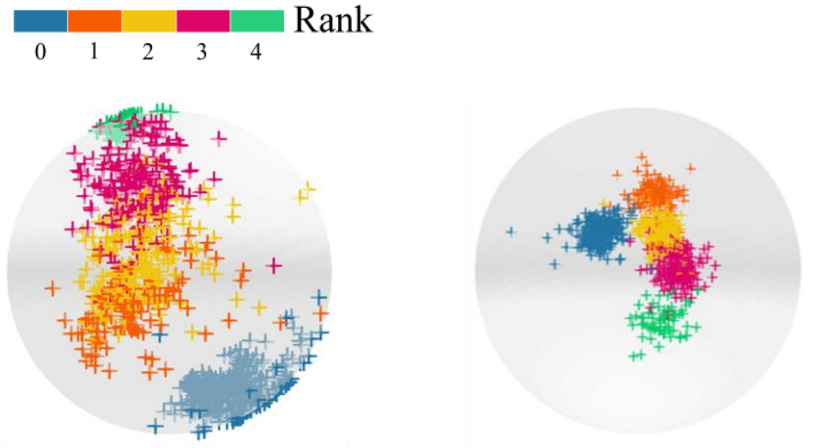

(a) Order learning

ignores metric information

(b) Metric learning

not fully exploit the order of objects

Rank Estimation Methods

- Ordinal regression
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- Comparison-based approaches

GOL
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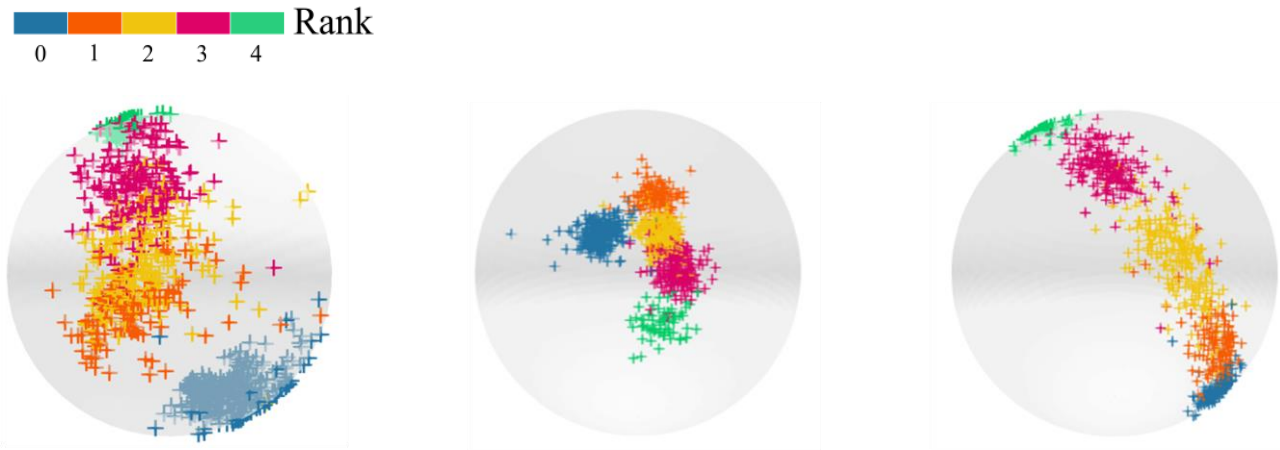


(a) Order learning (b) Metric learning (c) GOL

GOL

- **Order constraint**
  - sorts instances directionally according to the ranks

- **Metric constraint**
  - separates two instances farther if their rank difference is larger

Feature Extraction

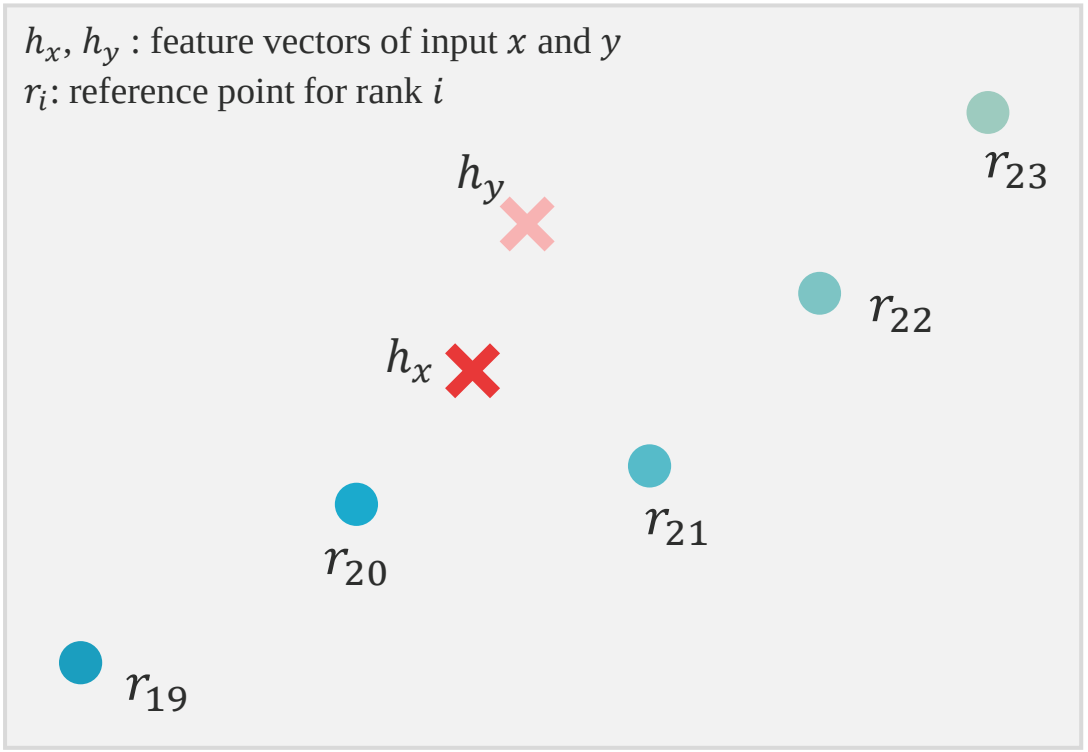
Input x (age 20)

Input y (age 22)

Encoder

Encoder

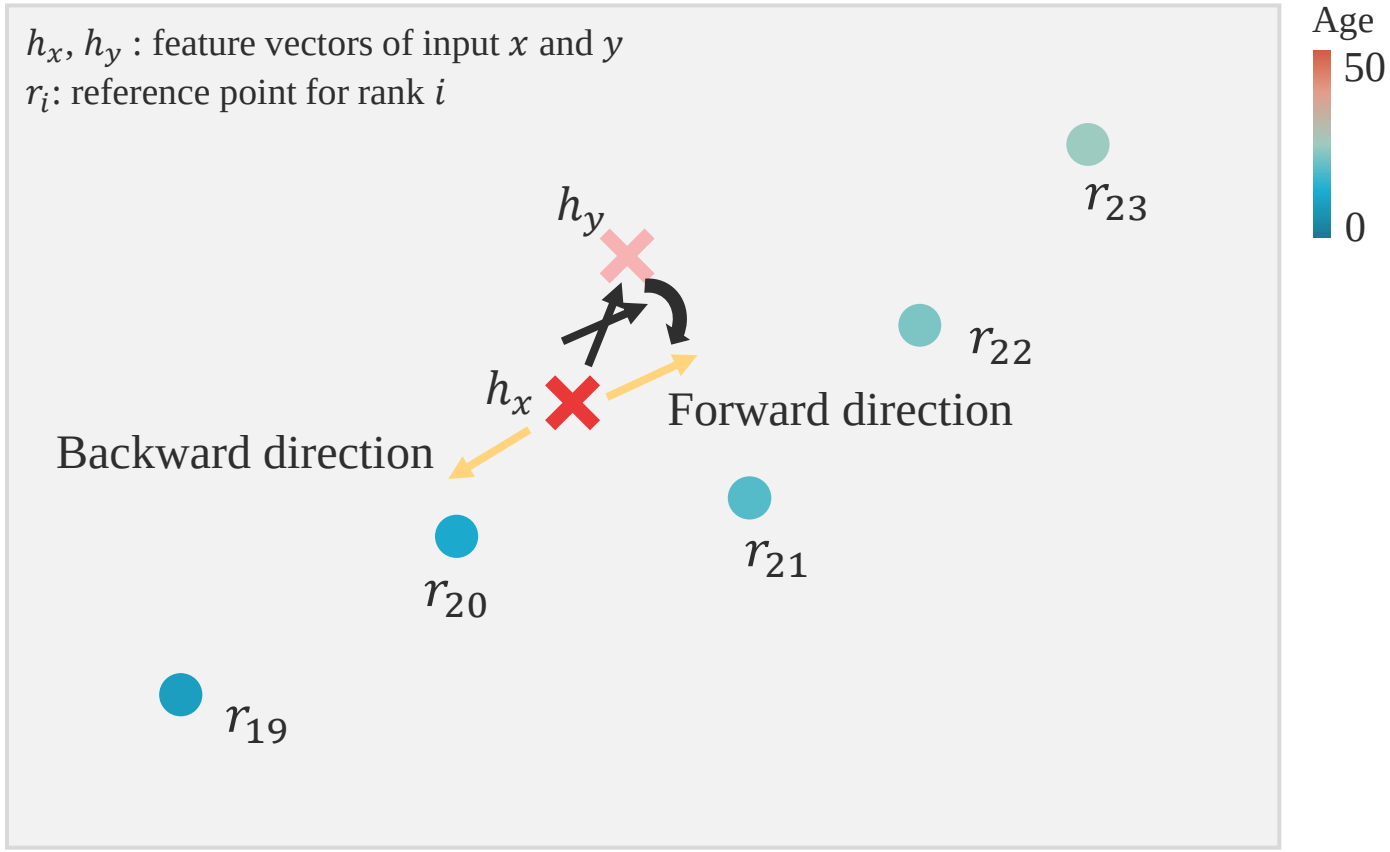
Feature Extraction



Embedding Space

- Encode object instances into an embedding space

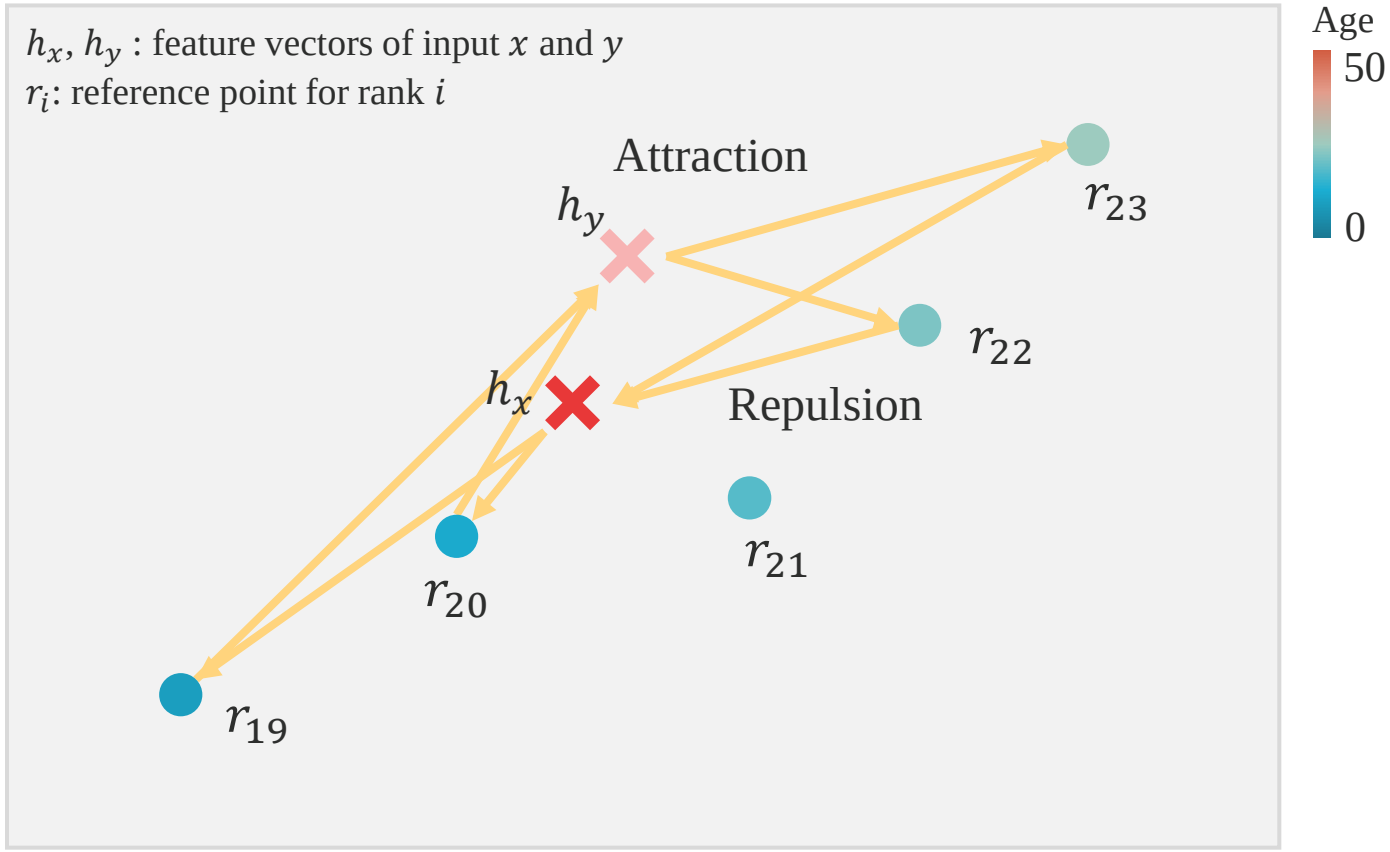
Order Constraint



Embedding Space

- Arrange instances according to their rank directions

Metric Constraint



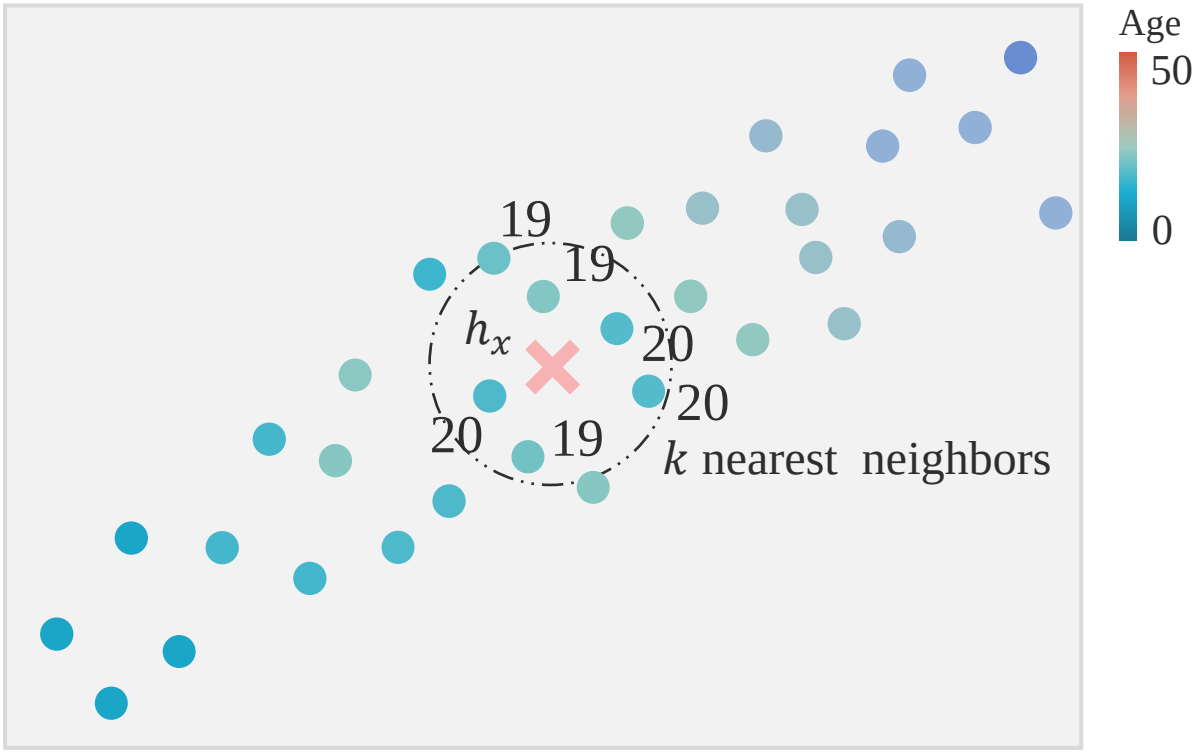
Embedding Space

- Make the distance between instances reflect their rank difference

k-NN Estimation

Input x
(age 20)

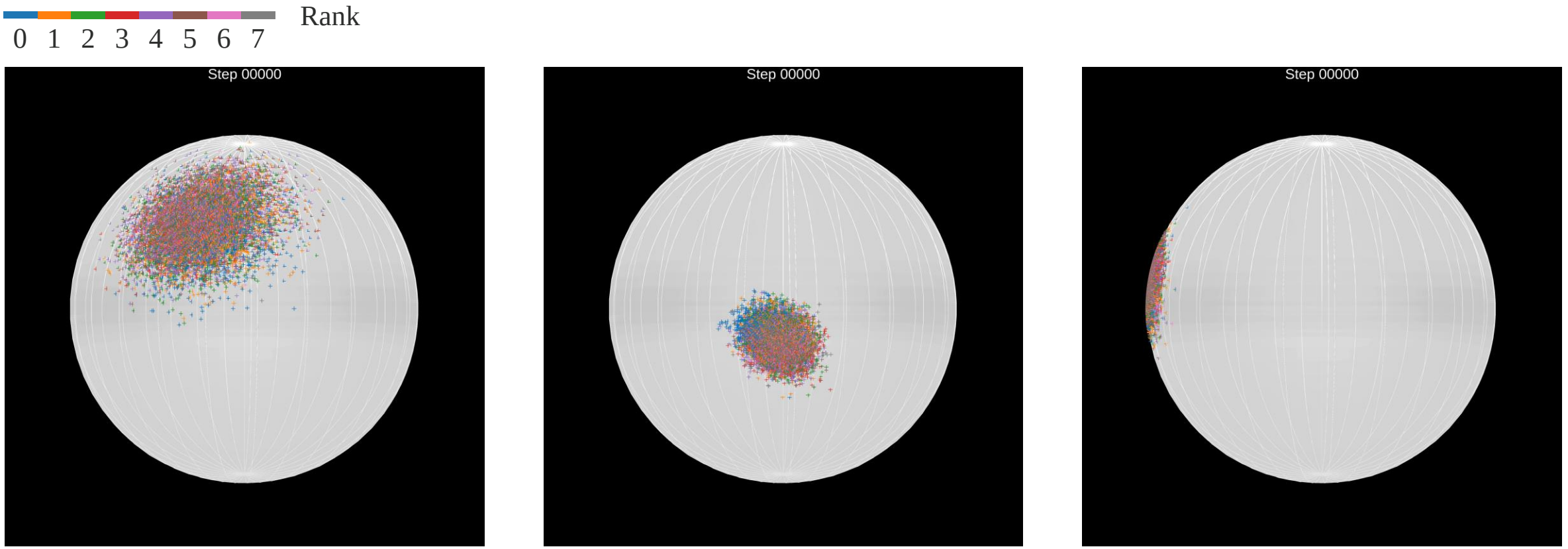
Feature Extraction



Embedding Space

- Estimate the rank of a test instance by finding the nearest neighbors

Transition of Embedding Spaces



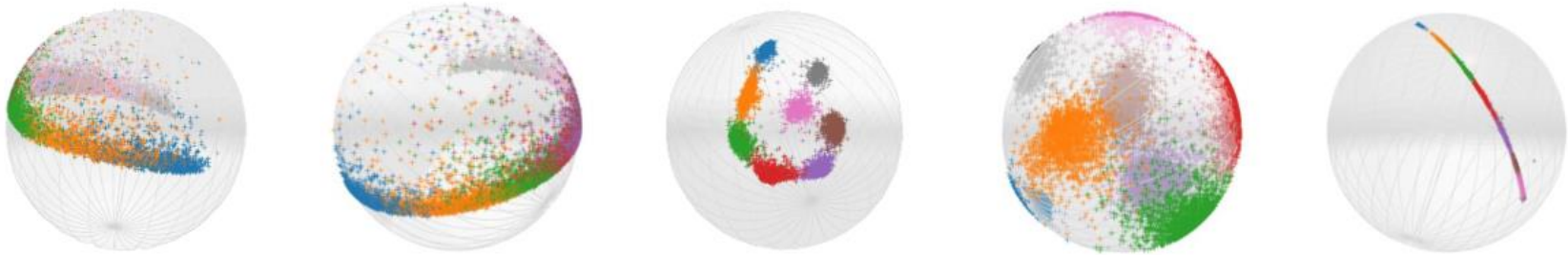
Order Learning

Metric Learning

GOL

Embedding Space Evaluation

Algorithm	MORPH II (setting A)			CACD (validation split)			Adience		
	B2W	$DRR_{1.0}$	$DRR_{0.5}$	B2W	$DRR_{1.0}$	$DRR_{0.5}$	B2W	$DRR_{1.0}$	$DRR_{0.5}$
ML (Schroff et al., 2015)	41.20	10.06	8.94	3.90	2.89	2.55	5.12	3.21	2.98
MV (Pan et al., 2018)	72.47	10.37	9.80	24.21	6.23	5.84	7.08	3.29	3.24
OL (Lim et al., 2020)	43.94	12.79	11.44	8.77	5.60	4.86	13.29	7.27	6.53
MWR-G (Shin et al., 2022)	30.42	10.66	9.28	9.99	6.00	5.24	7.84	5.20	4.71
Proposed GOL	292.72	29.40	25.77	53.06	12.59	10.82	70.31	32.09	28.37



(a) OL (b) MWR-G (c) ML (d) MV (e) GOL

Age Estimation

Algorithm	Setting A		Setting B		Setting C		Setting D	
	MAE	CS (%)	MAE	CS (%)	MAE	CS (%)	MAE	CS (%)
DRFs (Shen et al., 2018)	2.91	82.9	2.98	-	-	-	2.17	91.3
MV (Pan et al., 2018)*	-	-	-	-	2.79	-	2.16	-
C3AE (Chao et al., 2019)*	-	-	-	-	-	-	2.75	-
BridgeNet (Li et al., 2019)*	2.38	91.0	2.63	86.0	-	-	-	-
AVDL (Wen et al., 2020)*	2.37	-	2.53	-	-	-	**1.94**	-
OL (Lim et al., 2020)*	2.41	91.7	2.75	88.2	2.68	88.8	2.22	93.3
DRC-ORID (Lee & Kim, 2021)*	2.26	**93.8**	**2.51**	89.7	2.58	89.5	2.16	93.5
MWR-G (Shin et al., 2022)*	2.24	93.5	2.55	**90.1**	2.61	89.5	2.16	93.0
Proposed GOL	**2.17**	**93.8**	2.60	89.3	**2.51**	**90.0**	2.09	**94.2**

Aesthetic Score Estimation

	Nature		Animal		Urban		People		Overall	
Algorithm	Acc.	MAE	Acc.	MAE	Acc.	MAE	Acc.	MAE	Acc.	MAE
CNNm (Liu et al., 2018)	71.0	0.31	68.0	0.34	68.2	0.36	71.6	0.32	69.5	0.33
CNNPOR (Liu et al., 2018)	71.9	0.29	69.3	0.32	69.1	0.33	69.9	0.32	70.1	0.32
SORD (Diaz & Marathe, 2019)	73.6	**0.27**	70.3	0.31	73.3	0.28	70.6	0.31	72.0	0.29
POE (Li et al., 2021)	73.6	**0.27**	71.1	0.30	72.8	0.28	**72.2**	**0.29**	72.4	0.29
Proposed GOL	**73.8**	**0.27**	**72.4**	**0.28**	**74.2**	**0.26**	69.6	0.31	**72.7**	**0.28**

Order Learning

- New concept
- Applicable to most ranking, assessment, diagnosis problems
  - Cancer stage classification
  - Smart farm - fruit quality assessment
  - Recommendation systems

Smart Factory


Medical Diagnosis


Smart Farm


Autonomous driving

Q & A

- 감사합니다.