Supplementary Materials

Make Privacy Renewable! Generating Privacy-Preserving Faces Supporting Cancelable Biometric Recognition

A PROOF OF DISTANCE-PRESERVING ORTHOGONAL TRANSFORMATIONS

A.1 Equidistance

Let A be an orthogonal matrix, and $\mathbf{p}_1$ and $\mathbf{p}_2$ be any two points in space represented by their position vectors. The Euclidean distance between these two points is given by:

$$d(\mathbf{p}_1, \mathbf{p}_2) = \|\mathbf{p}_2 - \mathbf{p}_1\|$$

Under the transformation by the orthogonal matrix A, the new positions of these points are $A\mathbf{p}_1$ and $A\mathbf{p}_2$. The distance between these transformed points is:

$$d(A\mathbf{p}_1, A\mathbf{p}_2) = \|A\mathbf{p}_2 - A\mathbf{p}_1\|$$

Since the column vectors of an orthogonal matrix maintain their lengths, we have $\|A\mathbf{v}\| = \|\mathbf{v}\|$ for any vector $\mathbf{v}$. Therefore, $\|A\mathbf{p}_2 - A\mathbf{p}_1\| = \|\mathbf{p}_2 - \mathbf{p}_1\|$, indicating that the distance between the transformed points $A\mathbf{p}_1$ and $A\mathbf{p}_2$ is equal to the distance between the original points $\mathbf{p}_1$ and $\mathbf{p}_2$. Thus, orthogonal matrix transformations preserve the distances between points, demonstrating equidistance.

A.2 Equiangularity

Let A be an orthogonal matrix, and $\mathbf{v}_1$ and $\mathbf{v}_2$ be any two vectors. The dot product of these two vectors is:

$$\mathbf{v}_1 \cdot \mathbf{v}_2 = \mathbf{v}_1^T \mathbf{v}_2$$

If $\mathbf{v}_1$ and $\mathbf{v}_2$ are unit vectors (i.e., $\|\mathbf{v}_1\| = \|\mathbf{v}_2\| = 1$), their angle θ can be expressed as the arccosine of their dot product:

$$\cos(\theta) = \frac{\mathbf{v}_1 \cdot \mathbf{v}_2}{\|\mathbf{v}_1\| \cdot \|\mathbf{v}_2\|}$$

Since the column vectors of an orthogonal matrix maintain their lengths, $\|A\mathbf{v}_1\| = \|\mathbf{v}_1\|$ and $\|A\mathbf{v}_2\| = \|\mathbf{v}_2\|$. Thus, $A\mathbf{v}_1$ and $A\mathbf{v}_2$ are also unit vectors. Therefore, their dot product's cosine, $\cos(\theta')$, is equal to $\cos(\theta)$, which means that the angle θ between $\mathbf{v}_1$ and $\mathbf{v}_2$ is preserved under the transformation by the orthogonal matrix A. Hence, orthogonal matrix transformations maintain the angles between vectors, demonstrating isometry.

Table 1: Recognition performance among different orthogonal matrices on VGGFace2.

	Q_1		Q_2		Q_3	
	EER↓	AUC↑	EER↓	AUC↑	EER↓	AUC↑
Q_1	**0.101**	**0.951**	0.493	0.494	0.499	0.486
Q_2	0.493	0.493	**0.097**	**0.952**	0.512	0.494
Q_3	0.499	0.486	0.512	0.494	**0.082**	**0.962**

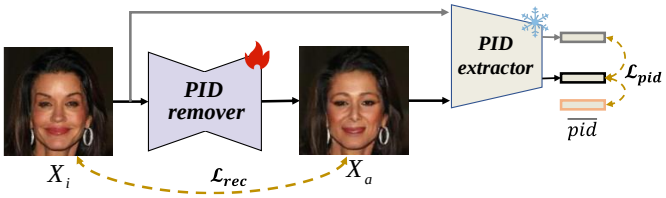

Figure 1: Training of the auxiliary physical identity remover.

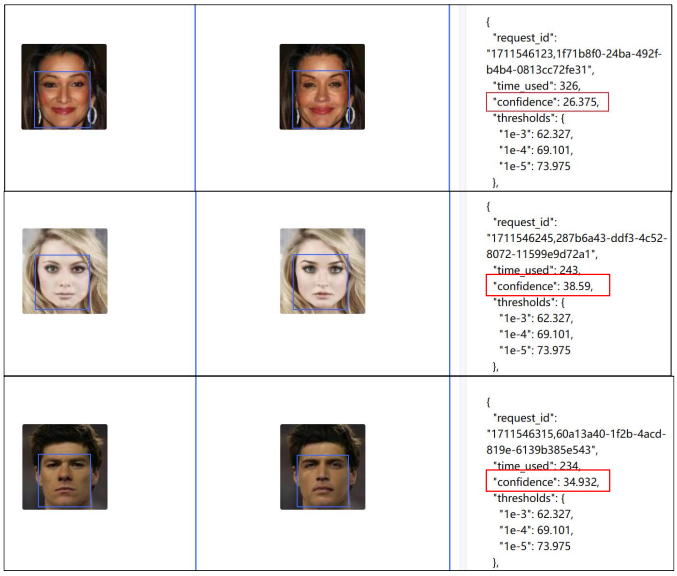

Figure 2: Physical identity protection test on Face++.

B MORE FIGURE PRESENTATIONS

In addition, we show more figures from Fig. 1 to Fig. 3, which help readers understand the relevant content more quickly.

C MORE TABLE RESULTS

Due to page limitations in the main manuscript, we add additional experimental results for reference, including more results on VGGFace2 in Table 1, Table 2, Table 4, and the TAR values on CelebA

Table 2: Ablation Experiment on VGGFace2.

	EER↓	AUC↑	PSR↑	FID↓	SSIM↑
Full strategy	0.101	0.951	0.982	13.655	0.839
W/o DH	0.150	0.919	0.998	18.021	0.827
W/o FT	0.085	0.961	0.212	9.987	0.911

Table 3: TARs with different FARs of the four face recognition models on CelebA and VGGFace2.

	InceptionResNet		IResNet50		SEResNet50		IResNet100	
	FAR=0.01	FAR=0.1	FAR=0.01	FAR=0.1	FAR=0.01	FAR=0.1	FAR=0.01	FAR=0.1
PRO-Face(CelebA)	0.862	0.969	0.742	0.924	0.631	0.875	0.614	0.876
CanFG(CelebA)	**0.883**	0.969	**0.897**	**0.954**	**0.905**	**0.972**	**0.941**	**0.974**
PRO-Face(VGGFace2)	0.512	0.889	0.445	0.798	0.342	0.714	0.437	0.777
CanFG(VGGFace2)	**0.674**	**0.906**	**0.577**	**0.876**	**0.731**	**0.902**	**0.747**	**0.866**

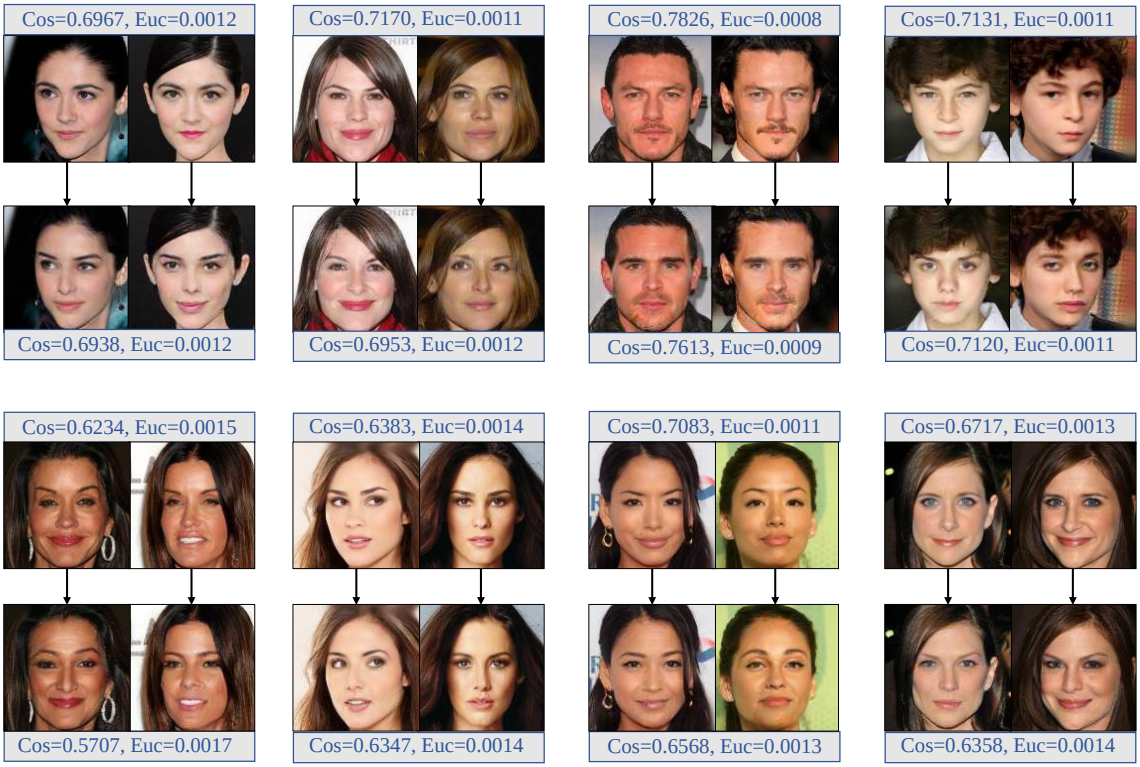

Figure 3: Visual results of distance preserving test.

Table 5: The Parameter Number and Running Time

	IVFG	PRO-Face	CanFG
Parameter Number (M)	224	184	**43**
Running time (s)	2.63797	0.01263	**0.00055**

Table 4: Robustness test on VGGFace2.

	EER↓	AUC↑
No process	0.101	0.951
Gaussian noise	0.099(-0.002)	0.951(-0.000)
JPEG compression	0.147(+0.062)	0.922(-0.029)
Median filtering	0.178(+0.077)	0.900(-0.051)

and VGGFace2 in Table 3. Table 5 compares the parameter number and running time.