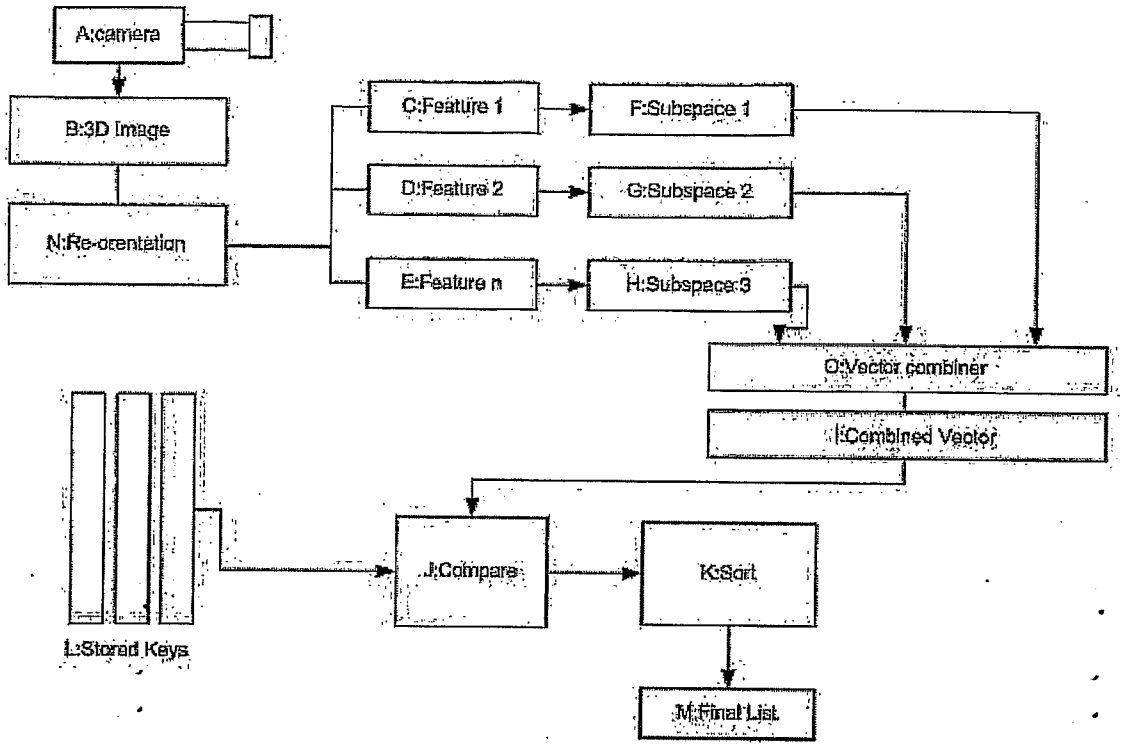


Fig 1: Identification System

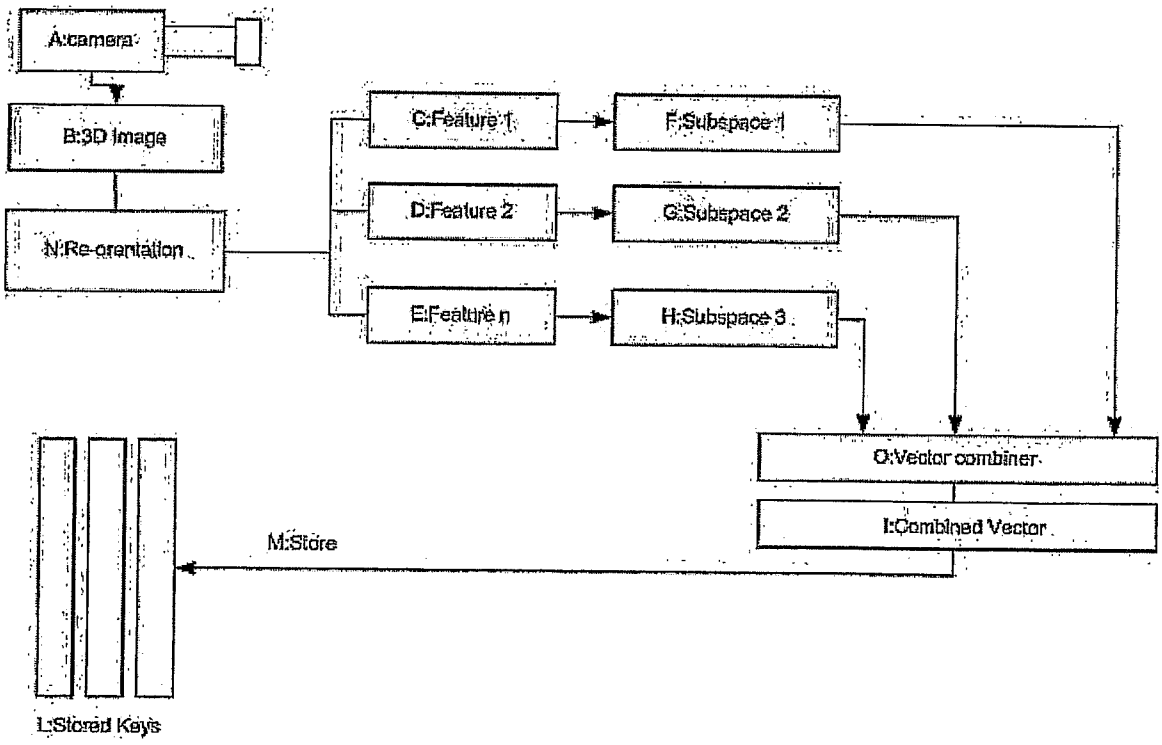


Fig 2 : Training system

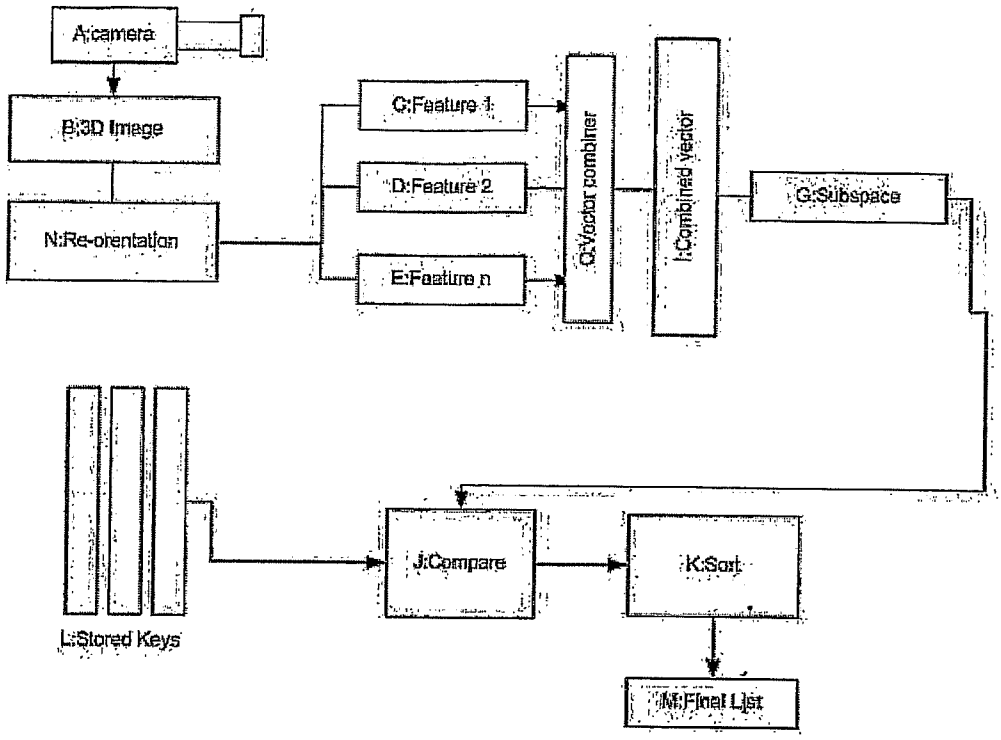


Fig3 : Identification system using Combiner before the subspace method

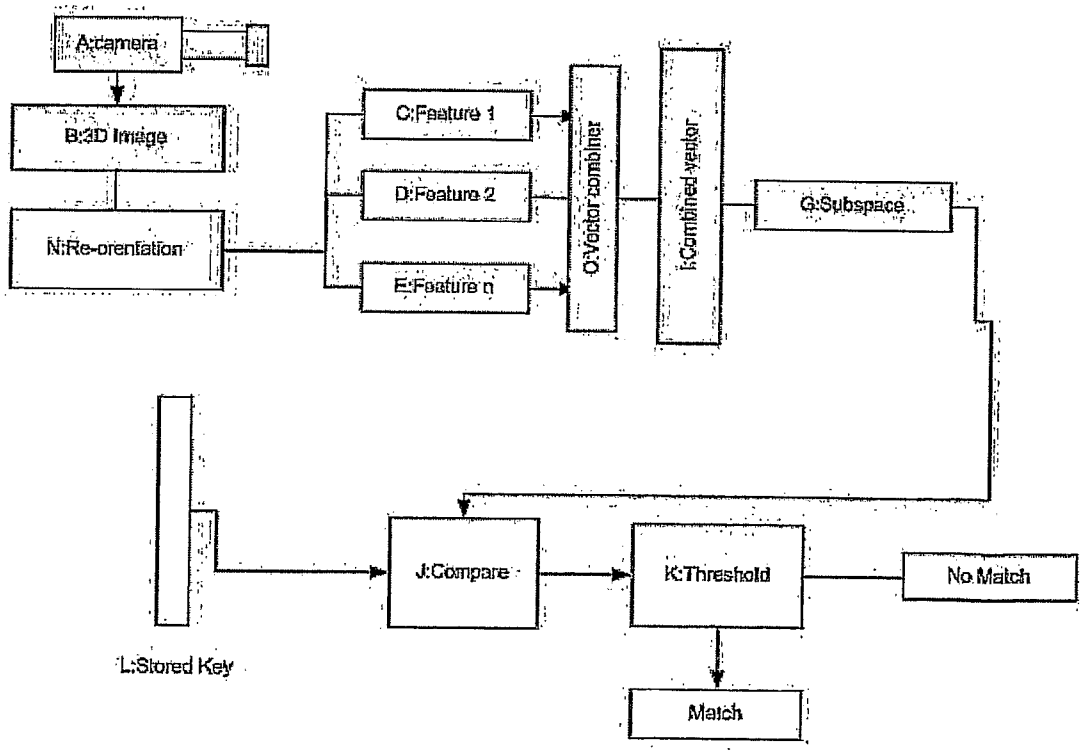


Fig 4 : Verification system using Combiner before the subspace method

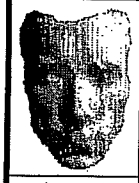
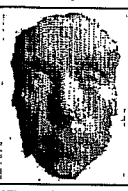
01	02	03	04	05
Front neutral expression	Facing 45° up	Facing 45° down	Happy expression	Eyes closed
06	07	08	09	10
				
Angry expression	2nd Neutral	Eyebrows raised	3rd Neutral	Farther from camera

Fig. 5. Example face models taken from a 3D face database

Fig. 6. Orientation of a raw 3D face model (*left*) to a frontal pose (*middle*) and facial surface depth map (*right*)

Fig. 7. Average depth map (*left most*) and first eight eigensurfaces

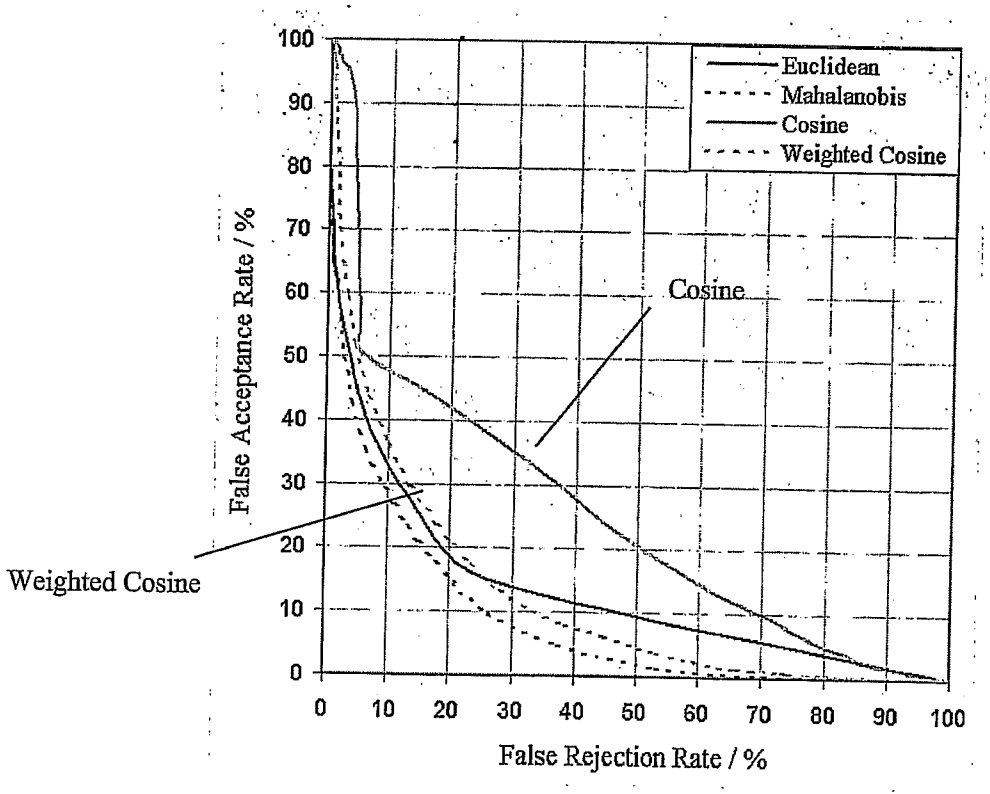


Fig. 8. Results from previous 3D face recognition systems using facial surface depth maps and a range of distance metrics

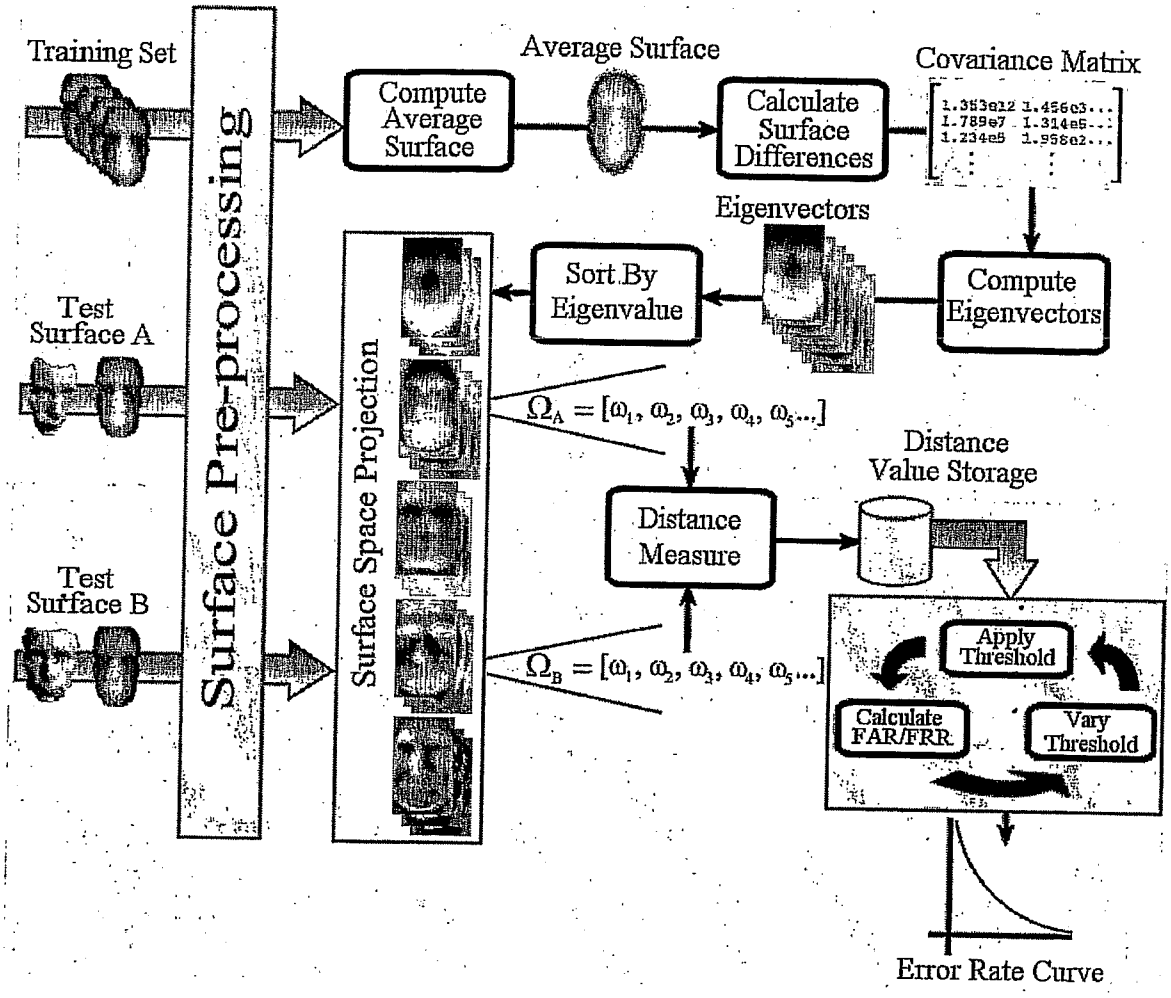


Fig. 9. Experimental framework for evaluating verification systems

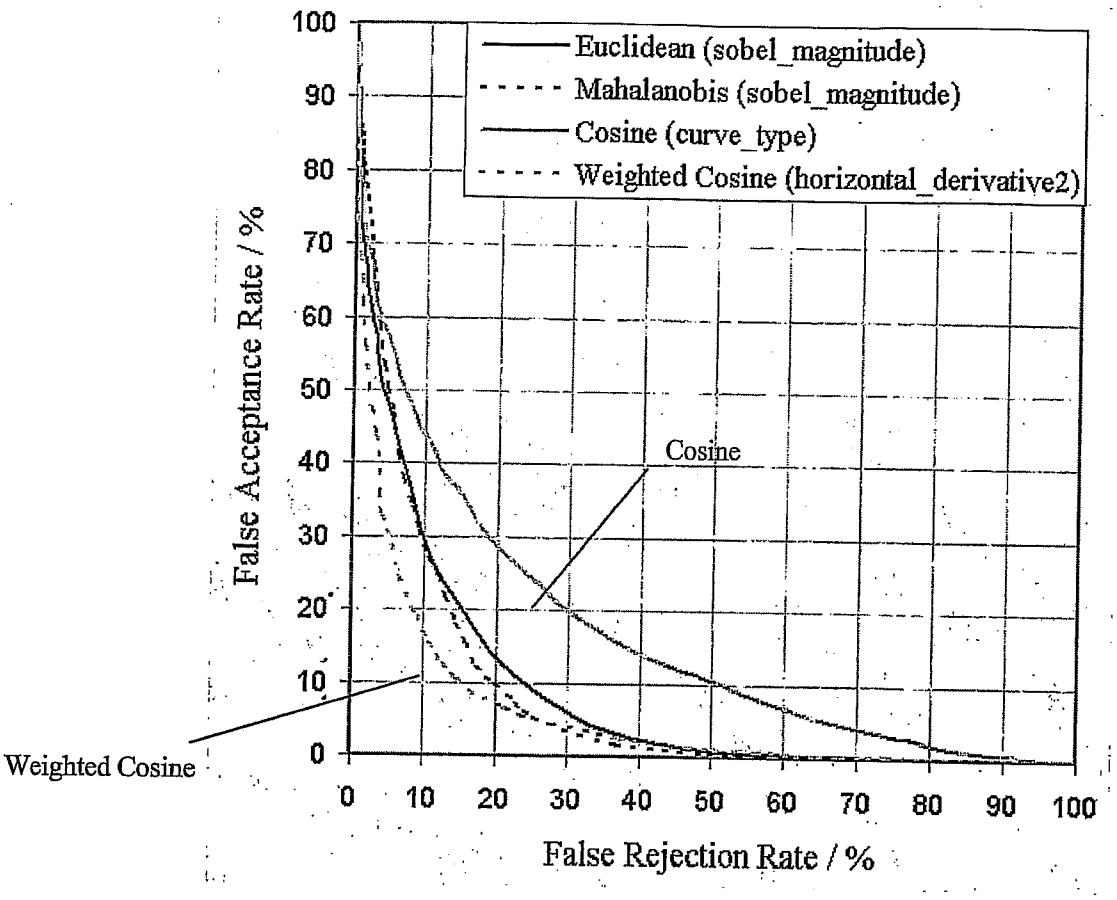


Fig. 10. Error rates of 3D face recognition systems using optimum surface representations and distance metrics.

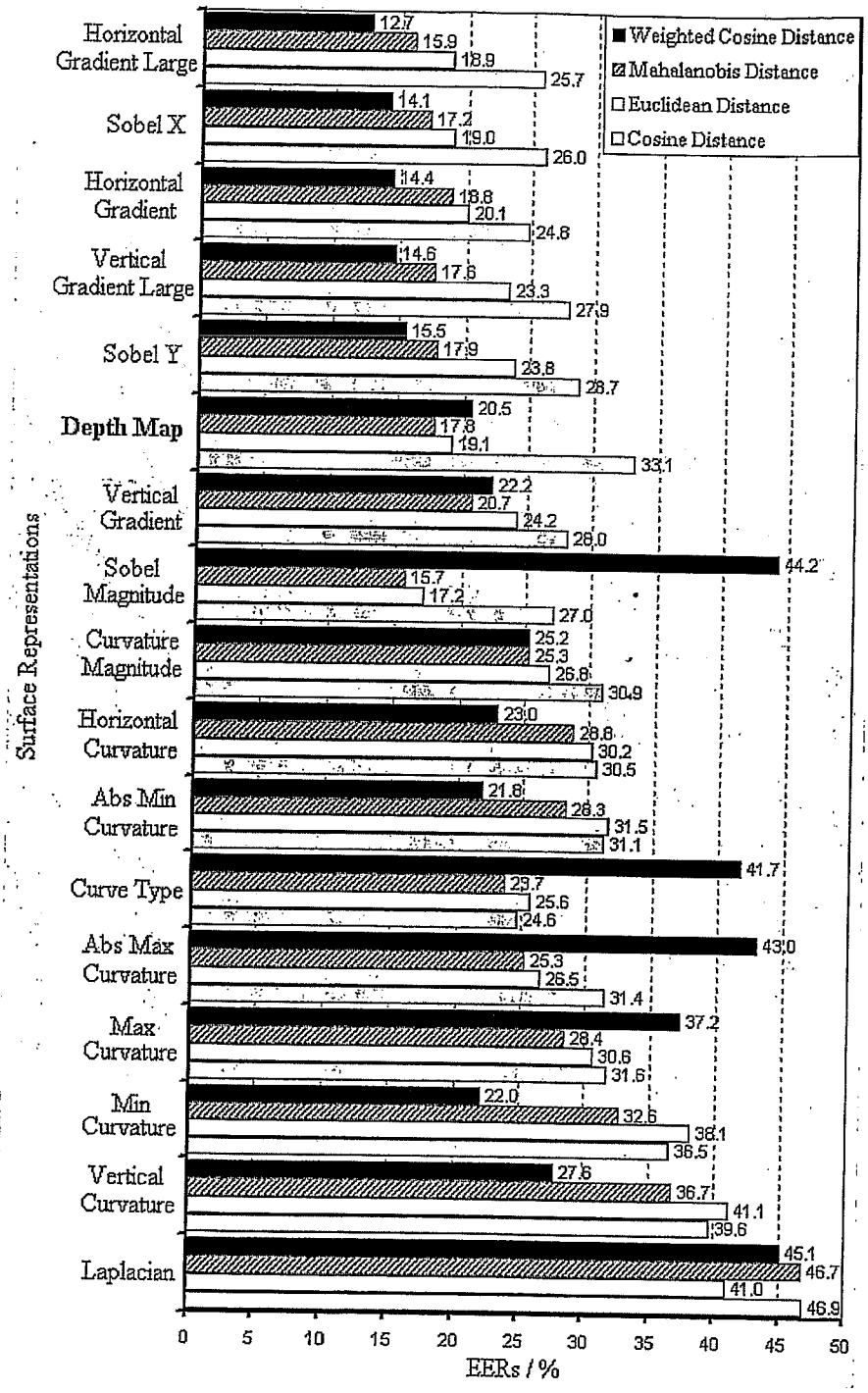


Fig. 11. Equal error rates of 3D face recognition systems using a variety of surface representations and distance metrics

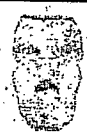
Horizontal Gradient	Vertical Gradient	Horizontal Gradient Large	Vertical Gradient Large
-1 1	-1 1	-1 0 0 0 1	-1 0 0 0 1
Applies the 2x1 kernel to compute the horizontal derivative	Applies the 1x2 kernel to compute the vertical derivative	Horizontal gradient calculated over a greater horizontal distance	Vertical gradient calculated over a greater vertical distance
Laplacian	Sobel X	Sobel Y	Sobel Magnitude
0 1 0 1 -4 1 0 1 0	-1 0 1 -2 0 2 -1 0 1	1 2 1 0 0 0 -1 -2 -1	
An isotropic measure of the second spatial derivative	Application of the sobel derivative filter in the horizontal direction	Application of the sobel derivative filter in the vertical direction	The magnitude of the X and Y sobel derivatives
Horizontal Curvature	Vertical Curvature	Curvature Magnitude	Curve Type
			
Applies the sobel X kernel twice to calculate the second horizontal derivative	Applies the sobel Y kernel twice to calculate the second vertical derivative	The magnitude of the vertical and horizontal curvatures	Segmentation of the surface into 8 discreet curvature types
Min Curvature	Max Curvature	Abs Min Curvature	Abs Max Curvature
The minimum of the horizontal and vertical curvature values	The maximum of the horizontal and vertical curvature values	The minimum of the absolute horizontal and vertical curvatures	The maximum of the absolute horizontal and vertical curvatures

Figure 12. Brief descriptions of surface representations with the convolution kernels used.

Horizontal Derivative	Vertical Derivative	Horizontal Derivative 2	Vertical Derivative 2
-1 1	-1 1	-1 0 0 0 1	-1 0 0 0 1
Applies the 2x1 kernel to compute the horizontal derivative	Applies the 1x2 kernel to compute the vertical derivative	Horizontal gradient over a greater horizontal distance	Vertical gradient over a greater vertical distance
Laplacian	Sobel X	Sobel Y	Sobel Magnitude
0 1 0 1 -4 1 0 1 0	-1 0 1 -2 0 2 -1 0 1	1 2 1 0 0 0 -1 -2 -1	
An isotropic measure of the second spatial derivative	Application of the horizontal sobel derivative filter	Application of the vertical sobel derivative filter	The magnitude of Sobel X and Y combined.
Horizontal Curvature	Vertical Curvature	Curvature Magnitude	Curve Type
Applies sobel X twice to calculate the second horizontal derivative	Applies sobel Y twice to calculate the second vertical derivative	The magnitude of the vertical and horizontal curvatures	Segmentation of the surface into 8 discreet curvature types
Min Curvature	Max Curvature	Abs Min Curvature	Abs Max Curvature
The minimum of the horizontal and vertical curvature values	The maximum of the horizontal and vertical curvature values	The minimum of the absolute horizontal and vertical curvatures	The maximum of the absolute horizontal and vertical curvatures

Fig. 13

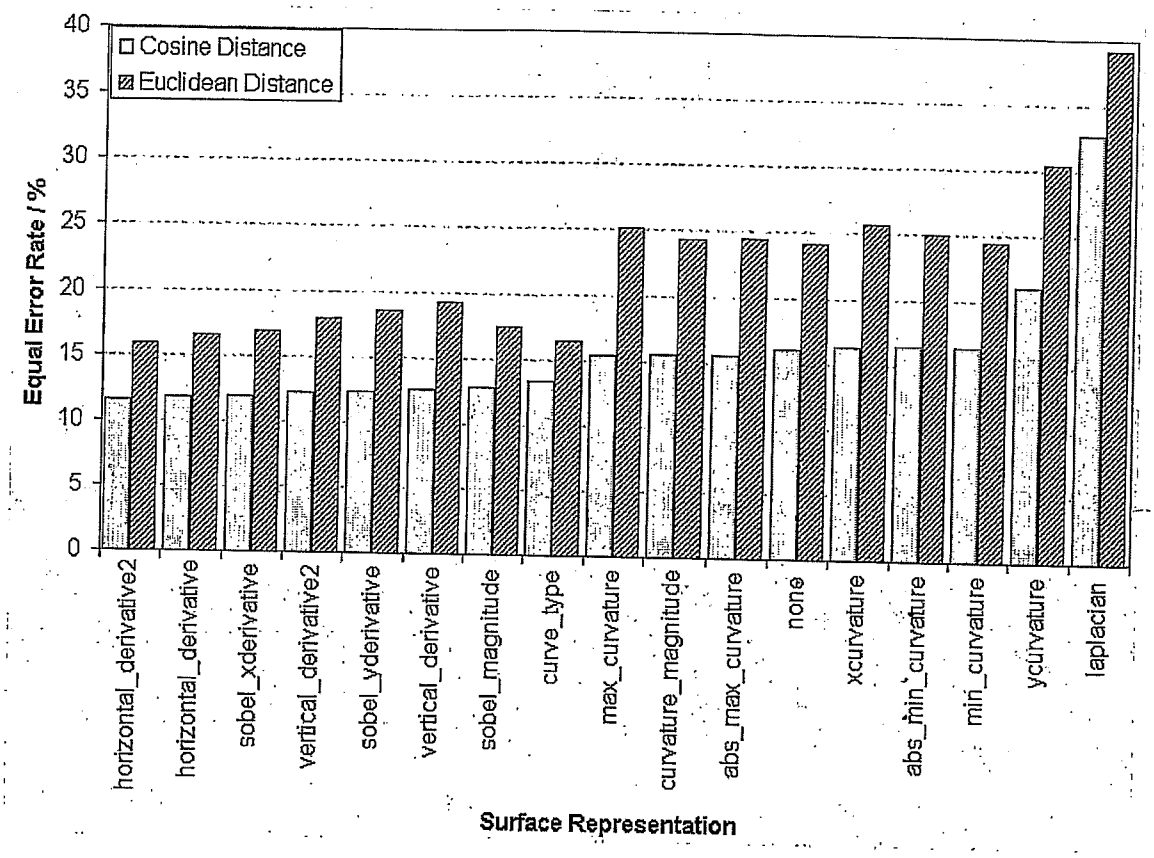

Cosine Distance
Euclidean Distance
Equal Error Rate / %
40
35
30
25
20
15
10
5
0
horizontal_derivative2
horizontal_derivative
sobel_xderivative
vertical_derivative2
sobel_yderivative
vertical_derivative
sobel_magnitude
curve_type
max_curvature
curvature_magnitude
abs_max_curvature
none
xcurvature
abs_min_curvature
min_curvature
ycurvature
laplacian
Surface Representation

Fig. 14

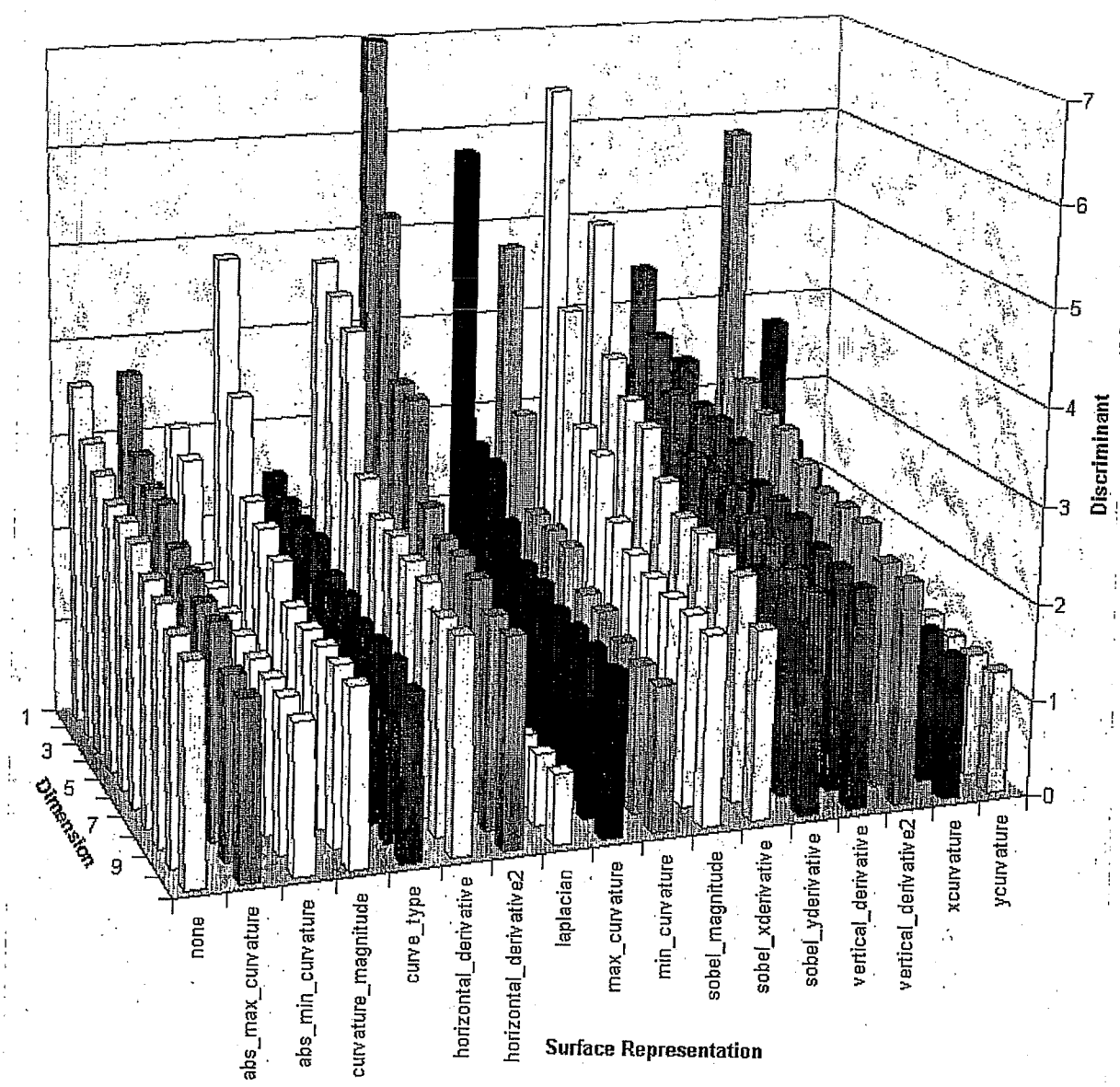

Discriminant
0
1
2
3
4
5
6
7
Dimension
1
3
5
7
9
none
abs_max_curvature
abs_min_curvature
curvature_magnitude
curve_type
horizontal_derivative
horizontal_derivative2
laplacian
max_curvature
min_curvature
sobel_magnitude
sobel_xderivative
sobel_yderivative
vertical_derivative
vertical_derivative2
xcurvature
ycurvature
Surface Representation

Fig. 15

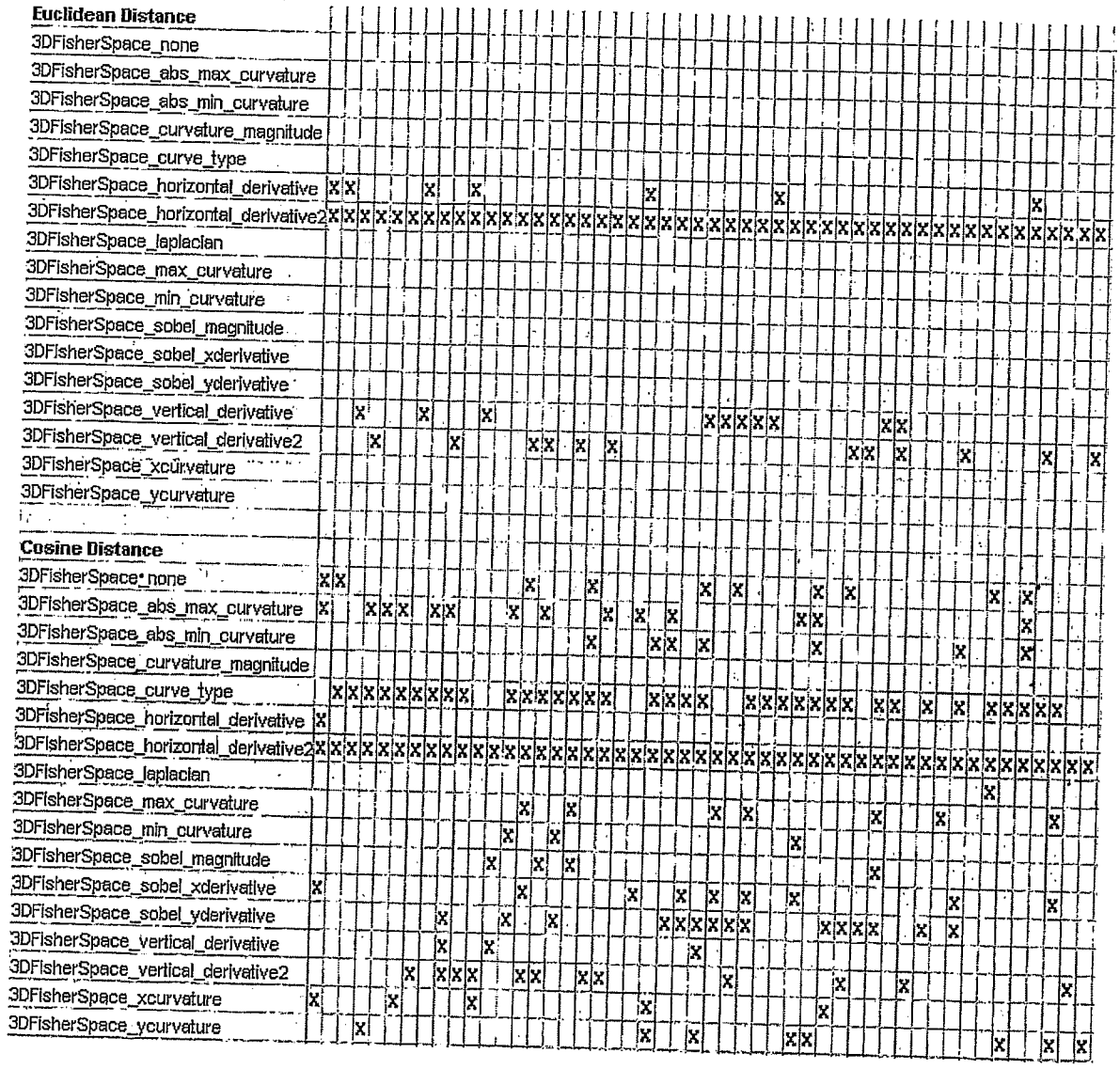

Euclidean Distance
3DFisherSpace_none
3DFisherSpace_abs_max_curvature
3DFisherSpace_abs_min_curvature
3DFisherSpace_curvature_magnitude
3DFisherSpace_curve_type
3DFisherSpace_horizontal_derivative
3DFisherSpace_horizontal_derivative2
3DFisherSpace_laplacian
3DFisherSpace_max_curvature
3DFisherSpace_min_curvature
3DFisherSpace_sobel_magnitude
3DFisherSpace_sobel_xderivative
3DFisherSpace_sobel_yderivative
3DFisherSpace_vertical_derivative
3DFisherSpace_vertical_derivative2
3DFisherSpace_xcurvature
3DFisherSpace_ycurvature
Cosine Distance
3DFisherSpace_none
3DFisherSpace_abs_max_curvature
3DFisherSpace_abs_min_curvature
3DFisherSpace_curvature_magnitude
3DFisherSpace_curve_type
3DFisherSpace_horizontal_derivative
3DFisherSpace_horizontal_derivative2
3DFisherSpace_laplacian
3DFisherSpace_max_curvature
3DFisherSpace_min_curvature
3DFisherSpace_sobel_magnitude
3DFisherSpace_sobel_xderivative
3DFisherSpace_sobel_yderivative
3DFisherSpace_vertical_derivative
3DFisherSpace_vertical_derivative2
3DFisherSpace_xcurvature
3DFisherSpace_ycurvature

Fig. 16

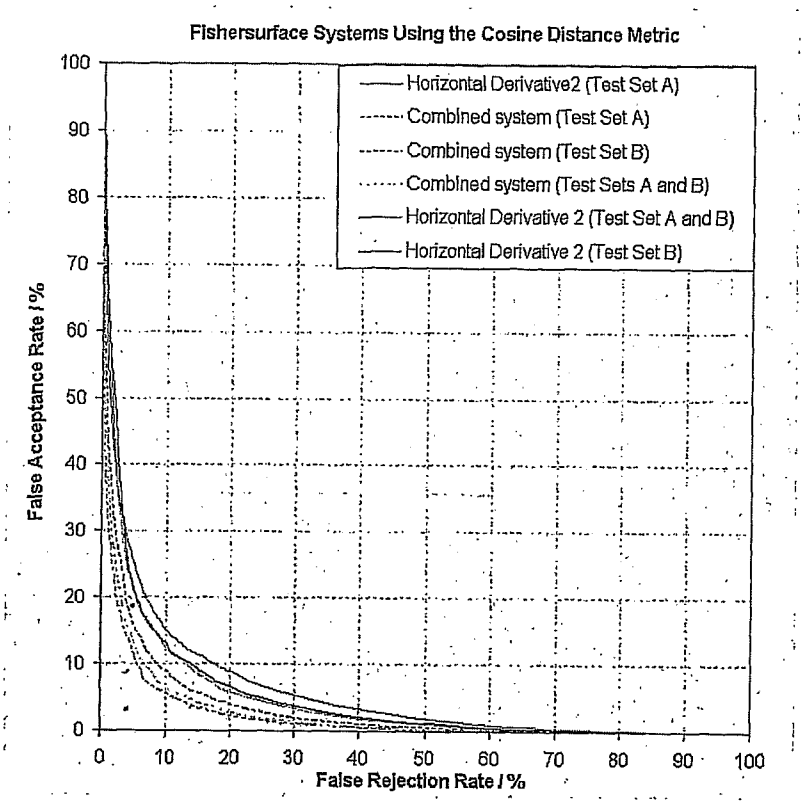

Fishersurface Systems Using the Cosine Distance Metric
Horizontal Derivative2 (Test Set A)
Combined system (Test Set A)
Combined system (Test Set B)
Combined system (Test Sets A and B)
Horizontal Derivative 2 (Test Set A and B)
Horizontal Derivative 2 (Test Set B)
False Acceptance Rate / %
False Rejection Rate / %
0
10
20
30
40
50
60
70
80
90
100

Fig. 17

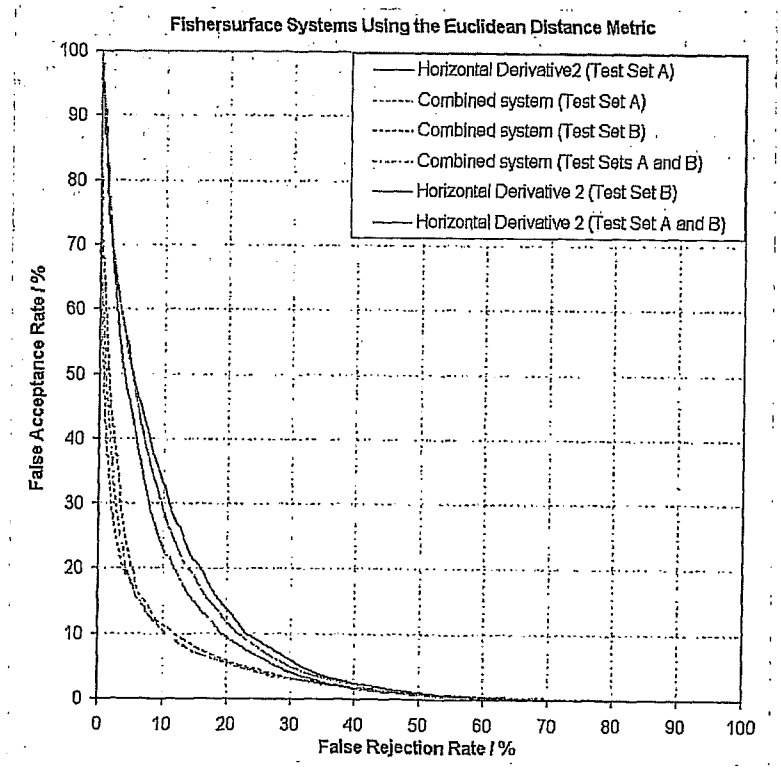

Fishersurface Systems Using the Euclidean Distance Metric
Horizontal Derivative2 (Test Set A)
Combined system (Test Set A)
Combined system (Test Set B)
Combined system (Test Sets A and B)
Horizontal Derivative 2 (Test Set B)
Horizontal Derivative 2 (Test Set A and B)
False Acceptance Rate / %
False Rejection Rate / %
0
10
20
30
40
50
60
70
80
90
100

Fig. 18