

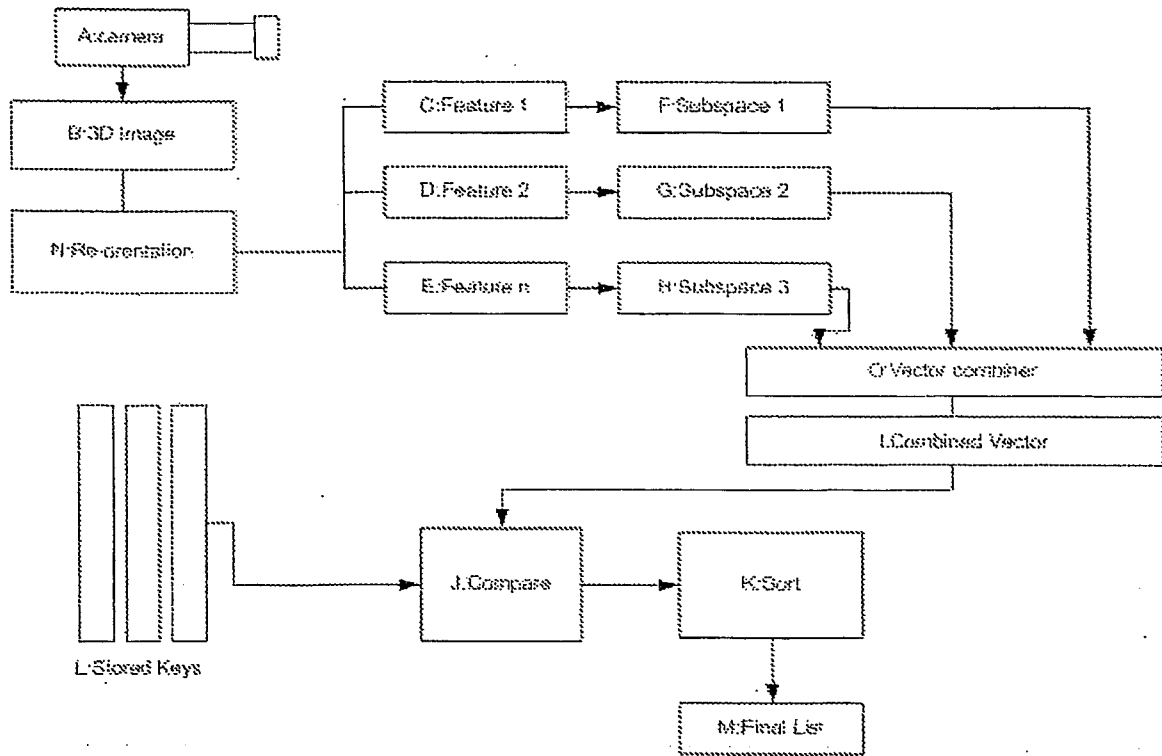


Fig 1: Identification System

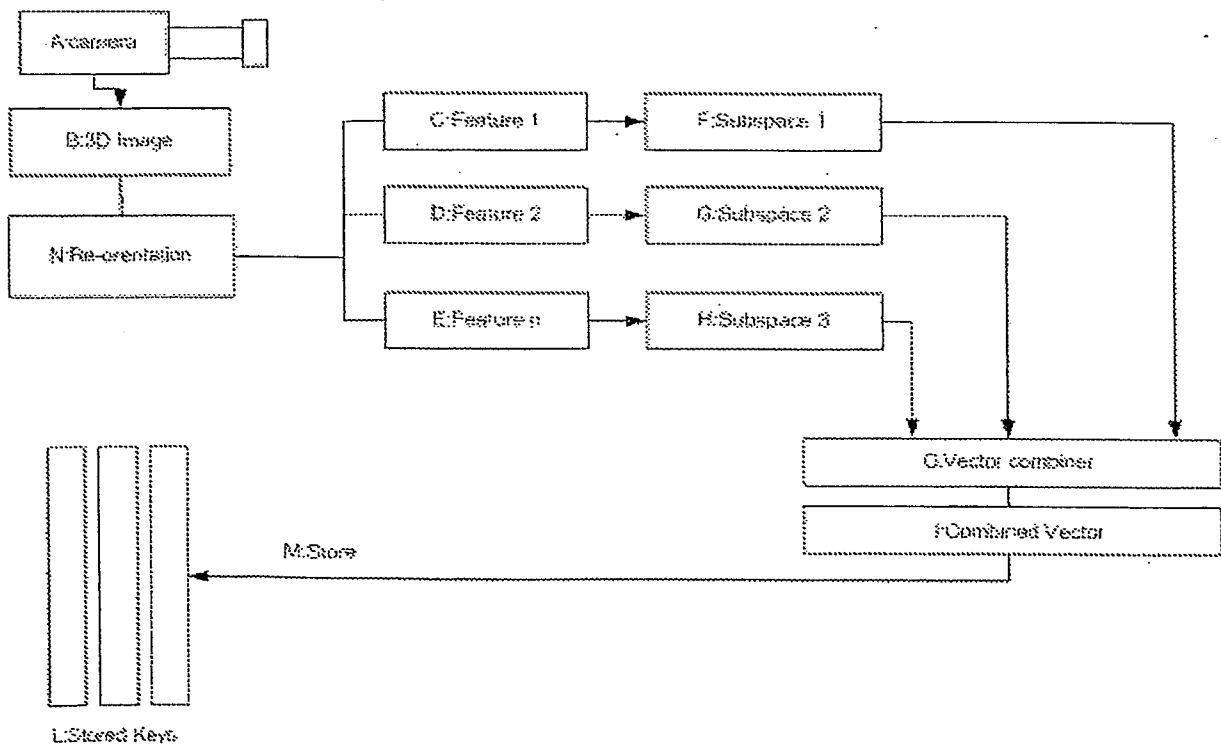


Fig 2: Training system

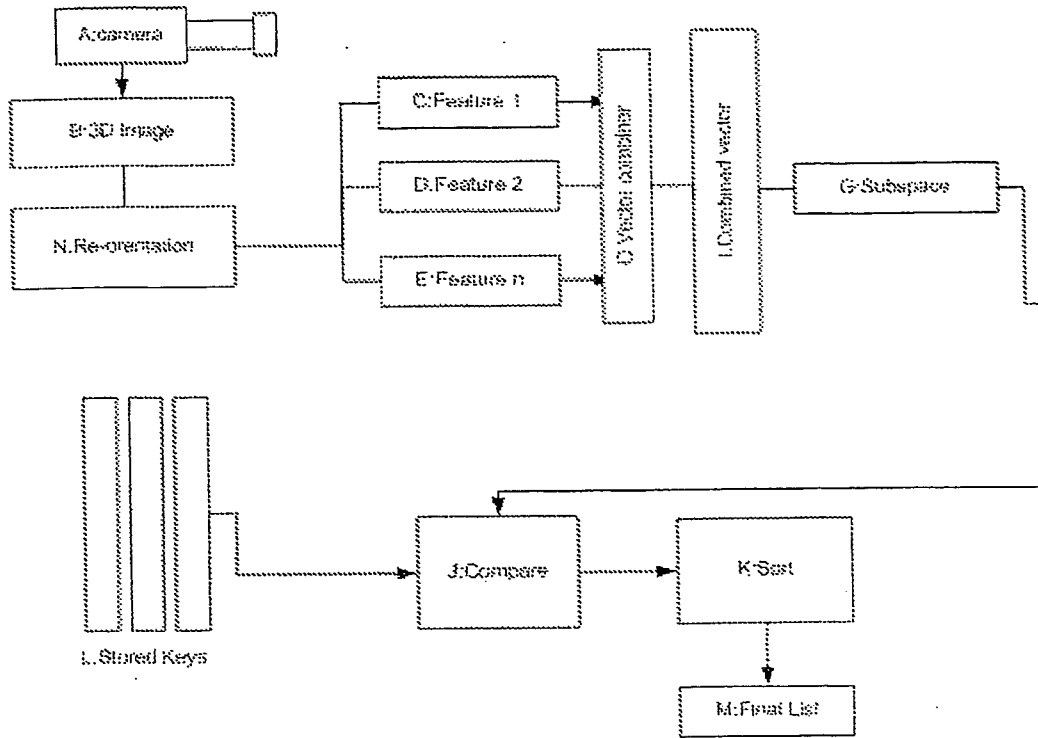


Fig3 : Identification system using Combiner before the subspace method

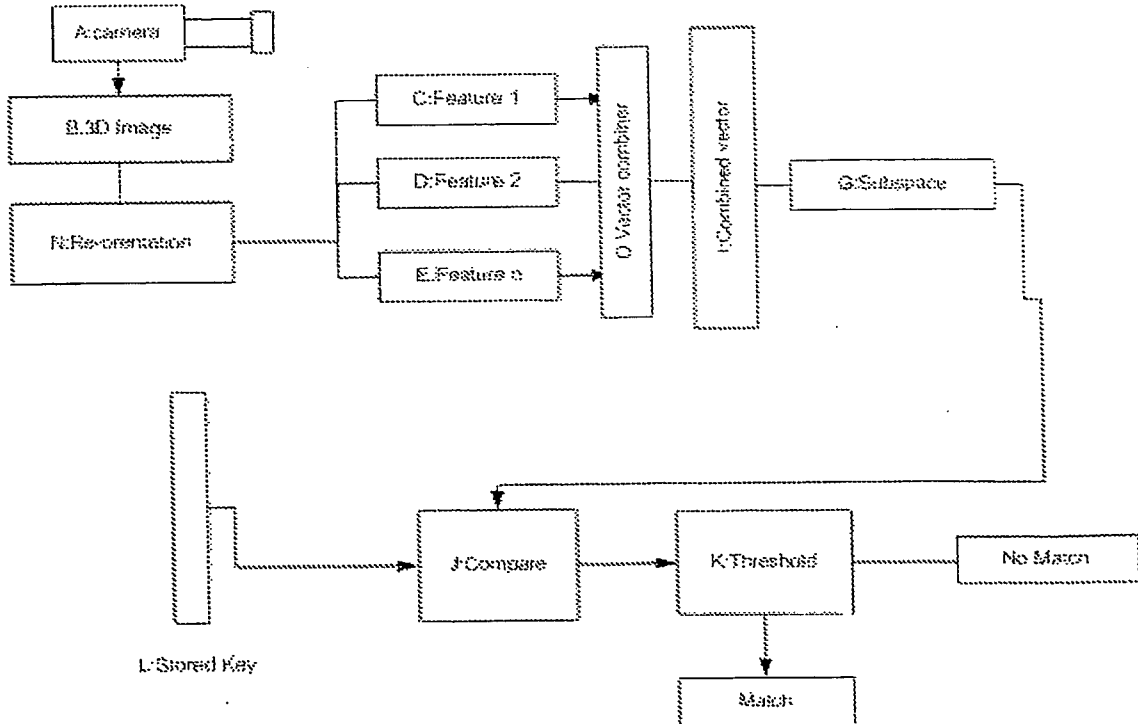


Fig 4 : Verification system using Combiner before the subspace method

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	2 nd Neutral	Eyebrows raised	3 rd 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

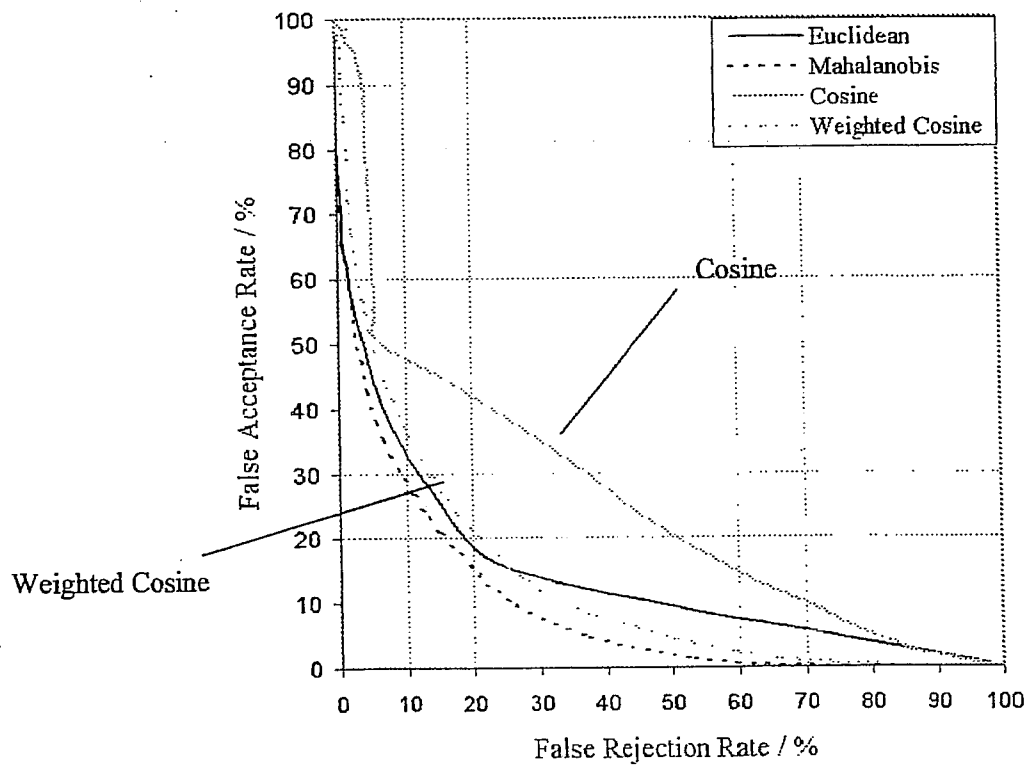


Fig. 8. Results from previous 3D face recognition systems using facial surface depth maps and a range of distance metrics

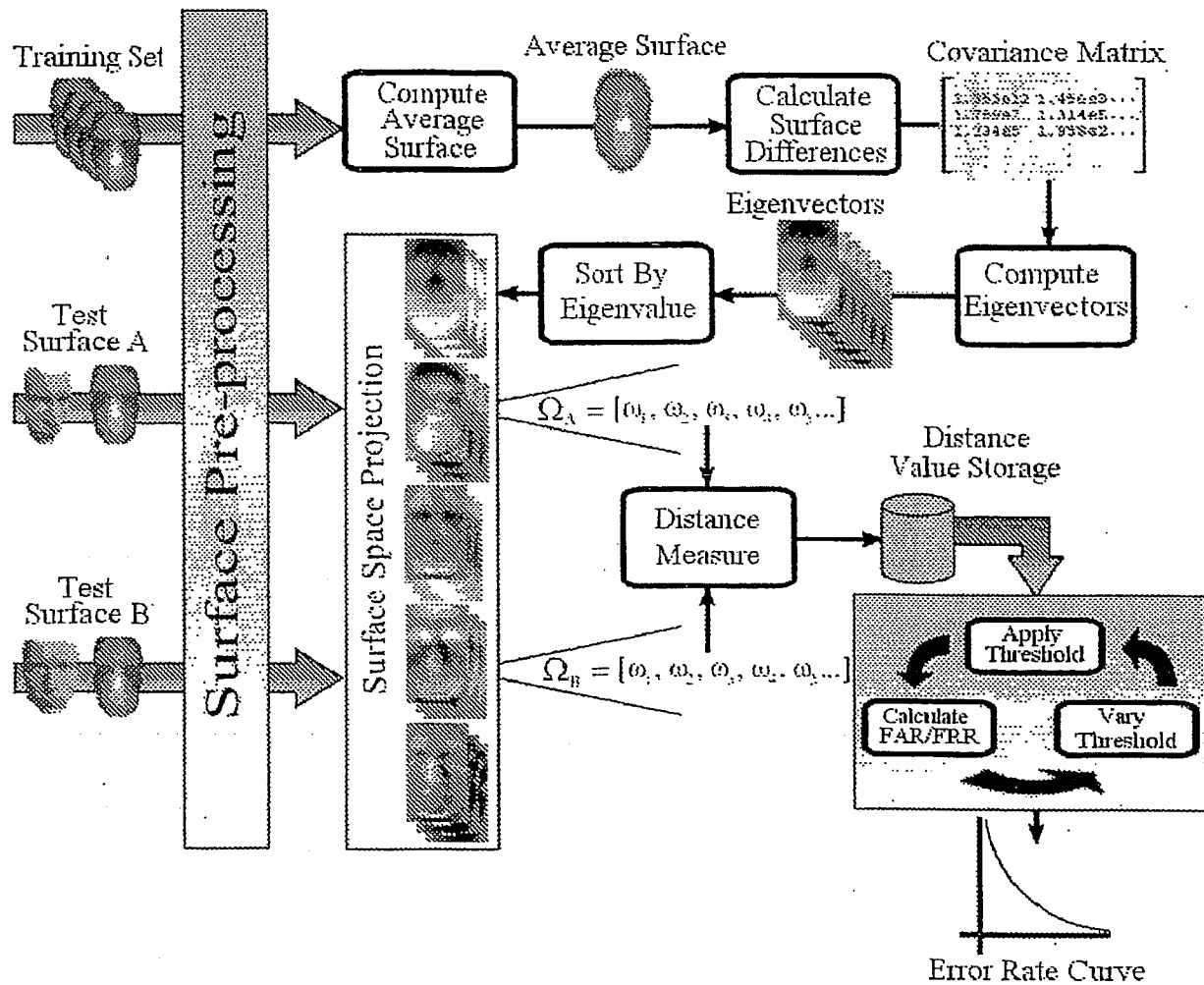


Fig. 9. Experimental framework for evaluating verification systems

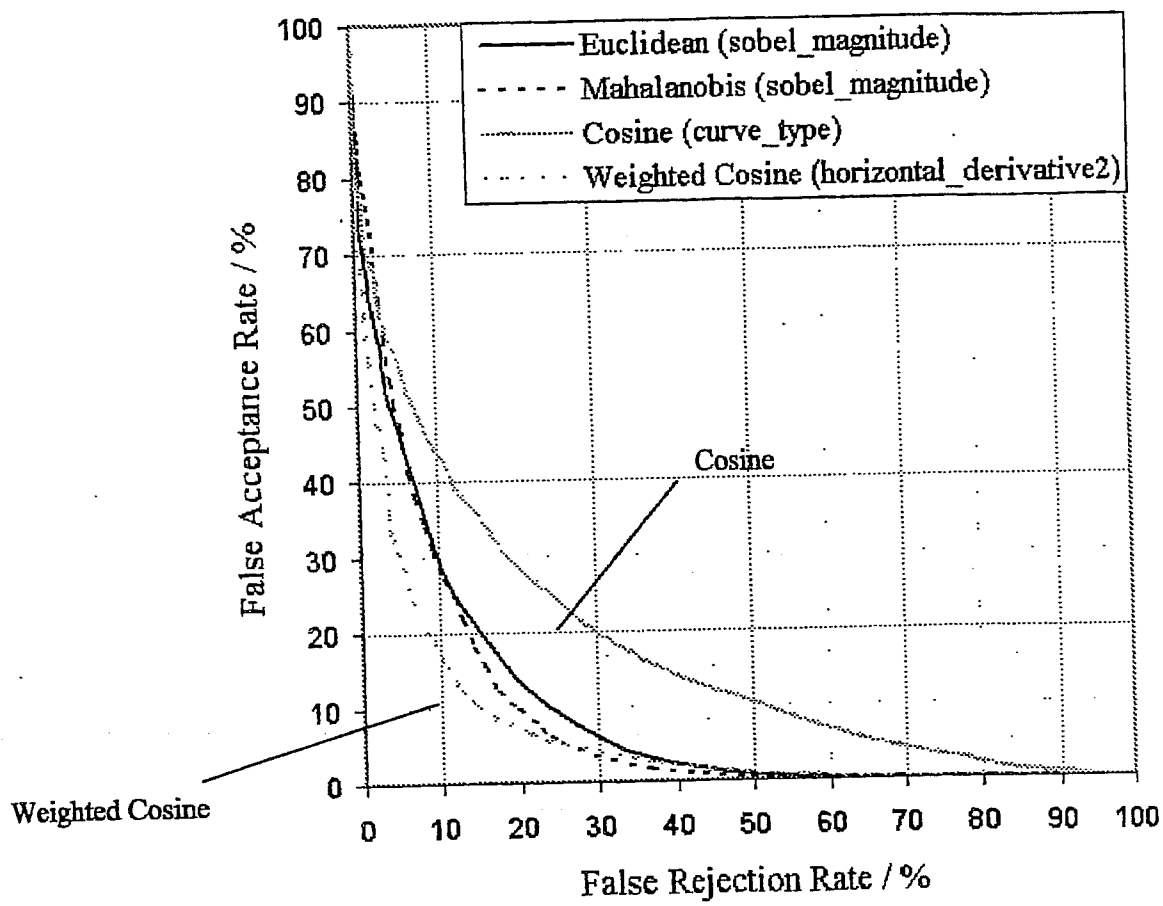


Fig. 10. Error rates of 3D face recognition systems using optimum surface representations and distance metrics.

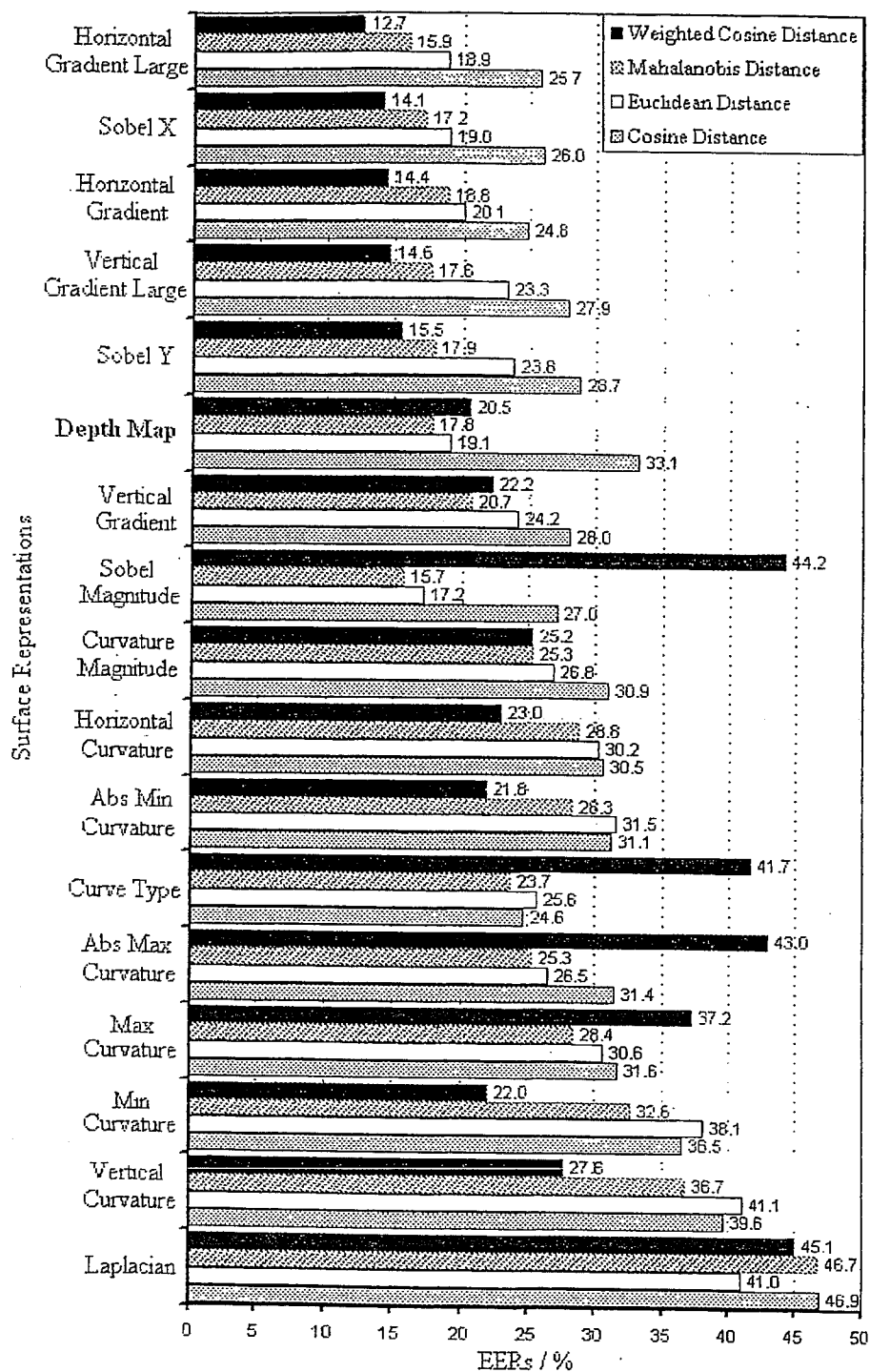


Fig. 11. Equal error rates of 3D face recognition systems using a variety of surface representations and distance metrics

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 discrete 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 discrete 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

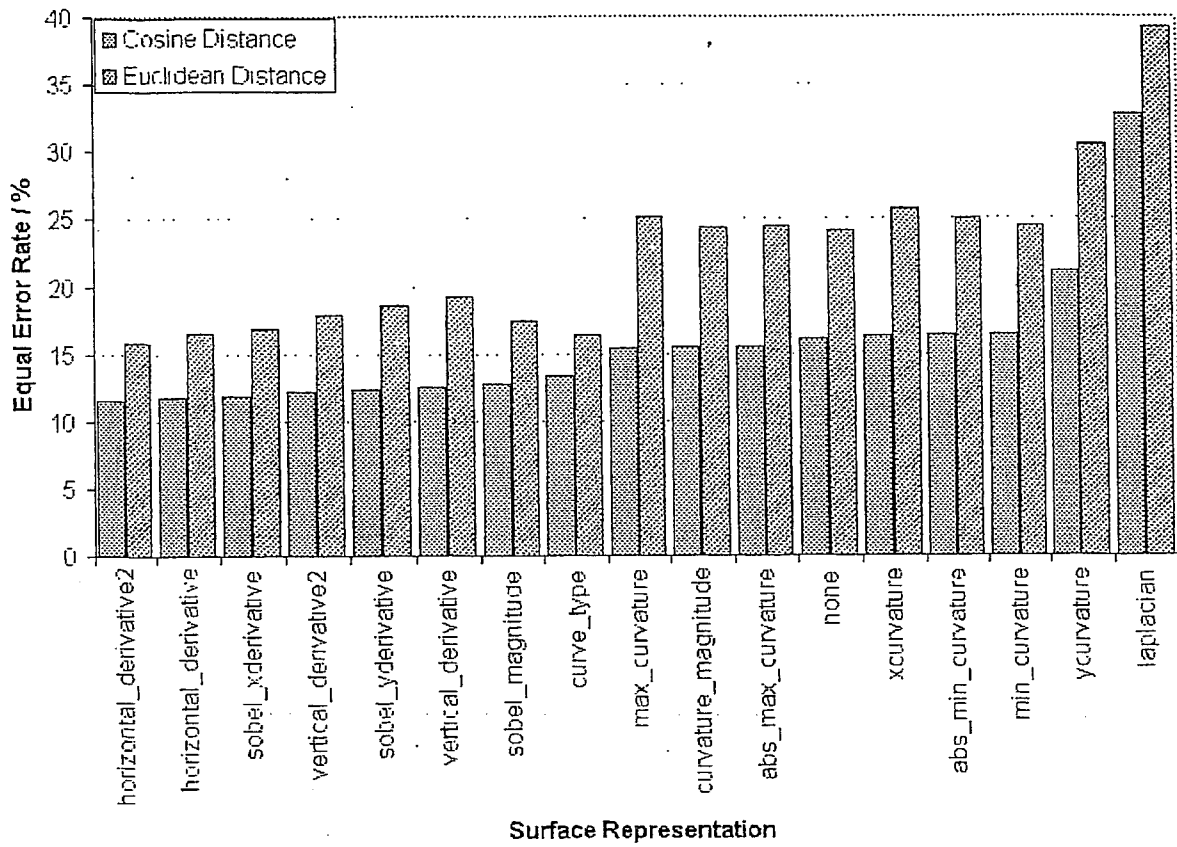


Fig. 14

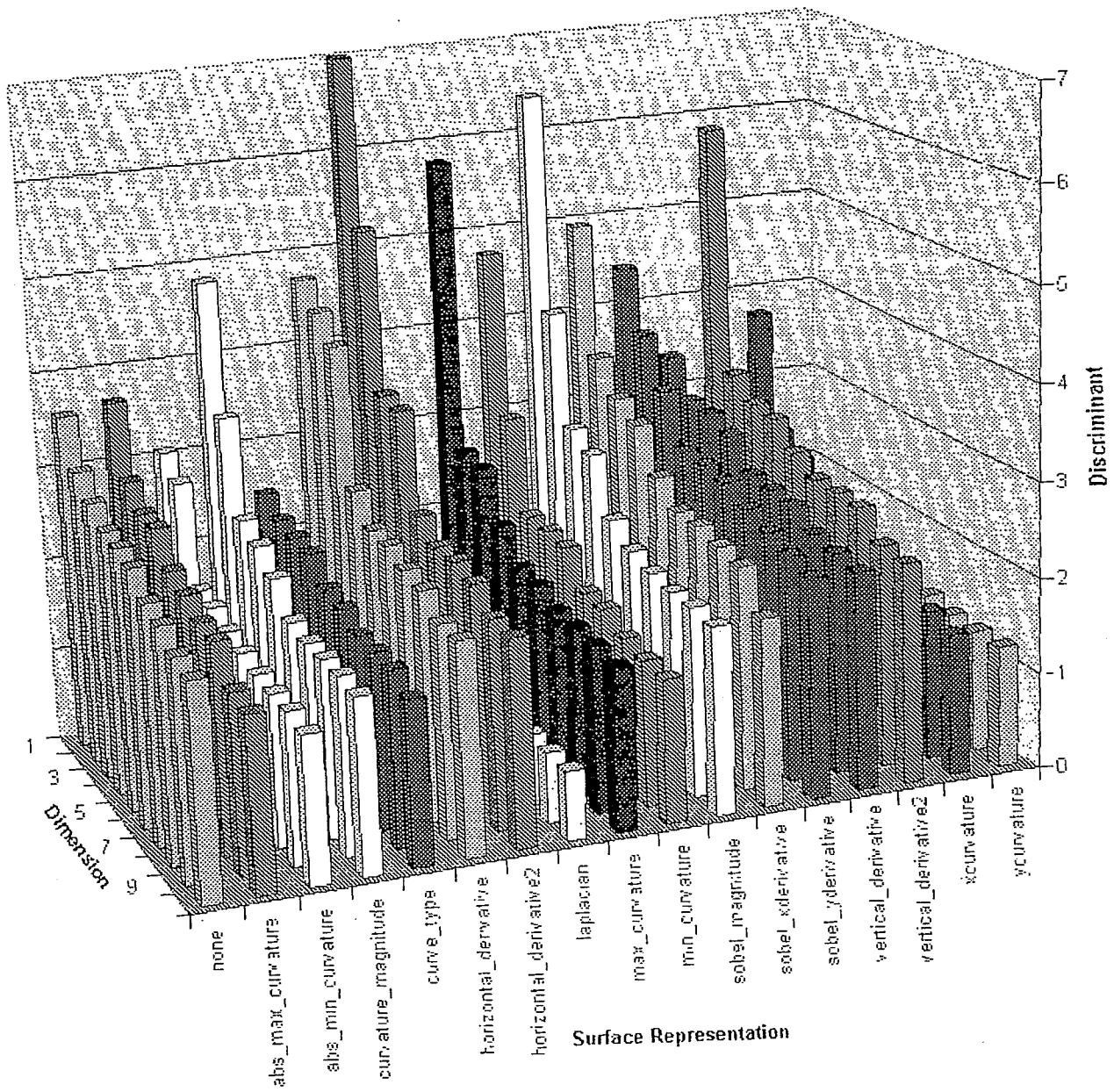
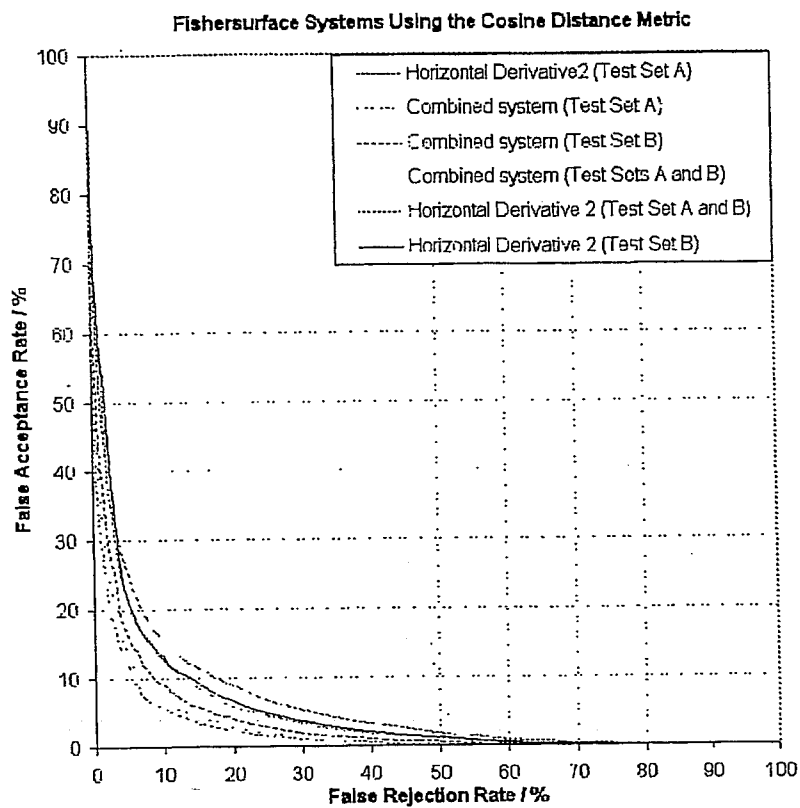
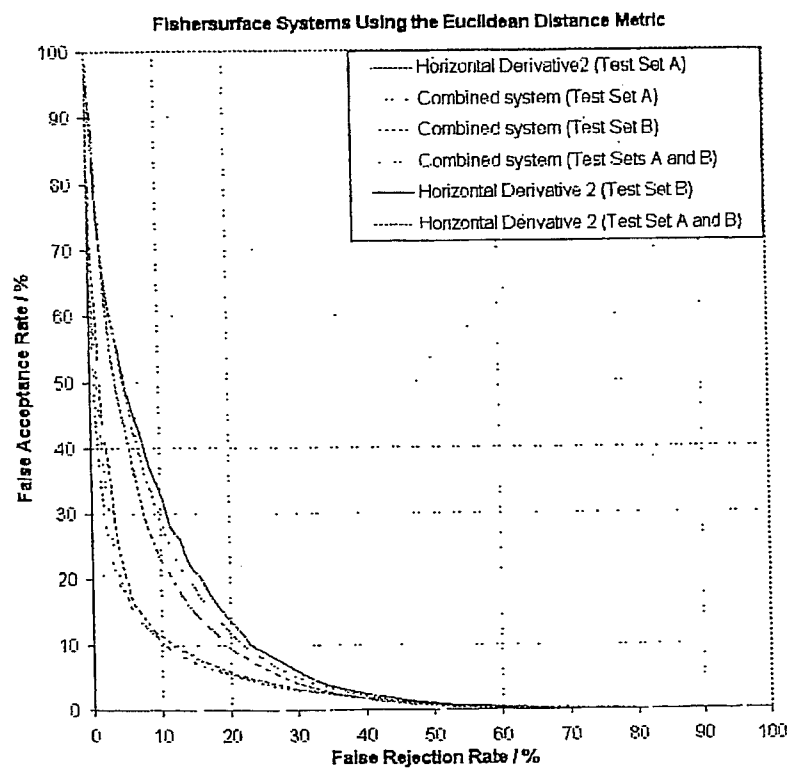


Fig. 15

Euclidean Distance	
3DFisherSpace_none	
3DFisherSpace_abs_max_curvature	
3DFisherSpace_abs_min_curvature	
3DFisherSpace_curvature_magnitude	
3DFisherSpace_curve_type	
3DFisherSpace_horizontal_derivative	XX
3DFisherSpace_horizontal_derivative2	XX
3DFisherSpace_laplacian	
3DFisherSpace_max_curvature	
3DFisherSpace_min_curvature	
3DFisherSpace_sobel_magnitude	
3DFisherSpace_sobel_xderivative	
3DFisherSpace_sobel_yderivative	
3DFisherSpace_vertical_derivative	X X X XXXXX XX X X X
3DFisherSpace_vertical_derivative2	X X X XX X X
3DFisherSpace_xcurvature	
3DFisherSpace_ycurvature	
Cosine Distance	
3DFisherSpace_none	XX
3DFisherSpace_abs_max_curvature	X XXX XX X X X X X XX
3DFisherSpace_abs_min_curvature	
3DFisherSpace_curvature_magnitude	
3DFisherSpace_curve_type	XXXXXXXXXX XXXXXX XXXX XXXXXXXX XX X X XXXXX
3DFisherSpace_horizontal_derivative	X
3DFisherSpace_horizontal_derivative2	XX
3DFisherSpace_laplacian	
3DFisherSpace_max_curvature	X X X X X X X X X
3DFisherSpace_min_curvature	X X X X X X X X X
3DFisherSpace_sobel_magnitude	X X X X X X X X X
3DFisherSpace_sobel_xderivative	X X X X X X X X X
3DFisherSpace_sobel_yderivative	X X X X X X X X X
3DFisherSpace_vertical_derivative	X X X X X X X X X
3DFisherSpace_vertical_derivative2	X X X X X X X X X
3DFisherSpace_xcurvature	X X X X X X X X X
3DFisherSpace_ycurvature	X X X X X X X X X

Fig. 16

**Fig. 17****Fig. 18**