$\left[4^{\circ},28^{\circ}\right]$ and $\left[4^{\circ},32^{\circ}\right]$; angular position pose at $\left[8^{\circ},24^{\circ}\right]$, $\left[8^{\circ},28^{\circ}\right]$ and $\left[8^{\circ},32^{\circ}\right]$; angular position pose at $\left[12^{\circ},28^{\circ}\right]$ and $\left[12^{\circ},32^{\circ}\right]$; angular position pose at $\left[16^{\circ},32^{\circ}\right]$ are statistical significantly different in median recognition distance.

It can therefore be concluded that recognition distances of head-poses 4° and 8° are significantly lower than those of head-poses 20° and above, when these constraints are being recognised by the study algorithm. Recognition distances of head-pose 12° is significantly lower that those of head-poses 28° and above, when these constraints are being recognised by the study algorithm whereas recognition distances for head-pose 16° is significantly lower than that head-pose 32°, when these constraints are being recognised by the study algorithm. It can be inferred from submission below that, the higher the degrees of head-pose the larger the recognition distances and that at 20° and above, the recognition distances become profoundly larger compared to the 4° head pose.

Table 4.4: Pairwise comparisons (Post hoc of the Friedman Test)

	4°	8°	12°	16°	20°	24°	28°
8°	0.99939	-	-	-	-	-	-
12°	0.7239	0.95797	-	-	-	-	-
16°	0.1723	0.47609	0.98494	-	-	-	-
20°	0.00635*	0.04024*	0.47609	0.95797	-	-	-
24°	0.00014*	0.00152*	0.06841**	0.47609	0.98494	-	-
28°	2.00E-06*	3.60E-05*	0.00451*	0.0877**	0.66454	0.99196	-
32°	2.50E-07*	5.40E-06*	0.00104*	0.03036*	0.41504	0.93595	0.99996

* implies significance difference exist between angular constraints at 5% significance level

** implies significance difference exist between angular constraints at 10% significance level

4.3.4 Recognition Rate

The Massachusetts Institute Technology (MIT) database is used to test the performance of the recognition rate adopting the modify DWT-PCA/SVD under angular constraints.

Recall, equation (3.51), the total number of correct recognition $\sum_{j=1}^{q=20} n_{cls}^{j} = 70$ for algorithm, the total number of experimental runs $q = 20$ and the total number of face images in a single experimental runs $n_{tot} = 4$.

The average (mean) recognition rate of the face algorithm is

$$R_{avg} = \frac{70}{20 \times 4} \times 100 = 87.5\%$$

The average error rate of the face algorithm is

$$E_{avg} = 100 - 87.5 = 12.5\%$$

The average runtime of the face algorithm in the recognition of the 80 face images is approximately 4 seconds.

Table 4.5: Recognition Rate

4°	8°	12°	16°	20°	24°	28°	32°
100%	100%	100%	100%	100%	90%	60%	50%

Source: R output

With reference to Table (4.5), there is an evidence that the modify DWT-PCA/SVD algorithm recognition rate obtained an 100% precision for the angular constraints $\left(4^\circ, 8^\circ, 12^\circ, 16^\circ \text{and } 20^\circ\right)$ but decline steeply for all angular constraints that exceed 20°.

4.3.5 Recognition Curve

The study displayed the graphical representation of the recognition rate with respect to the angular pose.

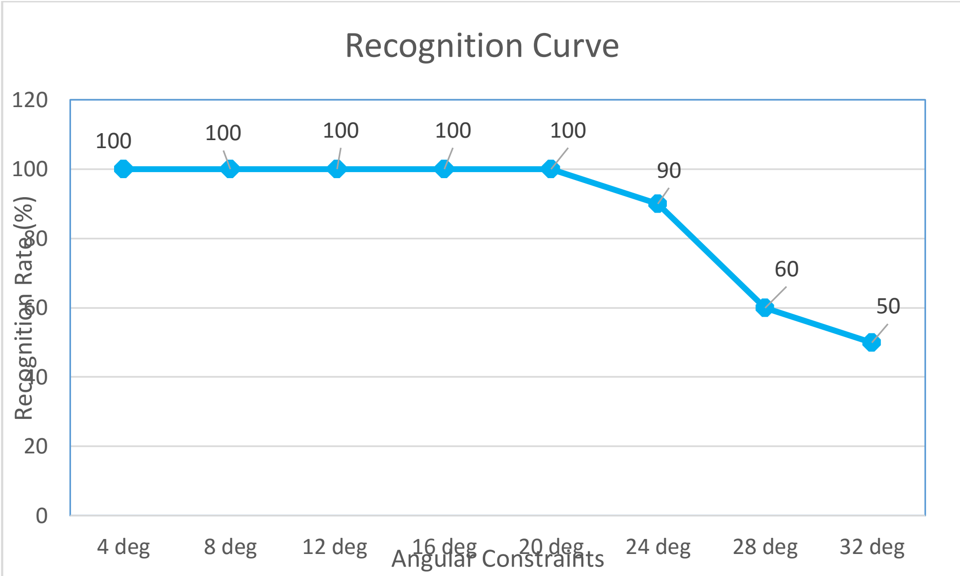

Figure 4.5: Displayed the recognition curve

This implies that adopting a DWT-PCA/SVD algorithm, the recognition rate decline for the varying angular constraint above 20°.

Plate 4.5: Example of correctly recognised individual across all angular poses

Source: [Weyrauch, Huang, Heisele & Blanz (2004)]

CHAPTER FIVE

Summary, Conclusion and Recommendation

5.1 Introduction

This is the final chapter of the study and also makes recommendations for future thesis work to be done in this field.

5.2 Summary

The study provided a concrete application of face recognition algorithm using Discrete Wavelet Transform and Principal Component Analysis with Singular Value Decomposition (DWT-PCA/SVD) under angular constraint. The study used ten images with an angular constraint from Massachusetts Institute of Technology database (2002-2005).

From the numerical evaluations in the previous chapter, the recognition rates of Principal Component Analysis with Singular Value Decomposition (PCA/SVD) with Discrete Wavelet Transform as a noise removal technique in preprocessing stage (DWT-PCA/SVD) is 87.5% and a mean error rate is 12.5%.

The average runtime of the modify DWT-PCA/SVD algorithm in the recognition of the 80 face images in the dataset is approximately 4 seconds. The time used by DWT-PCA/SVD algorithm in preprocessing accounts for the algorithm's runtime (speed).

It can be concluded from the results of the Friedman Rank Sum test design that, statistically there exist statistical significance difference in the recognition distances between the varying angular constraints $\left(4^{\circ},8^{\circ},12^{\circ},16^{\circ},20^{\circ},24^{\circ},28^{\circ}\text{and } 32^{\circ}\right)$ and their straight-pose$\left(0^{\circ}\right)$. The post hoc revealed that median euclidean distance for the angular pose position, there exists a significance difference whenever the angular position are far apart.

5.3 Conclusions and Recommendations

The study successfully modified the Principal Component Analysis and Singular Value Decomposition (PCA/SVD) algorithm by using Discrete Wavelet Transform as noise removal mechanisms during the face image pre-processing stage.

Adopting the study numerical evaluation, it can be concluded that, DWT-PCA/SVD has an appreciable performance when used to recognise face images under angular constraints.

A non-parametric statistical technique (Friedman Rank Sum test) has been used to assess whether statistical significant difference exist between the mean recognition distances of the varying angular head pose and their straight pose when recognised by DWT-PCA/SVD. From the study finding, it is highly probable that the face images captured with angular constraints less than or equal to 20° can be recognise by the study algorithm (DWT-PCA/SVD). Discrete Wavelet Transform is therefore suggested as a feasible de-noise technique, which ought to be employed throughout pre-processing stages in image processing.

Future studies should be carried out to analyse the effect of other noise removal mechanism. Another area for future research could be a study on other constraints like, ageing, occlusions, face images in glasses and lightening conditions.

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APPENDIX I

CODES

```
Imdata <- read.csv(file.choose(),header = TRUE)
Imdata
attach(Imdata)
names(Imdata)
Imdata <- as.matrix(Imdata)
names(Imdata)
shapiro.test(Imdata[,1])
shapiro.test(Imdata[,2])
shapiro.test(Imdata[,3])
shapiro.test(Imdata[,4])
shapiro.test(Imdata[,5])
shapiro.test(Imdata[,6])
shapiro.test(Imdata[,7])
shapiro.test(Imdata[,8])
a=cbind(c(0.0184,-0.0045,-0.0097,0.0052,-0.0090,-0.0005),c(-0.0045,0.0315,-0.0125,-0.0033,-
0.0063,-0.0049),c(-0.0097,-0.0125,0.0331,-0.0080,-0,-0.0028),c(0.0052,-0.0033,-
0.0080,0.0215,-0.010,-0.0055),c(-0.0090,-0.0063,-0,-0.01,0.0289,-0.0035),c(-0.0005,-0.0049,-
0.0028,-0.0055,-0.0035,0.0171))
a
eigen(a, symmetric, only.values = FALSE, EISPACK = FALSE)
Eigenvalues <- eigen(cov(a))
g=sort(Eigenvalues$values)
g
```

```
attach(g)

q=sort(g, decreasing=TRUE)

q

t=q/sum(q)

t

plot(cumsum(t),type="l",xlab="No. of eigenvalues", ylab="Variance accounted")
```

APPENDIX II

Univariate normal test for varying angular constraints

4°	8°	12°	16°	20°	24°	28°	32°
0.6684	0.8023	0.628	0.1372	0.2469	0.6082	0.4598	0.2476