7. THE CONCLUSIONS AND A ROAD-MAP

This chapter summarizes the research work into two parts. The first section gives the inferences that have been derived through this work based on the experiments and their results' analysis. From the experiences and the inferences through this work, the second section throws light on some of the areas where the further work can be done.

7.1 THE CONCLUSIONS

After going through an exhaustive testing and meticulous result analysis, the following inferences have been drawn:

First, the hybrid feature detectors, the *HORB* and the *ACORB*, which have been proposed, work far better than the original ORB and give better performance. However, to improve the recognition performance, a give-and-take policy have been adopted wherein the execution time is increased, almost doubled. This increase is due to the added layers of histogram generations and histogram intersection processes in the case of the *HORB*. In case of the *ACORB*, the execution time is increased due to pheromone updates, probability calculation for the specific feature being part of the given input image or not, etc. But, this increased time gets compensated by a 20% increase in recognition accuracy for the fully visible images. Unfortunately, these two proposed approaches could not improve the recognition accuracy for the partially visible images keeping it around 10% same as the ORB. The results of the *HORB* and the *ACORB* give an inference that **"*Feature detectors independently can recognize the fully visible images with higher accuracy but are not capable of recognizing the partially visible images and give the poorest performance*."**

Second, in the hunt of an improved classifier for partially visible images, two hybrid classifiers, named *HORBoVF* and *ACORBoVF* and a CNN TensorFlow based classifier - *Te₹₹ency* have been created. In this, one of the most widely used approaches, a Bag of Visual Words, has been combined with the proposed feature detectors, the *HORB* and the *ACORB*, to take advantage of their improved performance. The results were beyond the expectations. Both the classifiers work better and show a tremendous increase in the performance. The Bag of Visual Features classifier gives 98.351% recognition accuracy for the fully visible images whereas it gives 75.454% accuracy in case of the partially

visible images. The increase in accuracy by 65% for the partially visible images is a big achievement. *Te₹₹ency* also performs similar by giving 93.787% and 71.688% accuracy for the fully and partially visible images respectively. These figures lead to a conclusion that **"*A classifier, be it a bag of visual words based or neural network based, can improve the accuracy for partially visible images also*."**

Third, it has been observed that for K=20 and 24, the performance of the *HORBoVF* and the *ACORBoVF* remains almost similar. The same has been experienced in the case of *Te₹₹ency* for 2000 and 4000 iterations where the performance is almost the same. This infers that **"*After a certain level of clustering or training, the performance improvement in the accuracy is not possible*."**

Finally, for the TensorFlow model, there were 4208 images used for training *Te₹₹ency*. Since the training dataset is considerably smaller in size, the *Te₹₹ency* is not able to perform at par in comparison with the *HORBoVF* and the *ACORBoVF*. The reason is that for the CNN based models, the number of training images should be large enough in quantity, possibly millions of images, to achieve the best performance. Thus, the results of *Te₹₹ency* prove that **"*For the CNN based models, the larger the number of training images, the better the performance*."**

7.2 A ROAD-MAP TO FUTURE WORK

In this work, all the proposed approaches are feature-based, i.e., the image recognition, and classification is carried out based on a certain number of features matching and some classification algorithm. For testing of the genuineness of the currency, few fake currency images were obtained by getting it color photocopied, and some playing currency notes for the children. Upon testing, the results were reliable and the currencies were recognized as fake, yet a lot of work can be done in this direction to detect if the currency is counterfeit or not. For, the feature detection can help in recognizing the denomination of the currency, but it is not sufficient to detect if the currency is fake or real. This has been a Holy Grail for all the researchers, and still, it is. So, a lot of work can be done in this direction to detect if the currency is counterfeit or genuine.

Apart from recognizing the fake or real currency, another challenging part, which has been observed in chapter 4, is the recognition of the partially visible images. For this work, in spite of having an appropriate number of clusters (K=24) in BoVF and the training iterations (4000) in the *Te₹₹ency*, it has not been possible to achieve more than

80% accuracy for the partially visible images. This is another area where a lot of work can be done to improve the classification accuracy for the partially visible images.

In BoVF, the K-Means clustering has been used for the dictionary creation. To keep the dictionary latest, a dynamic clustering is performed whenever a set of images are obtained for verification of the image label. Instead of this, an incremental clustering approach can be used. By this, as and when if any new images are detected into the dataset, clustering could be carried out only for the new images with reference to the existing clusters and corresponding new visual words can be added into the current dictionary. So, in the direction of incremental clustering also, a lot of work can be done.