Chapter 9

Summary and conclusions

9.1 Major contributions of this work

The major contributions of this work are listed below.

1. In Section 3.2 a new class of filter banks, QMF filter banks, is proposed for texture feature extraction. Furthermore, a framework for feature extraction with multi rate (sub-sampled) filter banks is proposed. It is seen in several experiments that the features derived from the QMF filters yield good segmentation quality.

2. A new approach to texture filter design based on linear prediction error filters is proposed in Chapter 4. The approach is optimal with respect to representation. Hence, it is not optimal with respect to discrimination. Most texture images are successfully discriminated by the approach, but the method is unsuccessful for some images. The results are more or less of the same quality as with several non-optimized filter bank approaches, but with a considerably lower computational complexity.

3. In Section 5.2 and Appendix A, a new model for estimating the mean and variance of texture features extracted with linear FIR filters and local energy functions is developed. The model is applicable for analyzing the performance of a given filter or for filter optimization.

4. Multiple new two-texture optimal one-filter design approaches are presented in Section 5.3. Exact closed form optimization to mean feature value criteria and approximate closed form solutions to mean and variance criteria, in particular the Fisher criterion, are developed. Experiments in Section 5.3 and in Chapter 6 indicate that these new techniques are very good.

5. The mean value optimization approaches are extended to multiple-texture cases in Section 5.4. Experiments show very good results compared to other optimal and non-optimal filtering approaches. Advantages with the two- and multiple-texture optimization approaches are that they yield features that may be extracted with relatively low computational complexity. Furthermore, these features may be classified with low complexity.

6. The new methods proposed here along with methods broadly covering most categories of filters and filter banks used for texture feature extraction are evaluated in Chapter 6. In the experiments, the focus is put on making the results as comparable as possible. Model based and statistical features are also included in the test for reference.

7. Experiments on document image segmentation and content based image queries are reported in Chapter 7. In these experiments, it is shown that the decimated version of the QMF filter bank of Section 3.2 is a powerful texture feature extractor for real world images.

8. In Chapter 8, a method for estimating the local orientation in seismic data is discussed. A method for utilizing this estimate for detecting patterns corresponding to terminating sedimentary layers in seismic data is proposed. Furthermore, an approach to fault feature extraction in seismic signals based on the orientation estimate is proposed and tested. Finally, methods for interpreting fault planes from the fault features are discussed.

9.2 Major conclusions from this work

Several conclusions may be drawn from the experiments reported in this dissertation. Below is a summary of the major conclusions:

1. It may from the experiments in Chapters 3 and 6 be concluded that the dyadic decomposition in most cases is not optimal for texture feature extraction with filter banks. This supports similar findings reported by Chang and Kuo [16].

2. Numerous works have concentrated on tuning Gabor filters or filters derived from the wavelet transform for texture recognition. In this work, other filter bases have been shown to yield comparable or better results. Hence, restricting the filter basis to the Gabor or wavelet derived filters will limit the potential of the filtering.

3. By applying sub-sampled perfect reconstruction filter banks, good segmentation performance can be achieved with significant savings in computational complexity. However, with sub-sampling, some increase in edge inaccuracy is observed.

4. Several filter optimization approaches are evaluated and optimal filter designs do in many cases yield features that are superior compared to non-optimized filters. Furthermore considerable reductions in computational complexity are obtained by many optimal filter approaches.

9.3 Suggestions for further research

1. Due to mathematical constraints, a few assumptions and approximations had to be made to obtain the closed form optimal solutions of Chapter 5. These were Gaussian assumption, in some cases restrictions to criterion functions incorporating

only the feature mean, etc. Further effort should be put on working around these assumptions and approximations.

2. A few attempts to filter optimization with respect to the Fisher criterion have been made in Sections 5.3.2 and 5.3.3. Approximate closed form, gradient search, simulated annealing, annealing evolution, and exact iterative solutions have been proposed. Other iterative or closed form solutions should also be targeted. Furthermore, approaches based on the alternate expressions and derivations of Appendix A.4 should be examined further.

3. The ultimate criterion in texture segmentation is the classification error rate. All optimization approaches in this dissertation have been with respect to criteria that are only indirectly related to the error rate. The optimal solutions are consequently not optimal with respect to the error rate. The only reported approaches on optimization with respect to the error rate are some Gabor filter design approaches [31, 30, 138, 139] and a neural net approach [51]. The first approach is restricted in the class of filters, while the second is limited by the lack of a global optimum and closed form solution. Further effort should be put on minimum error optimization.

4. The multi-texture optimization strategy developed in Section 5.4 is based on forming pairs of textures and designing filters for these pairs. Alternate optimal filter bank design schemes should be developed, to see if even better results may be obtained.

5. The section on unsupervised optimal filter design, Section 5.5, did show good results. However, more effort should be put on testing the approach and developing the block clustering scheme further.

6. The experiments on document segmentation and content based image search were focused on the texture feature extraction. Several issues of pre- and post processing remain unresolved. The features proposed here are very advantageous with respect to computational complexity. More effort should be made in combining these features with proper pre- and post-processing systems.

7. The seismic interpretation approaches presented in Sections 8.2 and 8.3 were limited to two dimensions. For most of the techniques, extensions to multiple dimensions are readily available with only a moderate increase in complexity (e.g. most filtering approaches were separable). Extensions to multiple dimensions should be developed and tested.