Chapter 8

Concluding Remarks and Future Directions

In the final chapter, We have highlighted the main contributions of our work.

8.1 Contribution Summary

Semantic image labelling has been studied for efficient segmentation mechanisms in image processing and computer vision domain. In this thesis, machine learning, deep learning, and relaxation labeling-based methods have been studied to enhance image labelling's accuracy and efficiency. We have first reviewed the literature, which focuses on efficient labelling and classification techniques. The image labelling methods have been divided into three parts: (1)classical machine learning methods, (2) deep learning-based approaches, (3) relaxation labelling and variational optimization techniques. We have also studied the effect of high dimensionality in data-sets for testing of the frameworks. The methods and frameworks have been tested on both types of data-sets, i.e., high dimensional, and low dimensional RGB. The main contributions of the thesis are listed below.

Deep CNN Feature Fusion with Manifold Learning and Regression :
Investigated CNN based features and original spectral features of high dimensional images.

These features have fused with spectral features by using a graph-based spatiality preserving different embedding methods. The embedded features have used in logistic regression to result in the probability of prediction. This probability has termed a global probability. Subsequently, a regional probability has computed to model the noise effect of pixels in the image. Both regional and global probabilities have fused with a linear decision fusion method to obtain the final labelled image. This framework has shown better results than other state-of-arts.

CNN and correlation based Salient Features for Image Labelling :
Developed a salient features selection approach that selects the features from both 'off-the-shelf' CNNs and an expansion based feature extraction technique. Before saliency selection, the informative features have extracted by two approaches: (1) By CNNs and bi-cubic interpolation and (2) expansion of low correlated features. The saliency selection method has based on local descriptors and the maximum identified object in an image.

Two phase label optimization, and efficient edge preservation scheme(EPS) for Relaxation Labelling :
We have studied the notion of optimization for the relaxation labelling. Relaxation labelling based methods are highly effective in noise reduction and cluster optimization-based techniques. In the thesis, a variational optimization has solved by two-phase optimization and EPS based optimization methods. Variational optimization has improvised the label prediction outcome obtained from multinomial regression.

CNN-EFF: CNN based Edge Feature Fusion :
We developed a custom CNN architecture that produces probabilistic outcomes for the label predictions of RGB images. The result of CNN has optimized with a variational optimization-based Jacobi method for label relaxation. The label relaxation process fuses the edge feature information into the optimization equation. This process is increasing the performance of algorithms up-to a significant level. Various comparative tests and statistical tests have asserted our notion experimentally.

LM-MFP: Large Scale Morphology and Multi-criteria Feature pooling :
We designed a large scale morphological operations based framework that preserves the spatial resolution of features, which is a drawback in the CNN feature, followed by the study of a novel feature selection method to downscale the redundant features for accurate and efficient image labelling. The main aim is to address the take away of CNN based features by replacing them with large scale morphological features. The experimental validation has performed for both categorical and semantic image data-sets.

8.2 Scope for Future Work

This section illustrates various new research lines that have been opened up by this thesis.

Graph based embedding and matching techniques for informative knowledge fusion : Laplace graph-based fusion algorithm that uses Gelies bowles weights and potential spatial weights in the embedding process for feature dimension reduction has used in chapter-3. We aim to develop some new weight matrices such that random walk, nonlinear edge weights, etc. to fuse more external knowledge for better labelling in big image datasets. Since embedding techniques take massive computation time for graph construction and weights computation, various evolutionary feature selection techniques have also used to reduce the feature space.

Application of CNN based metric learning, extreme learning machines for better feature search :
We have studied the 'off-the-shelf' CNNs such as AlexNet, VGG for deep features, and detailed about custom CNN architecture design for a thorough understanding of CNN design. The softmax output of CNNs has also improved by a relaxation labelling based jacobian optimization method. The CNN outcome can be further improved by introducing metric learning and extreme learning-based optimization techniques. In the future, both relaxation and metric learning-based solutions can be provided for semantic labelling frameworks.

Variational optimization by using convex methods and classical techniques :
Variational optimization is an essential problem in image labelling based computer vision. In this thesis, variational optimization has solved by three methods: (1) Two-phase label energy minimization, (2) EPS based edge preservation, and (3) CNN-Jacocbian optimization. The variational optimization can also be solved by convex optimization, evolutionary algorithms, partial differential equations(PDE) based optimization, and graph-cut based MRF techniques. This process can be used in image denoising, image in-painting, and clustering optimization.

Brain disease classification on MRI, fMRI and medical hyper-spectral images by using classical and deep learning techniques :
For future research lines, image labelling based methods can be validated on some other medical problems such as MRI and fMRI image classification for healthy and pathological images. The objects like tumor, brain lesion, and other disease segmentation can be implemented with the proposed frameworks.

Application on other semantically labelled data-sets for camouflage detection and object detection in images :
Some other applications, such as aerial objects and camouflage objects, can be detected by using COCO-CAMO datasets. The detection of hidden or camouflage objects requires strong feature engineering, such as salient features from camouflage images. The saliency selection approach in chapter-4 can be applied for the labelling of camouflage objects.