CHAPTER 6: CONCLUSION AND FUTURE DIRECTIONS

6.1 Conclusions

DEM characterizes the bare earth surface. The work reported in this thesis is a unified attempt in two particular research areas, namely, DEM registration and DEM quantification.

Very often, information obtained from different DEMs may appear differently, can vary in bulk, can be obtained using varied sensors, or multi-temporal, or multi-modal, or captured from different viewpoints, or have different resolution and sizes. These variations give rise to the need to establish a generic platform to aggregate such vide information to be presented as a single usable entity through the process of registration. Also, DEM registration is an ill-posed problem as any minor change in the initial data set can result in huge change in the transformation mapping function and affect the end result of registrations. The registration must not only be photometrical but also geometrically consistent. These requirements have ignited the need to present a successful registration approach in the research community.

The importance of DEM registration comes from the various applications that not only require larger DEMs but also DEMs that have high information content, and reduced level of errors and data holes. Other problems that plague the DEM registration domain include lack of multiple candidate DEM registrations, lack of symmetric and inverse-consistency, robustness of mapping function to DEM errors and data holes, and lack of study in quantification of DEMs. Our study has shown possibilities to solve DEM registration and DEM quantification successfully.

In this thesis our major contribution for DEM registration based on whether they are multi-temporal, multi-modal or multi-view and multi-resolution DEMs include - SVDWBM (Singular Value Decomposition extension for Window-Based Method) for Multi-temporal DEM registration; usage of Watershed Transform and Chain Coding based (WTCC), a thresholding and region growing method for Multi-modal DEM Registration; Cognitive Mapping and Contextual Pyramid (CMCP) based method for Multi-view and Multi-resolution DEM registrations; and finally the Diffeomorphism-based Symmetric and Inverse-Consistent Non-Rigid (DSICNR) method, for registration of all the above types of DEMs.
In SVDWBM approach, use of SVD was performed for a coarse-to-fine DEM registration of reference with candidate DEM with the use of multiple window-based numerous-sized matrices for finding and extract feature-points that would help in comparing the features within the candidate and reference scalar data files. In WTCC approach, watershed transform gave segments of various lengths and sizes. On these segments, after application of morphological operators, chain coding based matching was applied to segregate the corresponding features and then registration was performed. CMCP approach for multi-view and multi-resolution DEM registration applied the concepts of cognitive mapping for feature finding and correspondence. Use of contextual pyramid was done for the coarse-to-fine registering method.

The approach of DSICNR method, allowed for performing a consistent registration in forward as well as reverse directions as well as creating an adaptive deformation model that allows for stable deformations even for those parts of the surface for which good correspondences may not be available due to major variations in their values or due to presence of random errors and holes. We have been able to map small scale as well as large scale deformations using the proposed technique and have experimented for various terrain types. In addition, when candidate DEM data file is not provided to the system, the system chooses one from a given DEM folder.

Through experiments, we have demonstrated the success capability of the registration mechanisms. Our work compares well with other existing schemes too, as was shown with respect to various attributes. A major strength is the comprehensiveness of the model to work with data of varying sizes and varying noise types including data holes including registering of multiple candidate DEMs. As is depicted through our experimentation, the proposed approaches for the registration of DEMs converge well.

The methods here proposed deals with solving the spatial misalignment problem between not only the DEM pairs of reference and candidate DEMs, but also extended to be applicable to a group of candidate DEMs too. The approaches have been shown to be efficient and robust to noise up to a certain extent. Furthermore, we have also studied the content of the images involved in registration. The quantization of DEMs allowed for studying the nature of the DEMs with respect to certain information-theoretic factors. This included measuring content of individual images, measuring their differences and quantifying the content improvement of the registered output image. These quantifications have been performed using information-theoretic measures. Shannon’s Entropy and Sharma-Mittal Entropy has been used
for quantifying individual content. Symmetric divergence is measured using J-divergence measure. Content improvement has been measured using Theil’s measure. These measures have helped in not only increasing the understanding of the images involved in the task of registration, as also helped in some classification of DEMs based on their topologies.

6.2. **FUTURE SCOPE**

With several new directions that open with the study reported here, there is scope of further possibilities and extensions. Some that we suggest are:

- Extending registration to include for DEM-to-topographic map and DEM-to-remote sensed image registrations with DEM-to-DEM registrations.
- Explore the effect of regularization parameter while performing symmetric DEM registration on the global energy reduction, local spacing and orientation of landmarks, and their repercussions while performing coarse-to-fine registration.
- When performing multi-scale and multi-resolution registration, more in-depth study the effect of the effects of sampling on the registration accuracy may be initiated.
- Further investigate the effect of changing the number of bins while performing joint histogram calculation when transforming from one resolution to another to consider the effect of the change in number of DEM points or voxels so that their spatial arrangement is affected and modified.