Objectives

This research project studied problems of object-based image reconstruction and feature enhancement. Identification and extraction of object features is a critical aspect of automatic target recognition (ATR) systems. The robust estimation of geometric features becomes increasingly difficult as data quality and quantity are reduced. As such, it is important to develop methods which take into account from the outset the feature-oriented nature of scenes during the inversion, image formation, and enhancement process. A limitation to the practical use of such methods is the their computation cost, thus efficient algorithms are also important.

Status and Accomplishments

The incorporation of object geometry or shape during image formation and enhancement is a challenging but an important problem. To address these challenges, we developed methods which directly model and incorporate object shape in a scene. In particular, a level set model was used to capture object geometry and was coupled with an appropriate pixel model which captured scene texture or intensity. Thus, an explicit treatment of object shape was in our formulation.

Part of this work developed and applied such models for statistically-based segmentation tasks. For example, we are studied the problem of segmenting laser radar range imagery. To accomplish this task we combined a contour-based object model with a physically-motivated, statistical intensity model to obtain maximum likelihood estimates of the scene. We incorporated prior knowledge of both background and target behavior to directly estimate both target boundary as well as the scene range profile. In contrast to simple smoothing of the image, our approach directly used a statistical range anomaly model in an EM algorithm to estimate and correct for pixels with anomalous range values – a bane of laser radar imagery – as well as directly estimating object boundary location.

A critical challenge in the application of such contour-based methods to practical problems is their computational cost. As such, we have developed new, extremely fast implementations of the level-set curve evolution method. These methods appears to be the first implementation allowing real-time use of the level set method for image processing tasks.
This report summarizes the results on this project for developing approaches for feature enhanced and object-based image reconstruction and processing. Object-based methods for tasks such as segmentation and localization were developed. These tools were applied to problems such as segmentation of LiDAR. Object-based methods for dynamic tomography are also being developed together with prior models of object shape. New, real time algorithms for contour-based segmentation were developed. Preliminary examples have indicated the superior performance of these methods in challenging imaging environments.
We have developed a Matlab-based video segmentation demonstration to illustrate the true real time ability of the new approach. This work won the best paper award at ICASSP in 2005.

A related aspect of this work was the development of object or shape-based prior models. These models allow the incorporation of target and scene specific information concerning object boundary behavior into processing problems. In typical curve evolution methods stabilization of the boundary to noise is accomplished through inclusion of a prior term which simply penalizes overall boundary length. Such a generic prior may be inappropriate in some applications, but does not capture scene specific object information that may be available. We developed a feature-histogram-based shape prior for use in curve evolution-based segmentation methods. Such feature-histogram representations of object shape have had great success in classification tasks, and our work represents their first application to continuous-valued inferencing problems, such as segmentation. We continued to extend our approach to allow the development of prior shape models capturing the interaction of multiple scene objects. In addition, we also developed methods for the direct incorporation of topographic object constraints into the segmentation process.

A final aspect of our work focused on shape-based dynamic inverse problems, where the scene under consideration evolves in time. We have used the problem of real-valued dynamic tomography as an paradigm of such problems. The challenge of creating imagery from projection type data arises, for example, in Synthetic Aperture Radar (SAR) image formation. In our approach we have directly modeled the evolution of object shape in time and included this dynamic model in the image formation process. We have developed dynamic models reflecting specific classes of object motion (i.e. smoothness) and incorporated these into inversion tasks. In tomographic problems, a complete set of projection data at each time instant is typically required by standard inversion techniques to produce artifact free images and reliable quantitation. This requirement is almost never met in challenging dynamic problems. For these extremely difficult problems we have had good success in producing excellent reconstructions using our approach. In particular, we have demonstrated good target boundary localization as well as robust intensity estimation with as little as one projection per time instant.

3 Personnel Supported

W. Clem Karl, PI
Y. Shi, Research Assistant
A. Litvin, Research Assistant

4 Technical Publications

4.1 Journal Publications


4.2 Reviewed Conference Proceedings


5 Interactions/Transitions

5.1 Conference Presentations


• Presentation at the 2004 SIAM Conference on Imaging Science, Salt Lake City, May, 2004

• Presentation at the SPIE Conference on Computational Imaging, Santa Clara, January, 2004

• Invited presentation at IEEE Workshop on Statistical Signal Processing, St. Louis, Sept, 2003.

5.2 Transitions

• Gave invited presentation at Workshop on ATR Theory organized by Dr. Greg Arnold, AFRL, Acting ATR Team Leader, AFRL/SNAT.

• Interaction with Capt. Virgil E. Zetterlind on our fast level-set algorithm.

• Have had discussions on transition of our fast level-set algorithm into the ITK toolkit.

• Interacted with Guna Seetharaman and TJ Klausutis on a possible application of our fast level-set method to micro-UAV video stabilization.

6 Honors