

Final Report
Foundations of Automatic Target Recognition
AFOSR grant F49620-03-1-0257
Principal Investigator: W. Clem Karl

Boston University
Department of Electrical and Computer Engineering
8 St Mary's Street
Room Pho437
Boston, MA 02215

1 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.

2 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.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) 10-26-2006		2. REPORT TYPE Final		3. DATES COVERED (From - To) 9/1/03-8/31/06	
4. TITLE AND SUBTITLE Foundations of Automatic Target Recognition				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER F49620-03-1-0257	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) W. Clem Karl				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Boston University Dept. of Elec. & Comp. Eng. 8 St. Mary's Street Boston, MA 02215				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Office of Scientific Research (AFOSR) <i>AFOSR/NE</i> <i>Dr. Jon Sjogren</i>				10. SPONSOR/MONITOR'S ACRONYM(S) AFOSR	
				11. AFRL-SR-AR-TR-06-0489	
12. DISTRIBUTION / AVAILABILITY STATEMENT <i>Distribution Statement A: unlimited</i>					
13. SUPPLEMENTARY NOTES N/A					
14. ABSTRACT 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.					
15. SUBJECT TERMS N/A					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT None	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON W. C. Karl
a. REPORT None	b. ABSTRACT None	c. THIS PAGE None			19b. TELEPHONE NUMBER (include area code) 617-353-9788

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

1. N. Aggarwal, and W. C. Karl, "Line Detection in Images through Regularized Hough Transform," *IEEE Trans. Image Processing* Vol. 15, No. 3, pg. 582-591, March, 2006.

2. Y. Shi and W. C. Karl, "A Real-Time Algorithm For The Approximation Of Level-Set-Based Curve Evolution," *IEEE Trans. Image Processing*, in press.
3. Y. Shi and W. C. Karl, "Topological priors for shape based segmentation," in preparation.
4. H. Feng, D. A. Castanon, W. C. Karl, "Ladar Range Image Processing using Curve Evolution and Maximum Likelihood Estimation," *IEEE Trans. Image Processing*, in press.
5. R. Weisenseel and W. C. Karl, R. C. Chan, and T. J. Brady, "A Variational Approach to Multi-modality Subsurface Data Inversion and Fusion Based on Shared Image Structure," *Subsurface Sensing Technologies and Applications*, Vol.4, No.4, pgs 373-392, October 2003.

4.2 Reviewed Conference Proceedings

1. A. Litvin, W. C. Karl, J. Shah, "Shape and appearance modeling with feature distributions for image segmentation," Proceedings of the 2006 IEEE International Symposium on Biomedical Imaging, Arlington, VA, April 6-9, 2006.
2. H. Feng, W. C. Karl, D. A. Castanon, "LADAR Range Image Segmentation using Curve Evolution and Maximum Likelihood Estimation," Proc. of the Thirty-Ninth Asilomar Conference on Signals, Systems, and Computers, October 30-November 2, 2005.
3. Y. Shi and W. C. Karl, "Real-time tracking using level sets", IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2005 (CVPR 2005), Volume 2, Pgs. 34-41, June 20-25, 2005.
4. A. Litvin and W. C. Karl, "Coupled shape distribution-based segmentation of multiple objects," Proceeding of Information Processing in Medical Imaging (IPMI 2005), Glenwood Springs, Colorado, 2005.
5. Y. Shi and W. C. Karl, "A fast level set method without solving PDEs," Proc. 2005 IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, pg. II-97-II-100, Philadelphia, March 20-23, 2005. Student Paper Award Winner.
6. Y. Shi and W. C. Karl, "Differentiable Minimin Shape Distance for Maintaining Topology in Curve Evolution," Proc. 2004 SIAM Conference on Imaging Science, Salt Lake City, Utah, May 3-5, 2004.
7. A. Litvin and W. C. Karl, "Using Shape Distributions as Priors in a Curve Evolution Framework," Proc. 2004 IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, Montreal, pg. III-25-III-28, May 17-21, 2004.

8. Y. Shi and W. C. Karl, "Shape reconstruction for unorganized points with a data-driven level set methods," Proc. 2004 IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, pg. III-13-III-16, Montreal, May 17-21, 2004.
9. Y. Shi and W. C. Karl, "Tomographic Reconstruction of Multiple Dynamic Objects," Proc. 2004 SIAM Conference on Imaging Science, Salt Lake City, Utah, May 3-5, 2004.
10. Y. Shi and W. C. Karl, "Shape reconstruction for unorganized points with a data-driven level set methods," Proc. 2004 IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, pg. III-13-III-16, Montreal, May 17-21, 2004.
11. Y. Shi and W. C. Karl, "Level-set methods for dynamic tomography," Proc. 2004 IEEE Intl. Symposium on Biomedical Imaging, pg. 620-623, Arlington, VA, 15-18 April, 2004.
12. A. Litvin and W. C. Karl, "Shape distributions as priors for image segmentation," in *Computational Imaging*, C. A. Bouman and R. L. Stevenson editors, Proc. SPIE, Vol. 5016, SPIE, Santa Clara, CA, January 20-24, 2004.
13. Y. Shi and W. C. Karl, "Multiple Motion and Occlusion Segmentation with A Multiphase Level Set Method," in *Computational Imaging*, C. A. Bouman and R. L. Stevenson editors, Proc. SPIE, Vol. 5016, SPIE, Santa Clara, CA, January 20-24, 2004.
14. Y. Shi and W. C. Karl, "A Multiphase Level Set method for tomographic reconstruction of dynamic objects," Proc. 2003 IEEE Workshop on Statistical Signal Processing, pg. 169-172, St. Louis, Sept. 28-Oct. 1, 2003
15. A. Litvin and W. C. Karl, "Level set-based segmentation using feature histogram shape priors," Proc. 2003 IEEE Workshop on Statistical Signal Processing, pg. 153-156, St. Louis, Sept. 28-Oct. 1, 2003

5 Interactions/Transitions

5.1 Conference Presentations

- Presentation at the 2005 IEEE Conference on Computer Vision and Pattern Recognition, June, 2005.
- Presentation at the 2005 Conference on Information Processing in Medical Imaging, Glenwood Springs, Colorado, 2005.
- Presentation at the 2005 IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, Philadelphia, 2005.
- Presentation at the IEEE Int'l Conf. on Acoustics, Speech, and Signal Processing, Montreal, May, 2004.

- 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

Our 2005 ICASSP Paper on our fast level-set method won best student paper award.