Visualization and Verification of Automatic Target Recognition Results Using Combined Range and Optical Imager *

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Abstract

The Rangeview software system presented here addresses two significant issues in the development and deployment of an Automatic Target Recognizer: visualization of progress of the recognizer in finding a target, and verification by an operator of the correctness of the match. The system combines range imagery from a LADAR device with optical imagery from a color CCD camera and/or FLIR sensor to display a three-dimensional representation of the scene and the target model. Range imagery creates a partial three-dimensional representation of the scene. Optical imagery is mapped onto this partial three-dimensional representation. Output from the ATR is registered in three dimensions with the scene. Recognized targets are displayed in correct spatial relation to the scene, and the registered scene and target may be visually inspected from any viewpoint.

1 Introduction

Model-Based Object Recognition techniques use sensor data to find the three-dimensional position in a scene of an object which matches one of a set of object models known to the system. Monitoring progress and verifying correctness while the recognizer is finding objects requires visualization in order to assess the geometric plausibility of the resulting object pose and sensor registration. To support monitoring and verification, our prototype system allows a user to interact with sensor data and object models in a three-dimensional environment.

This visualization environment combines range imagery, color imagery, thermal (infrared) imagery, and CAD models of objects to be recognized. We are currently using imagery of vehicles in natural terrain. Range imagery is used to create a partial three-dimensional representation of a scene. Optical imagery is mapped onto this partial three-dimensional representation. Output from the vision system is registered with the scene.

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2 Range Images in Three Dimensions

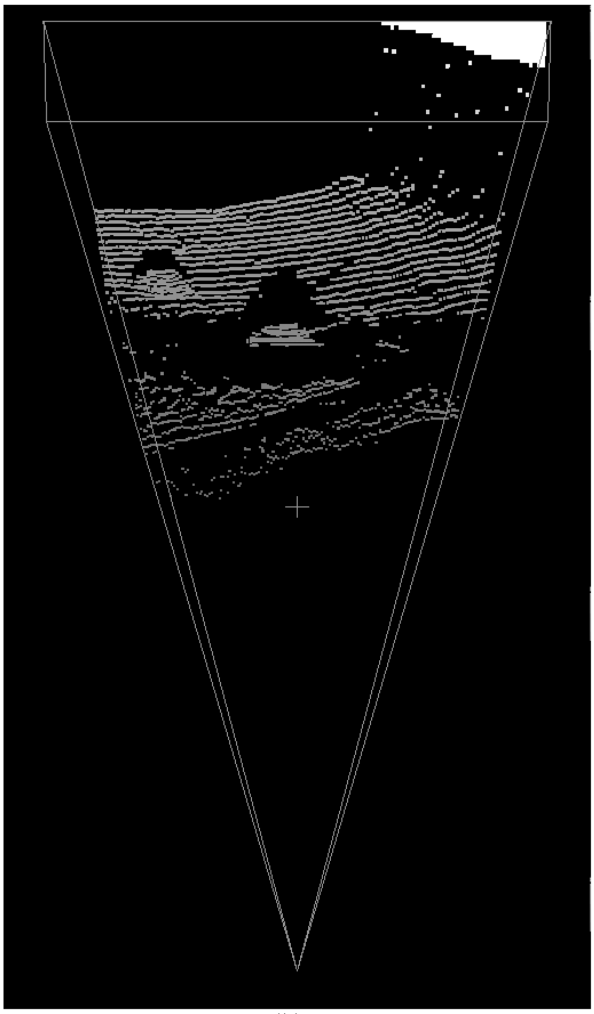
Range images are conventionally displayed as gray scale (or pseudo-color) images, as shown in Figure 1(a). The gray level of each pixel corresponds to the distance of a range sample from the sensor. We have developed a new method for display of range data which provides a three-dimensional view of the data, and allows the viewer to interactively roam through the data. Figure 1(b) shows a static view of this interactive system. Range data samples are shown as points in space relative to the sensor. The four-sided pyramid shows the view volume of the LADAR sensor. In this image, the colors assigned to the pixels are the same as in (a). A pseudo-color option is also available to the user, as well as several color schemes described below. Figure 2 shows the same data from a different viewpoint. A picture of the interactive viewer controls can be found elsewhere in these proceedings [Beveridge *et al.*, 1994a].

Display of the range data in three-dimensional space gives the user a more complete representation of the spatial configuration of the data. Interactive control of viewing parameters allows the user to examine the range data from many different viewpoints at any magnification level. User controlled de-cluttering of the image is accomplished by restricting the range of depth values displayed relative to the viewer, the sensor, or both. Gray scale or pseudo-color values are rescaled to represent the selected depth range. A workstation with hardware graphics acceleration is used to perform display update at interactive rates.

3 Optical Imagery

The three-dimensional display of the range data provides an intuitive method for the user to view the LADAR output. Since color (or gray scale) encoding of range information is no longer essential, other sensor information can be viewed simultaneously with the range data.

(a)



(b)

Figure 1: (a) Conventional view of range data as gray scale, (b) Three-dimensional view of range data

Figure 3(a) shows a color CCD image (shown here in gray scale) collected at the same time as the LADAR range image shown in Figure 1. The color image was registered to the range data using an interactive registration tool. The user can request that the color image be overlaid on the range data; the resulting image is shown in Figure 3(c). To maintain interactive display update speeds on the available hardware, the CCD image is normally resampled to the lower resolution of the range data (as shown in Figure 3), but it may also be displayed at full resolution. The lower resolution capability is also available for thermal (FLIR) images, shown in Figures 3(b) and (d). Thermal images can be displayed in gray scale or pseudo-color.

Another viewing mode allows the user to simultaneously view all sensors in a single three-dimensional image. Colors for the range data values are computed using the hue and intensity of the color CCD image; the saturation for each range value is computed from a function of the saturation of the source color image and the intensity of the thermal image. This results in an image which has vivid, highly saturated colors in areas of interest due to high thermal intensity (such as the tank) and has dull, unsaturated

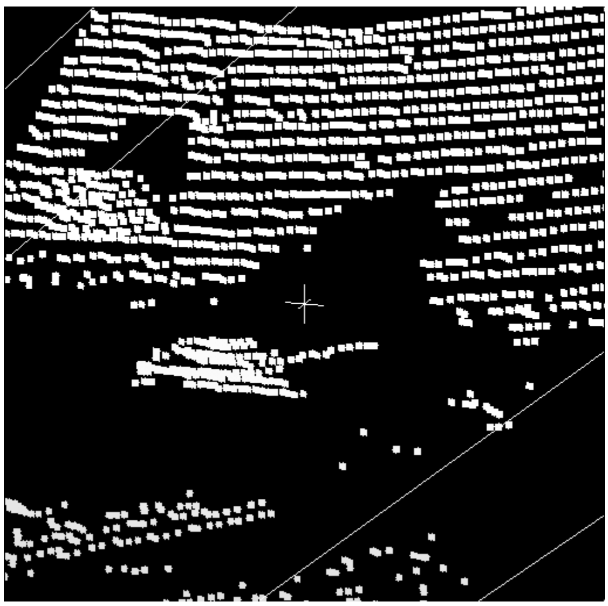


Figure 2: Oblique view of three-dimensional range data

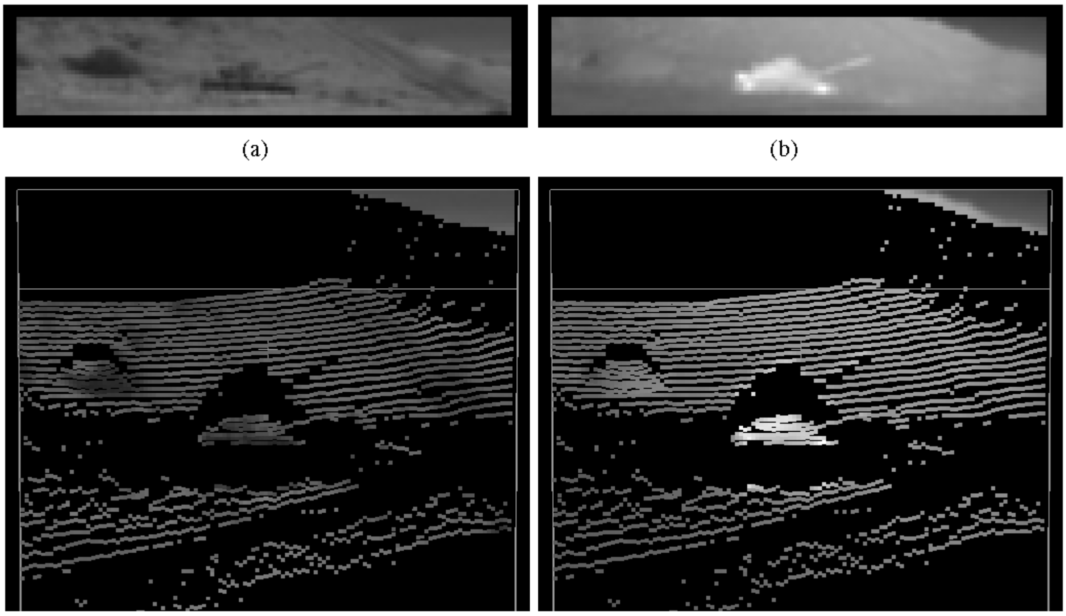

(a) (b) (c) (d)

Figure 3: (a) CCD image, (b) FLIR image, (c) CCD image superimposed on three-dimensional range data, (d) FLIR image superimposed on three-dimensional range data

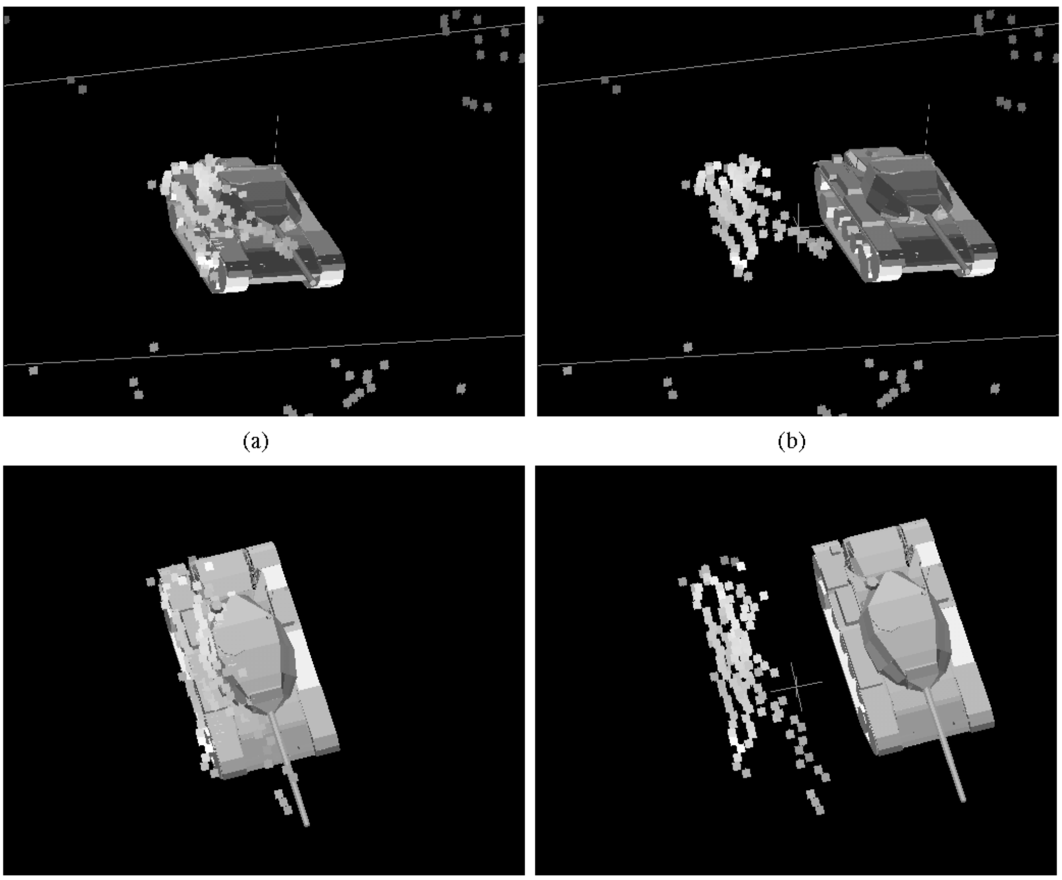

(a) (b) (c) (d)

Figure 4: Model of vehicle in relation to three-dimensional range data

(gray) colors in areas of low thermal intensity.

4 Object Models

The system is currently being developed in parallel with an Automatic Target Recognition (ATR) system [Beveridge *et al.*, 1994a] which uses the range, thermal, and color images. The ATR system will automatically hypothesize matches between the scene and object models, and iteratively refine the three-dimensional geometric relationship between the model and the multisensor imagery [Schwickerath and Beveridge, 1994]. As the ATR develops spatial relationships among the sensors and the model, it will update the three-dimensional display. The hypothesized position will be shown by the display of a wireframe or solid object in the same three-dimensional space occupied by the range data. It will be possible to view an animated trajectory of the object in real time (or user-controlled playback) as the ATR refines the model position. Figure 4 shows a manually-positioned model displayed in relation to range data. The range data can be displayed in any of the modes described above. In (a) and (c), the model is closely registered to the range values; in (b) and (d) the model is moved slightly away for illustration purposes.

5 A Three-Dimensional Multisensor Visualization Environment

When development began on this system, the goal was to develop a useful tool for working with an ATR system in a three-dimensional environment. The resulting tool, the Rangeview program, while satisfying our original goals, is also developing into a general purpose tool for working with multisensor data. By using the three-dimensional environment of Rangeview as a base, we were able to integrate other useful tools into a single program.

Early in the project, we realized the need for a way to interactively register data from multiple sensors, and also the need for interactive registration of models for comparison with ATR results. Since we had already developed a three-dimensional interactive environment, it made sense to integrate the registration task into this environment. This made it possible to display the source images and models within Rangeview, select registration points, and immediately view the results.

Rangeview is currently being used on LADAR, FLIR and color CCD data collected at Fort Carson in November of 1993 [Beveridge *et al.*, 1994b]. This data includes multiple frame LADAR sequences taken at evenly spaced time intervals. Rangeview provides the capability to display these frames as an animated loop. The animation capability will be extended in the future to multisensor time sequences if data becomes available.

6 Summary

The Rangeview three-dimensional visualization environment is proving to be extremely useful in the development of multisensor ATR algorithms. We foresee eventual use of this technology in fielded systems for operator verification of ATR results. Display of a target model registered to a partial three-dimensional scene could allow an operator to verify a target with greater confidence than is possible using current types of displays. In time-critical applications, multiple simultaneous views could be scanned rapidly by the operator.

References

[Beveridge *et al.*, 1994a] J. Ross Beveridge, Allen Hanson, and Durga Panda. RSTA Research of the Colorado State, University of Massachusetts and Alliant Techsystems Team. In *Proceedings: Image Understanding Workshop*, (to appear). Morgan Kaufmann, November 1994.

[Beveridge *et al.*, 1994b] J. Ross Beveridge, Durga P. Panda, and Theodore Yachik. November 1993 Fort Carson RSTA Data Collection Final Report. Technical Report CSS-94-118, Colorado State University, Fort Collins, CO, January 1994.

[Schwickerath and Beveridge, 1994] Anthony N. A. Schwickerath and J. Ross Beveridge. Three Dimensional Model to Multisensor Coregistration. In *Proceedings: Image Understanding Workshop*, (to appear), Los Altos, CA, November 1994. ARPA, Morgan Kaufmann.