Infrared target simulation environment for pattern recognition applications

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Infrared Target Simulation Environment for Pattern Recognition Applications

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ABSTRACT

The generation of complete databases of infrared (IR) data is extremely useful for training human observers and testing automatic pattern recognition algorithms. Field data may be used for realism, but require expensive and time-consuming procedures. Infrared scene simulation methods have emerged as a more economical and efficient alternative for the generation of IR databases. A novel approach to IR target simulation is presented in this paper. Model vehicles at 1:24 scale are used for the simulation of real targets. The temperature profile of the model vehicles is controlled using resistive circuits which are embedded inside the models. The infrared target is recorded using an Inframetrics dual channel IR camera system. Using computer processing we place the recorded IR target in a prerecorded background. The advantages of this approach are: (i) the range and 3-D target aspect can be controlled by the relative position between the camera and model vehicle; (ii) the temperature profile can be controlled by adjusting the power delivered to the resistive circuit; (iii) the IR sensor effects are directly incorporated in the recording process, because the real sensor is used; (iv) the recorded target can be embedded in various types of backgrounds recorded under different weather conditions, times of day etc. The effectiveness of this approach is demonstrated by generating an IR database of three vehicles which is used to train a back propagation neural network. The neural network is capable of classifying vehicle type, vehicle aspect, and relative temperature with a high degree of accuracy.

1. INTRODUCTION

Infrared (IR) sensor technology has advanced to the point where present-day staring arrays, such as the Kodak Platinum Silicide infrared camera system [1], provide high resolution images at video rates. Infrared imaging applications range from night vision surveillance and remote sensing to industrial inspection and medical imaging [2], [3]. One application area which has received considerable attention is the identification and classification of infrared targets by both humans and computers. The rapidly evolving IR detector technology yields infrared images of improved quality, but also places high demands on new methods for training and testing automatic target recognition (ATR)
algorithms which need to be continuously updated. Training and testing of both humans and machines require the generation of complete databases of infrared targets. An IR target database is preferably obtained from field data collected using various targets, operating temperatures, weather conditions, and sensors. However, generating field data is costly, time-consuming, does not allow control of the scene parameters, and can be done only for a limited number of targets and terrains. As an alternative to field data, scene simulation methods have been used to generate IR databases in a more efficient and cost-effective manner.

Infrared scene simulation is a challenging problem due to the large number of variables involved. In order to create a realistic IR scene, one must be able to control many scene characteristics related to IR targets, backgrounds, environmental and atmospheric conditions, and sensor characteristics. The parameters which are considered most important are listed below:

1. Target type
2. Target aspect
3. Target range
4. Depression angle
5. Partial obscuration
6. Inter target distance
7. Background type
8. Target to background contrast
9. Interactions between targets and background
10. Daily temperature variations
11. Atmospheric effects
12. Detector characteristics

A number of approaches for the generation of synthetic IR targets and backgrounds have been pursued. Here we briefly note two fundamental approaches, the physical terrain board and the digital terrain board [4], developed at the Night Vision and Electro-Optics Laboratory (NVEOL), which have served as motivation for developing the present method. In the physical terrain board approach, model vehicles are first hand-painted to simulate their temperature profile in the infrared, and then recorded in the visible under special lighting conditions to eliminate shades. Computer processing is used to introduce sensor and atmospheric effects. The digital terrain board is the most recent approach pursued by the NVEOL, where the entire infrared scene is generated digitally. This approach is efficient and flexible, but requires intense computations, and the development of models for representing the tree-dimensional targets and modeling the sensor response. As the sensor technology advances, models of new sensor characteristics need to be updated and incorporated in the generation of the IR scenes.

In many IR scene simulation approaches, including the physical and digital terrain boards, one of the most challenging problems is the realistic representation of sensor effects in the synthetic IR scene. Infrared sensor degradations are often incorporated by post-
processing the simulated scene [5]. In the IR scene simulation environment presented in the next section an alternative approach is presented, where realistic IR targets are generated easily, accurately, efficiently, without the need for computer post-processing to simulate the sensor characteristics.

2. INFRARED TARGET SIMULATION ENVIRONMENT

A novel environment for infrared target simulation is presented which combines fast acquisition of infrared images and realism in representing the sensor characteristics. The new approach taken is to simulate real infrared targets with model targets of variable temperature profile which are recorded with the infrared camera of choice. The model targets provide realism in the three-dimensional target representation, while the sensor effects are directly incorporated in the recording process by using an infrared camera.

The system block diagram is shown in Figure 1. Model vehicles are chosen at 1:24 scale. The temperature profile at the surface of each model vehicle is controlled by varying the current through a resistive network which is embedded inside the model. The power dissipated at each resistor generates heat which is conducted to the surface of the model vehicle.

Once the resistive network is hardwired inside the model vehicle, the infrared camera is used for recording. In our setup, the IR target is recorded using an Inframetrics 610 camera system, which has two output video channels corresponding to the 3-5 \( \mu \text{m} \) and the 8-12 \( \mu \text{m} \) bands. Depending on the relative position of the camera and model vehicle, an IR target may be recorded at any range and three-dimensional aspect. Sensor effects are directly incorporated in the image because the true IR sensor is used. This fact eliminates the difficult step of simulating sensor characteristics which is necessary in other methods.

The Inframetrics camera output is captured in digital form using a frame grabber. The digital image is processed so that the target is embedded in the infrared background of choice. In this paper, we assume that a number of backgrounds are available from field measurements and that it is not necessary to synthetically generate background images. The target embedding involves the following steps: (a) segmentation of the target image, (b) placing the target image in the background image, and (c) blending the edges of the segmented target the adjacent background region. Since the true IR detector is used to record the image, the sensor effects are present and need not be simulated. It should be noted that the target image should not be scaled in order to preserve identical sensor characteristics between the target and background images. The target size is adjusted during the recording process by the relative positioning of the target model and the IR camera.
3. TARGET SIMULATION RESULTS

An all important step in the IR target simulation process is the validation of the generated IR images. It is essential that the simulated IR targets offer realistic representations of true targets. In this experiment, we chose model automobiles for the generation of IR targets which could be compared with IR images of real automobiles. Three 1:24 model vehicles were used to obtain IR images as shown in Figure 2. The temperature profile of each vehicle was controlled by the positioning of the resistors inside each model, the power delivered to each resistor, and the time elapsed between switching on the power supply and recording the IR image. The variation of the temperature profile of a vehicle is illustrated in Figure 3.

The step of embedding the IR target in a background obtained from field data is illustrated in Figures 4 and 5. Figure 4 shows the IR image of a parking lot which was recorded at the University of Rochester from the 8-12 μm band of the Inframetrics camera. The parking lot image is used as the background where one of the simulated IR vehicles is embedded as shown in Figure 5. It can be seen in Figure 5, that the linear scanning artifacts of the sensor are preserved in the simulated vehicle. The model IR target blends well in the IR scene as a result of the edge processing algorithm. When compared with other vehicles in the parking lot of Figure 4, the simulated IR vehicle appears realistic.

4. PATTERN RECOGNITION USING NEURAL NETWORKS

In this section, we illustrate how a database of IR targets may be generated and used to train and test ATR algorithms. In this simple example, we train and test a neural network classifier using the three vehicles shown in Figure 2, named sedan, sports car, and vintage. All three vehicles were recorded at three aspects of 30, 60, and 90 degrees. The current through the resistors in each vehicle was adjusted to reflect a temperature profile of high, medium, and low heat generated by the working engine, friction on tires, and exhaust. The resulting 27 images formed the database which was used to train the ATR algorithm.

A back propagation neural network [6], [7] was trained to recognize the 27 IR targets. The neural network was designed to have 256 neurons at the input layer, corresponding to a 16x16 input image, one hidden layer with 50 neurons, and 9 neurons at the output layer. The output layer neurons correspond to the three vehicle types, the three aspects considered, and the three temperature levels. This neural network topology was preferred over one where the output layer has just three output neurons corresponding to the three vehicle types, because it provides more information about the scene and results in faster convergence during training. The dimensions of the 16x16 input image to the neural network may not always correspond to the dimensions of the target image. In such cases,
the target image should be appropriately scaled to fit the 16×16 window accepted by the neural network.

After training was completed, the neural network performance was tested using a set of 81 IR images. The testing set included the 27 images in the training set, 27 images obtained by rotating each image in the testing set clockwise by 5 degrees, and 27 images obtained by rotating each image in the testing set counterclockwise by 5 degrees. The neural network was able to successfully classify the vehicle type, vehicle aspect, and temperature level in 78 out of the 81 trials. In two trials the wrong vehicle type was selected, and in one trial the wrong temperature level was selected.

5. CONCLUSIONS

We have presented a new environment for the simulation of infrared targets. The advantages offered by this approach are fast and realistic representation of three-dimensional targets and direct incorporation of the sensor effects in the measurement process. The primary constraint is the requirement of an IR camera for recording the model targets. The usefulness of this environment was illustrated by generating a database of three targets which were used to train and test a back propagation neural network.

6. ACKNOWLEDGMENT

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7. REFERENCES


Figure 1. Infrared Target Simulation Environment at the University of Rochester
Figure 2. Infrared vehicle simulation using 1:24 scale models recorded in the 8-12 μm band: (a) Sedan, (b) Sport, (c) Vintage
Figure 3. Variations in the temperature profile of a simulated IR vehicle
Figure 4. Parking lot image recorded in the 8-12 μm band

Figure 5. Embedding of simulated IR vehicle in parking lot background (8-12 μm band).