Cooperative Coevolution Fusion for Moving Object Detection

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Abstract. In this paper we introduce a novel sensor fusion algorithm based on the cooperative coevolutionary paradigm. We develop a multisensor robust moving object detection system that can operate under a variety of illumination and environmental conditions. Our experiments indicate that this evolutionary paradigm is well suited as a sensor fusion model and can be extended to different sensing modalities.

1 Introduction

A moving object detection system attempts to detect and distinguish objects such as moving pedestrians, vehicles, animals, motorcycles, bicyclists, and generally animated objects in a scene. The scene is assumed to be static and is generally referred to as background. Moving object detection systems include feature-based [1] and featureless [2] methods. These methods generally use a single sensing modality such as a video camera, a near infrared camera, or a thermal infrared (IR) camera. The assumption of the static background is generally invalid for outdoor scenes. To adapt and capture background movements, such as swaying trees, and illumination changes, statistical-based techniques are applied to represent the background. Unfortunately no single modality can operate under all environmental and illumination conditions. For example, during the nighttime, without active illumination, video cameras are useless, and during high noon in warm places, temperatures of certain background objects such as asphalts and concrete can reach as high as vehicle or other moving objects in the scene which makes the task of distinguishing objects difficult.

We overcome the above problems by combining multiple sensors in a seamless fashion. Each sensor operates at a different part of the electromagnetic spectrum and provides advantages that can complement other sensors. Our sensor fusion algorithm automatically integrates sensors at the pixel level where the information loss is minimal. This integration is performed in a cooperative manner (e.g., each sensor contributes its best representation of the background scene at each instance in time.) In order to find this representation, we provide a search mechanism based on the cooperative coevolutionary paradigm. In this manner, the problem of moving object detection is divided into subtasks (for each sensor), video and longwave IR, in this paper. Each sensor then provides the best background representation in a cooperative manner.

2 Cooperative Coevolution Fusion

In order to detect a moving object in an image, first a background model for each pixel in an image must be constructed. The system uses both collected statistics and physics-based predictions of the signals from a video and thermal IR sensor. For each sensor, we represent each background pixel by a mixture of Gaussian distributions. The statistics are collected by simply observing a scene for a short period of time. During this time, various reflectance and thermal models, are applied to estimate the observed values. The physical models integrate contextual information into the system. These external conditions and variables include, time of day, location (latitude, longitude), sun's zenith angle, wind velocity, surface absorptivity and emissivity. These external conditions and variables are input to the physics-based models along with sensor inputs to provide predicted values for the observation from each sensor.

The degree of agreement between the physics-based predictions and the actual observations is the driving force in the coevolutionary adaptive module to generate the background model that can best describe the scene. The background models are input into a fusion module, which makes the decision (foreground pixel, background pixel) about the pixels in the current frame. This decision, along with a limited past history in turn provides training data for the co-evolutionary module. The success of this process ultimately relies on how well the background is modeled. In order to correctly estimate the background models in either the video or thermal images, we must collect a great deal of statistics. We have shown that a good estimate of the background can be achieved by observing a scene for a period of time where great deal of statistics can be collected [2]. The scene must then be tracked so the models can adapt to the dynamics of the environmental and illumination conditions. In the case of limited or non-existent statistics or sudden changes, purely statistics-based background modeling will be impractical if not useless. This is one place where the physics-based predictions for each sensor play an important role. They provide an estimate for the expected observations from each sensor.

In our approach, the cooperative coevolutionary algorithm [3], evolves populations of mixture of Gaussians. This evolution is affected by both observations and the physics-based predictions, which embed the environmental variables thorough a fitness function. The algorithm for building the background model starts by collecting some initial samples. These samples come from a moving window that is kept in the memory and contains an initial number of frames. For the given initial samples, and the environmental conditions, physics-based modules predict both reflectance (for video sensor) and temperature (for IR sensor) of the observed values. The cooperative coevolutionary algorithm is then applied to search for the best representation (mixture of Gaussians) for both sensing modalities.

After the background models are built, for each incoming frame from both video and IR, the frames are spatially registered. The value of each pixel in the registered image is then compared to the background models for that pixel, and the pixels whose values do not agree with the models for that pixel are detected as the foreground or moving object.

3 Experimental Results

Figure 1 shows the receiver operating characteristic (ROC) curves. These curves were obtained for two different periods of the day where IR performed better than video in early morning hours and vice-versa in the afternoon. As indicated, the fusion method clearly performed better consistently over the non-fused (single) sensors.

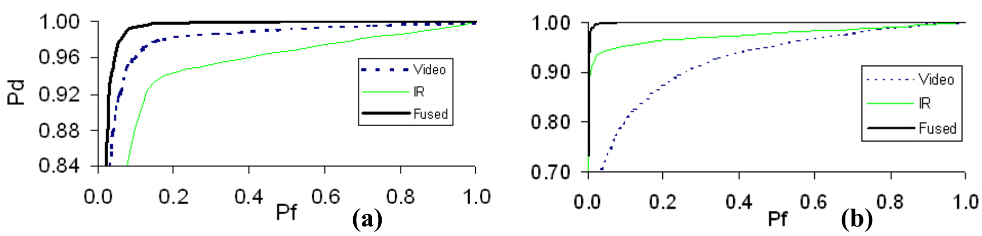

Figure 1. Roc curves for (a) afternoon, (b) early morning.

Conclusion

A new sensor fusion method based on cooperative coevolutionary paradigm was introduced for integrating sensors of different modality. Experiments for moving object detection indicate that our fusion approach is robust to many environmental changes.

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2. S. Nadimi and B. Bhanu, “Multistrategy fusion using mixture model for moving object detection,” *Intl. Conf. Multisensor Fusion & Integration for Intelligent Systems*, pp. 317-322, 2001.

3. M.A Potter and K.A. De Jong, “Cooperative coevolution: an architecture for evolving coadapted subcomponents,” *Evolutionray Computation*, Vol. 8, No. 1, pp. 1-29, 2000.