Presentation Summary

Background and Foreground Modeling using Nonparametric Kernel Density Estimation for Visual Surveillance

Robert F.K. Martin
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With the advent cheaper sensors, visual surveillance is a field that will continue to grow with almost no end in sight. As cameras and computers improve, there is an urgency to produce more robust algorithms that will provide better detection results.

One of the first steps in visual surveillance is to produce a background model. For systems involving a stationary camera this allows the user to label objects in the scene as either foreground or background. The most common method, around since the middle 19th century, is simple scene averaging. A similar method is to use an IIR filter. In the 1990's more complex algorithms were introduced. Backgrounds were modeled as an adaptive Gaussian process, with an additional modification of using a Kalman filter. Another modification was to model the background using multiple Gaussians which allowed for a richer background description.

Kernel density estimation (KDE) is used to move away from the explicit Gaussian model. The strength of KDE is that it can converge to any distribution given enough samples. The trade-off then is to find the number of samples that gives the best accuracy without being a computational nightmare.

Given a list of samples, KDE evaluates a kernel, typically a Gaussian but can be any unit area curve, at every point and sums the results which gives the underlying probability distribution function (pdf) from which the samples came. Given this pdf, a threshold is selected to optimally label the samples into one of two classes. An extension to color can be achieved by taking the product of the kernel for each color channel.

To prevent false detection, a modification is proposed in which the probability of a pixel is taken to be the maximum probability in its neighborhood. This will suppress lone pixels from being labeled as foreground. As a final step, holes in connected components are filled in considering the product of all the probabilities of the components.

KDE can also handle shadows by transforming RGB to chromaticity. Using r and g to create a pdf, the lightness s is used to guide which pixels could possibly be caused by a shadow. A shadow can never cause the lightness to increase nor can it decrease it beyond a certain threshold. By ignoring those pixels we can eliminate foreground pixels caused by shadow.

Elgammal and his colleagues have shown that KDE can be a powerful and robust tool for background modeling. However, careful consideration must be given to optimization so that this step does not overwhelm the processor.