Carnegie Mellon

DATA PRIVACY LAB

Smart Cameras: Counting People

Mining Images in Publicly-Available Cameras for Homeland Security

A dramatic increase or decrease in the number of people appearing at a location can be an indicator that something has happened that may be of interest to law-enforcement, public health, or security. This work demonstrates how low quality camera images can be used to automatically alert when an unusual number of people are absent or present at a location. We report on experiments using publicly available, inexpensive cameras already operational over the Web. A "historical database" (H) for each camera is constructed by capturing images at regular time intervals and applying a face detection algorithm to store the number of faces appearing in each image ("face count"). Later, given an image X having timestamp t, if the face count of X is significantly higher or lower than the expectation inferred from H for time t, an unusual number of people are considered to be present in the image.

Figure 1. Image captured from publicly available webcam on left and with automated face detection on right.

Face Detection

Given an image, Schneiderman's face detection program [2004] reports the number of faces found by exhaustively comparing varying size models faces against all pixel positions.

Anomaly Detection

Hutwagner et al. at CDC proposed an aberration detection model for bioterrorism surveillance of hospital data [2002]. Deviations in current data are compared to an historical average. Our approach builds on this notion. In the initial phase a historical database is constructed from which averages are computed (steps 1 and 2 in Figure 3). Then, in an operational phase, a decision is made about the number of people appearing in a given image based on shifts away from the mean (step 3 in Figure 3).

CameraWatch

Figure 2. Example URLS from NYC.

In 2003, Sweeney developed automated tools that mine the World Wide Web ("Web") for web addresses (or "URLs") of on-line cameras. More than 6000 webcams showing people in public spaces in the United States were found. A sample of 200 of these URLs are available at privacy.cs.cmu.edu/dataprivacy/projects/camwatch/.

One URL was selected from CameraWatch as the subject of these experiments. The URL is www.earthcam.com/cams/newyork/timessquare/. It views Time Square (1552 Broadway at 46th Street, New York, NY 10036). Figure 4 provides an example of an image from this webcam. We did not place this camera on-line! We're just using it.

1. A "historical database" (**H**) for a camera is constructed by capturing images at regular time intervals throughout each day and applying a face detection algorithm to each image captured. The number of faces appearing in each image ("face count") along with a date and timestamp are stored.
2. Averages and standard deviations are computed for each time interval in **H** over varying classes to which the date and time stamp belongs. Date classes include current weekdays/weekend, day of week, time of month, and seasons. Holidays and events are a special class.
3. Given an image *X* having timestamp t_X, if the face count of *X* is more than 2 standard deviations above the average (or 2 standard deviations below the average) of any class to which t_X belongs, then an unusual number of people are considered to be present in the image.

Figure 3. Overall approach for detecting whether an unusual number of people are appearing in a camera image.

Images from the webcam (Figure 4) were captured every 10 minutes, 24 hours a day, for 4 work days in the winter (December 6, 7, 8 and 10, 2004). It rained for 2 of the 4 days. The Face Detection Program was applied to each image and the results stored, along with the date and timestamp of the image capture.

Figure 5 shows the average the average number of faces detected for each time interval in the Historical Database. Someone is almost always present and the most number of people are present at lunch and dinnertime. 3am has fewest people.

A manual count of the actual number of people appearing in each image was done. People whose heads (not necessarily faces) appear in the store or on the sidewalk up to the mailboxes are included. See Figure 4, which has a manual count of 11 people. A linear regression between the number of faces detected in the Historical Database and the actual number of people counted in the earlier part of the day (no rain) has R2=0.76 (best is 1).

The range of values considered "normal" for the Historical Database for each time interval is computed by taking the averages (Figure 5) and adding and subtracting 2 standard deviations from each. Figure 6 shows the resulting range of values. If the number of people typical at noon appeared at 3am (or vice versa), the population would be considered "unusual." As an ad hoc example, on New Year's eve, the number of people was considered unusual by 11am when we did not account for that being a special holiday.

Figure 4. View from publicly available webcam in NYC. Ten faces were detected, and 11 were manually counted.

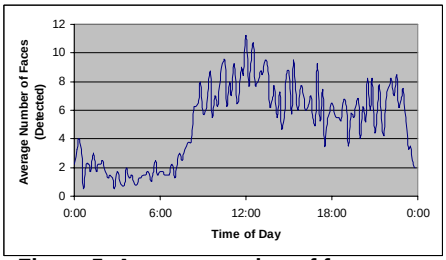

Figure 5. Average number of faces detected in webcam images (see Figure 2) during a standard weekday from one week in the winter. Noon (12:00) is the most popular time and 3am (3:00) is least popular.

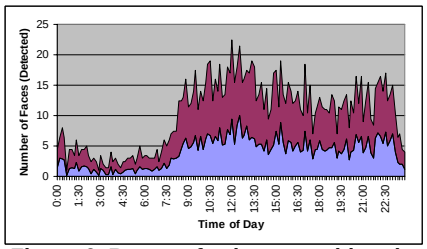

Figure 6. Range of values considered "normal" for the time of day (middle area). Values above (top) or below the middle area (bottom area) are considered "unusual."

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http://privacy.cs.cmu.edu/dataprivacy/projects/videocount/index.html