ADSA15:
Attribute-Based Searching and 360^{o} Surveillance Video

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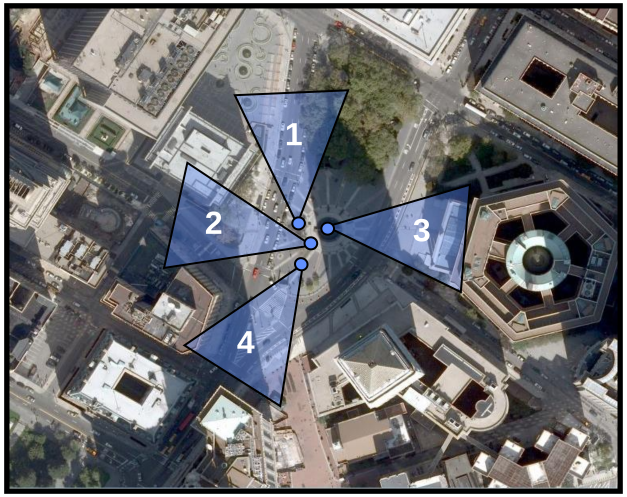
So what? Who cares?

- **Topic Areas:**
  - **Video Surveillance Technologies and Video Analytics**
- **Challenges addressed**
  - **Video surveillance trade-off between coverage and resolution**
  - **Forensic video search for a person of interest**
- **What did we do?**
  - **Built a high resolution 360 degree camera system with COTS parts and demonstrated system at Logan Airport**
  - **Developed an attribute-based search tool**
- **Benefits:**
  - **High quality video with coverage everywhere ensures every incident is recorded**
  - **Improve forensic search time from hours to tens of minutes**

Critical Infrastructure Protection
Video Surveillance

Typical problem: Foley Square, NYC



Typical operator control room

- **Video surveillance challenges**
  - **Inadequate resolution**
  - **Disjointed situational awareness**
  - **Gaps in camera coverage**
  - **Operator fatigue / overload**

Immersive Imaging System (IIS)

Size	13.5" diameter
Resolution	1.2 cm @ 100m
Pixels	240 megapixels
Frame Rate	8 frames/second
Data Rate	1 TB / hour

- **360 degree coverage from sensor location**
- **Compact and lightweight**
- **On-board electronics and firmware**
- **Inexpensive components – cell phone imagers**

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Logan Airport (Terminal A) Deployment

- **MASSPORT / TSA / Police Needs**
  - **Real-time scene monitoring and situational awareness**
    - **Comprehensive 360 degree coverage**
    - **Automated cuing of real-time events**
  - **Forensic incident review and suspect backtracking**
    - **Automated image search**

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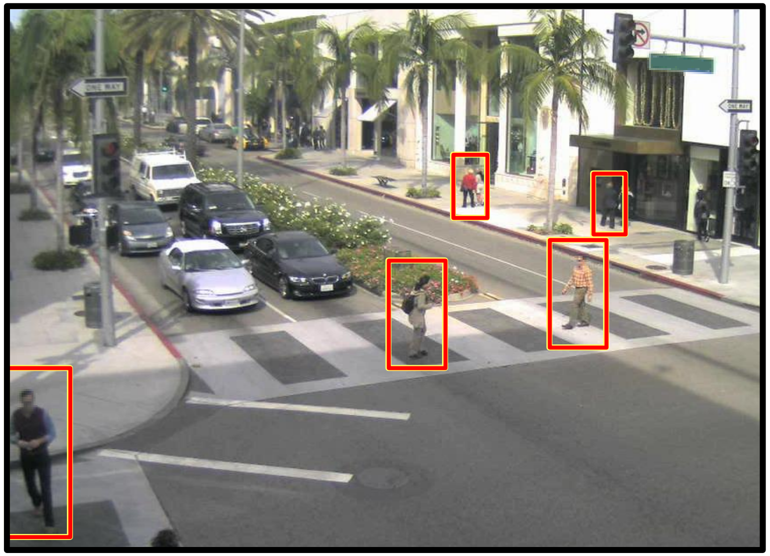
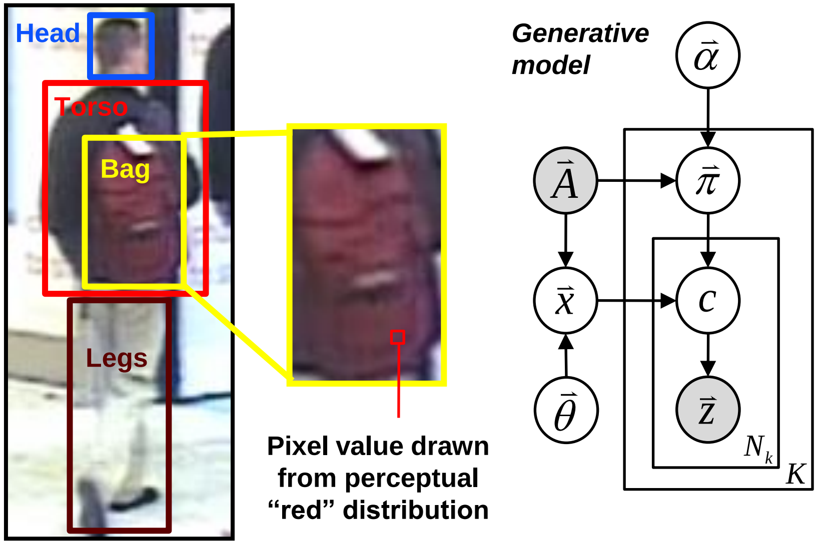
Attribute-Based Searching

Robust moving person detection

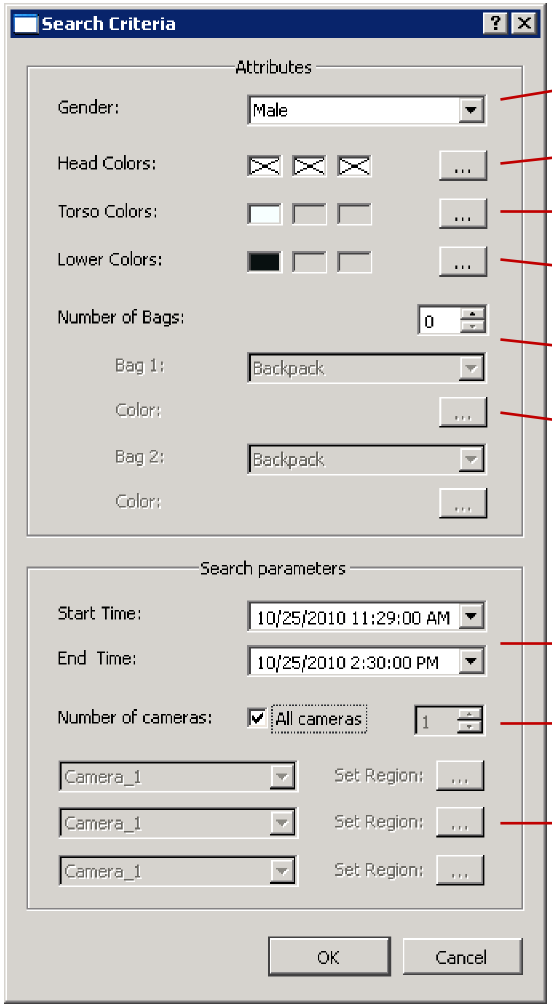


Probabilistic image interpretation



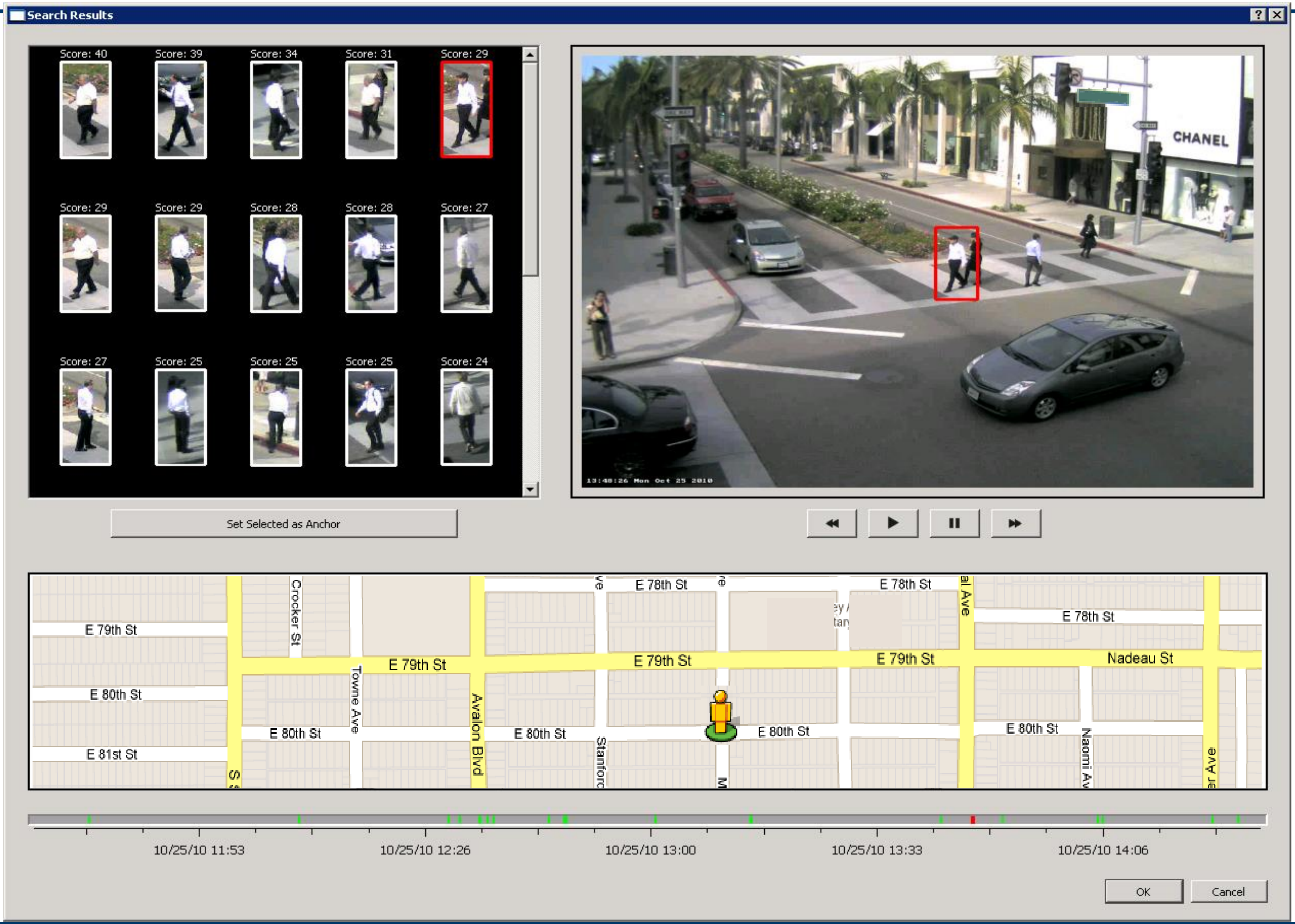
- **Key elements**
  - **Combining contour characterizations, foreground detection, and perspective information in order to get robust moving person detection**
  - **Defining flexible hierarchical probabilistic models for the appearance of persons and their sub-components**

Example : Search Input



- Gender
- Hair / hat color
- Torso clothing color
- Lower body clothing color
- Number and type of bags
- Bag color
- Search time window
- Cameras to search
- Search regions within camera views

Example : Search Results

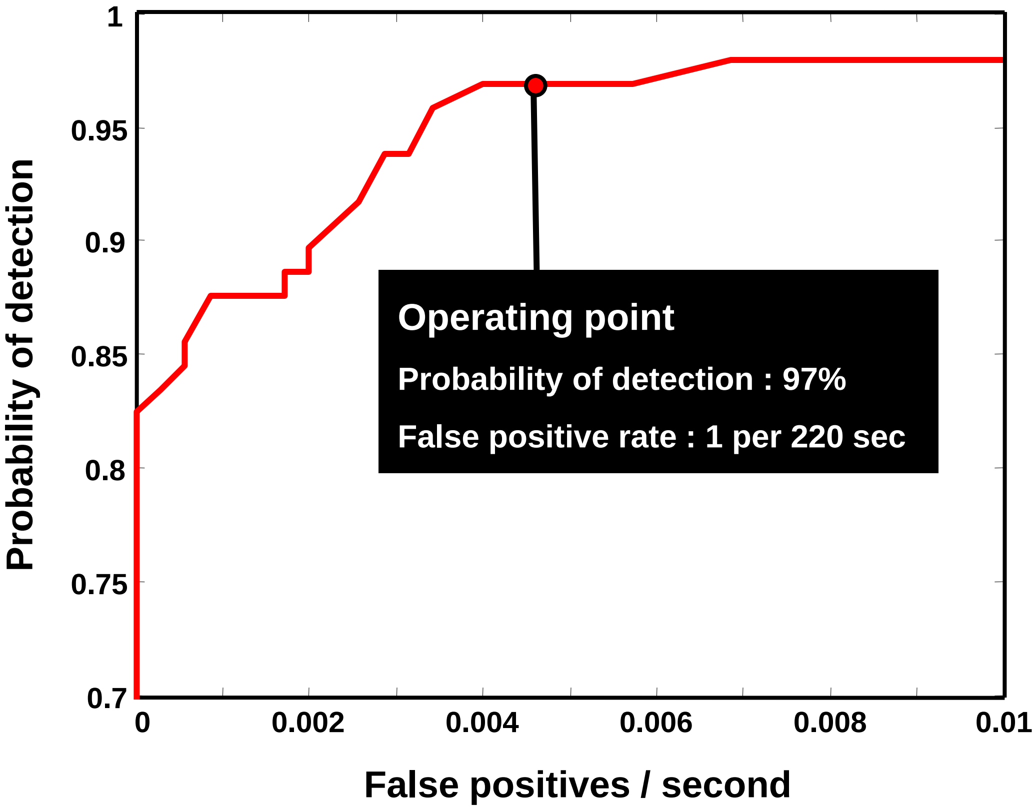


Person Detection Performance

Example surveillance region

- **Unobstructed view**
- **Average person height: ~100 pixels**
- **Moderate pedestrian flow**

ROC curve for person detection

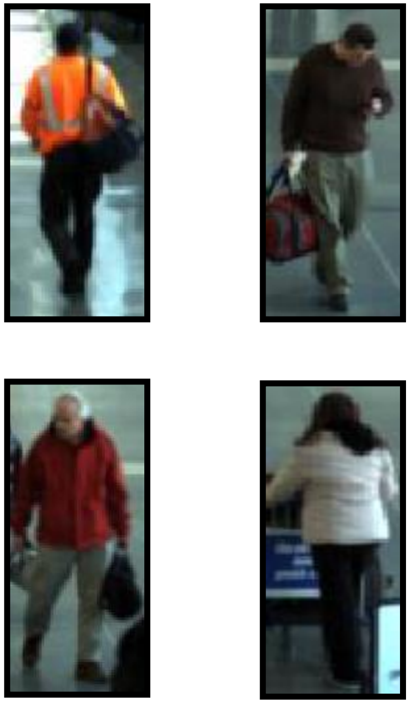


- **Person detection works very well for indoor views with moderate crowd flow and sufficient pixels-on-target**

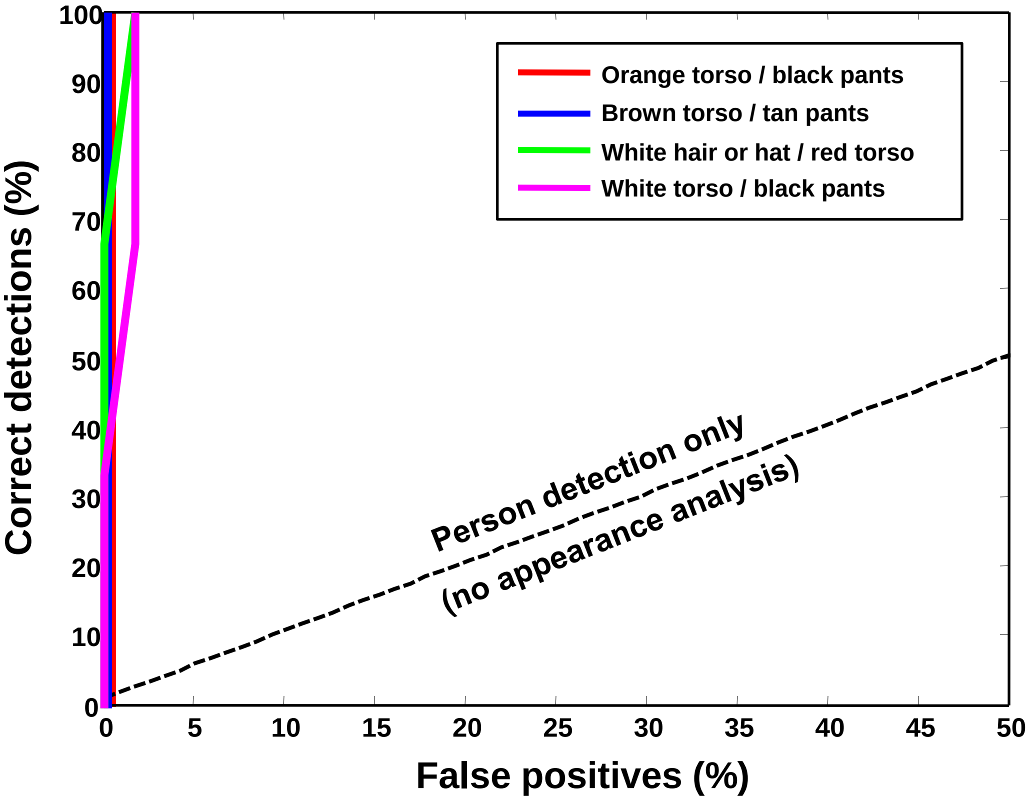
Attribute Scoring Performance

- **Label attributes for all persons who pass through one area of terminal**
- **Execute sample searches, then count missed detections or false positives**

Sample search targets



ROC curves



Summary

- **Built high-resolution 360 degree video surveillance system for critical infrastructure protection**
  - **Demonstrated system at Logan Airport and other public spaces**

- **Developed attribute-based search application**
  - **One of many video analytics applications from MITLL**

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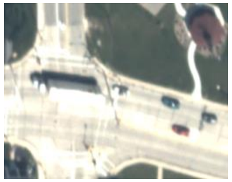
Backups

IIS System Goals

- **Capture high resolution imagery to detect and identify vehicles and people**

	Detection	Identification
Vehicles	**50 cm resolution** 	**13 cm resolution** 
People	**20 cm resolution** 	**1.2 cm resolution** 

240 million pixels for 360º coverage within 100m

- **Provide wide-area persistent camera coverage (240 Mpixels) - Challenges**
  - **High pixel count sensor**
  - **Efficiently manage and store data**
  - **Provide useful forensic and tactical tools to assist the user**
  - **Potential to be cost effective**

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Program Information

- **Immersive Imaging System (IIS)**

- **Sponsored by DHS S&T**
  - **POC: John Fortune**
- **Partners: Pacific Northwest National Labs**
  - **POC: Douglas MacDonald**
- **Patents Issued:**
  - **US Patent No. 9007432: Imaging Systems and Methods for Immersive Surveillance**
  - **US Patent No. 9036001: Imaging System for Immersive Surveillance**

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Pacific Northwest
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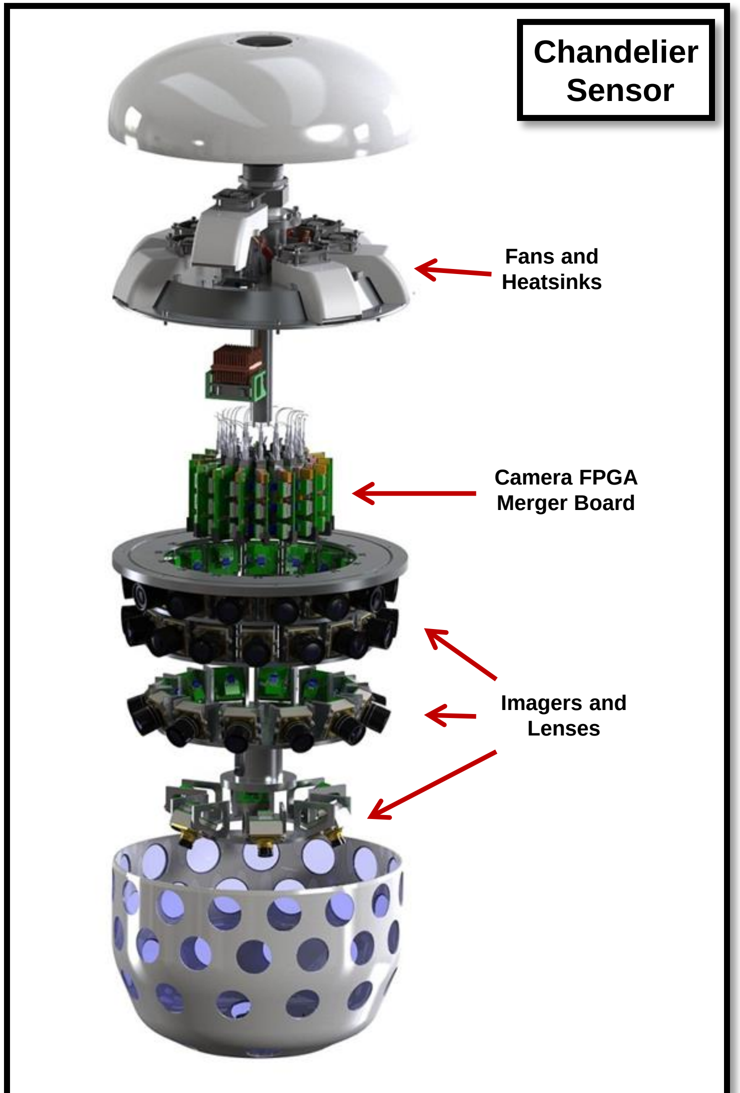
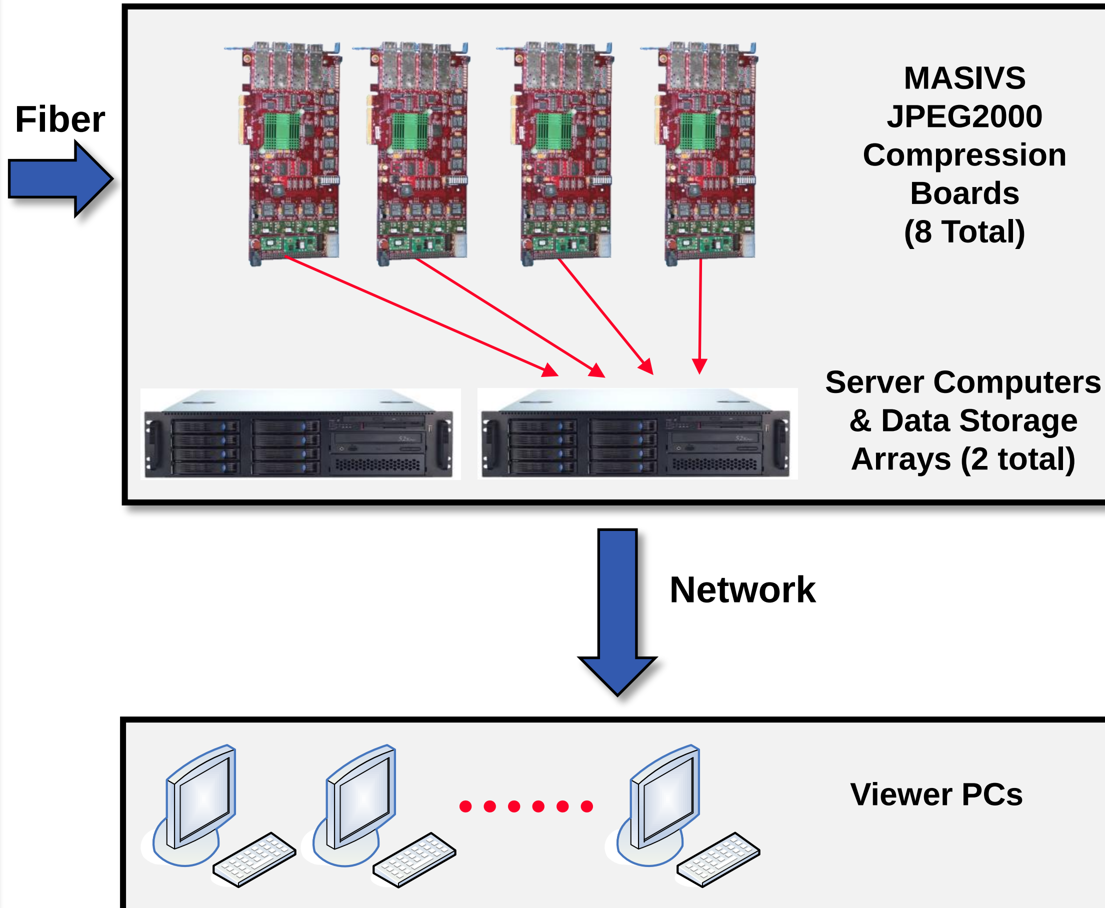
R&D Magazine Top 100 | **Popular Science** | **C4ISR Top 5 Award**

IIS Spiral 3 System Components





Seam Calibration

- **For each camera pair**
  - **Using nominal parameters approximate overlap**
  - **Extract common features**
  - **Find matching features in feature space**
  - **Refine matches using RANSAC algorithm assuming a projective transform**

- **Optimize over all parameters using error in projected features**

SIFT Features

Unprocessed IIS Image

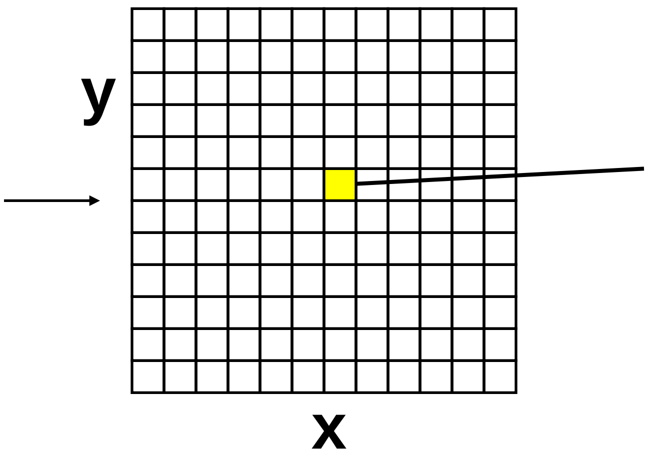
Processed IIS Image

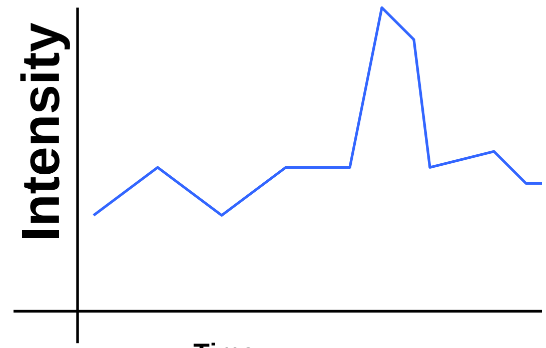
Mover Detection

- **Leverage detection algorithms from Constant Hawk**
  - **Adaptive statistical background modeling**

Rendered Image

Bin to increase SNR





Online computation of Mean (M) and Variance (σ^2)

α **= learning rate = 0.2**

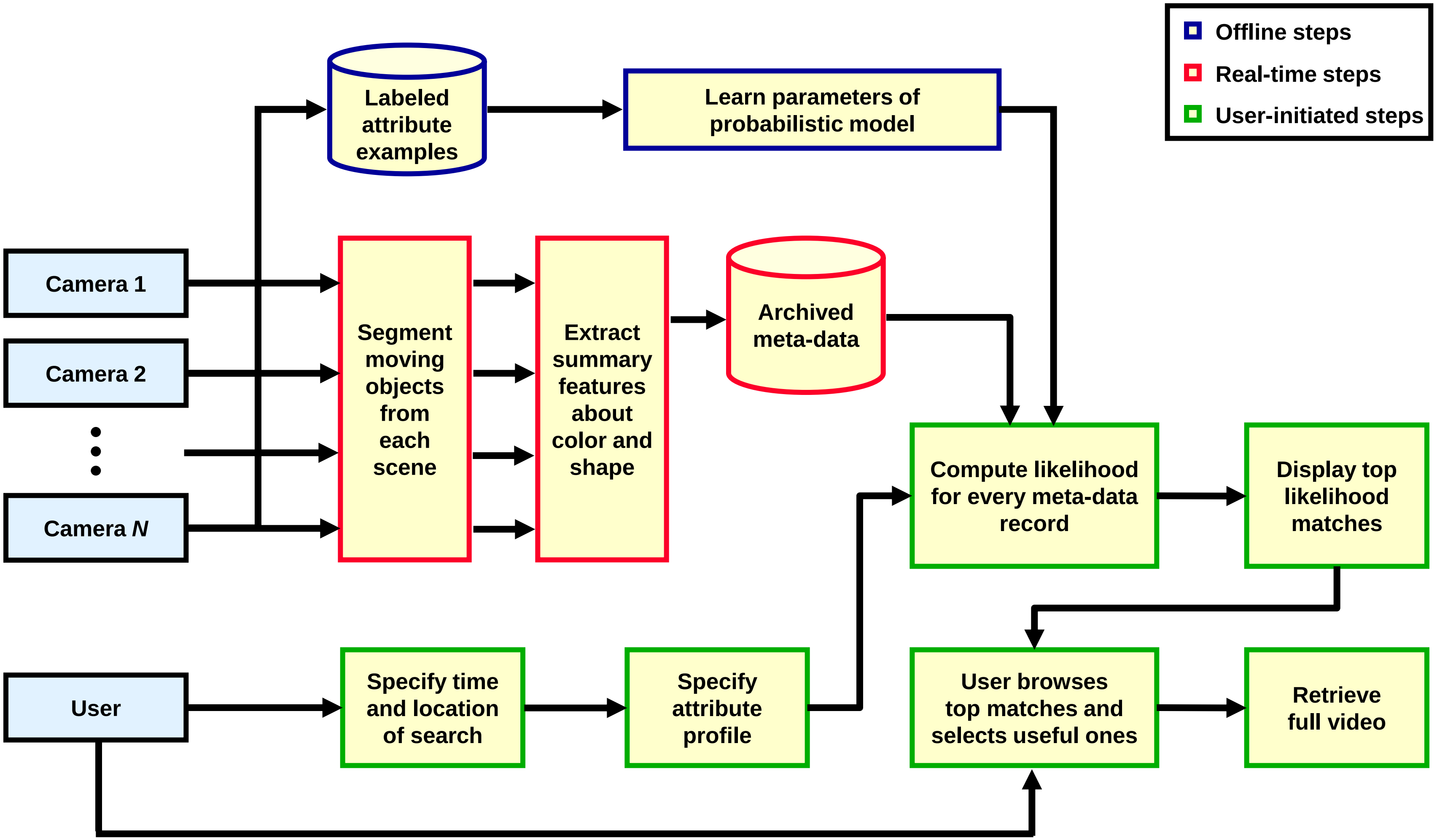
$$M_t(x,y) = \alpha I_t(x,y) + (1-\alpha) M_{t-1}(x,y)$$

$$\sigma_t^2(x,y) = \alpha \sigma_{t-1}^2(x,y) + (1-\alpha)\left(I_t(x,y) - M_t(x,y)\right)^2$$

Test: if I(x,y) > N_{std}*σ, I(x,y) is a foreground object **N_{std} = 5.5**

MIT LL Approach

Algorithm flow chart:



Robust Person Detection

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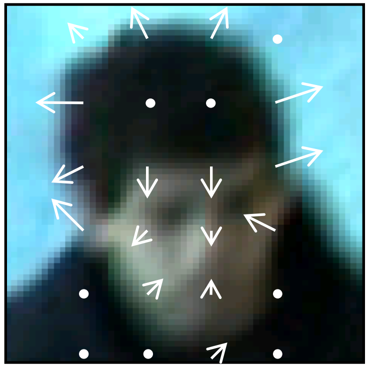
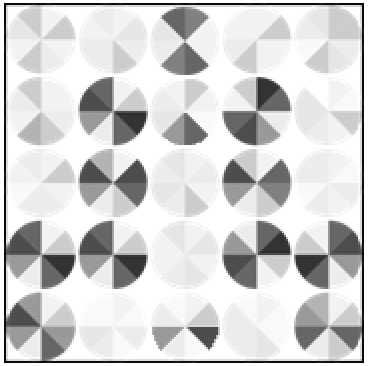
Contour analysis

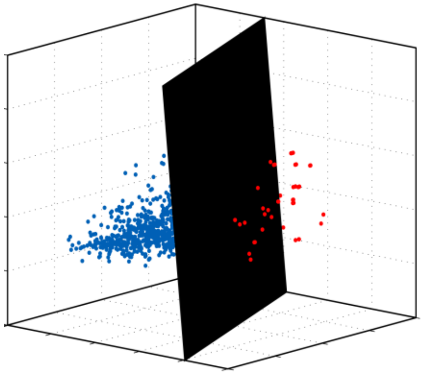
Compute image gradients



Compute local oriented gradient histograms



Apply SVM classifiers (trained on sample data)

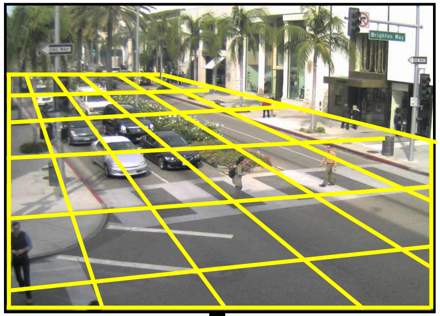


Male vs. female classification

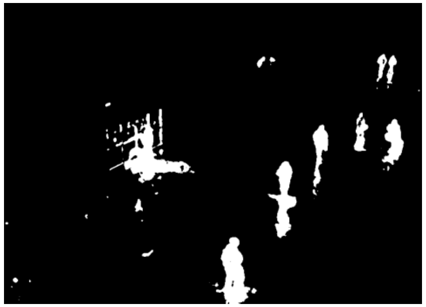
Person vs. non-person classification

Complete detection process

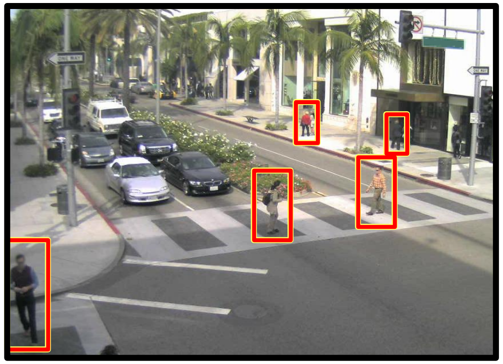
Ground plane estimation



Foreground estimation



Fused detections



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Gender Classification

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Male Samples

Female Samples

- **Retrain local gradient classifier for gender classification based on labeled examples**
- **Resulting classifier relies on contour characteristics (frame, hair, clothing, etc.)**

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Image Interpretation

Model concept

- Given a set of attributes, appearance of person is result of a hierarchical generative process
- At each level of hierarchy, there is a defined probability of generating observations at next level

Generative model structure

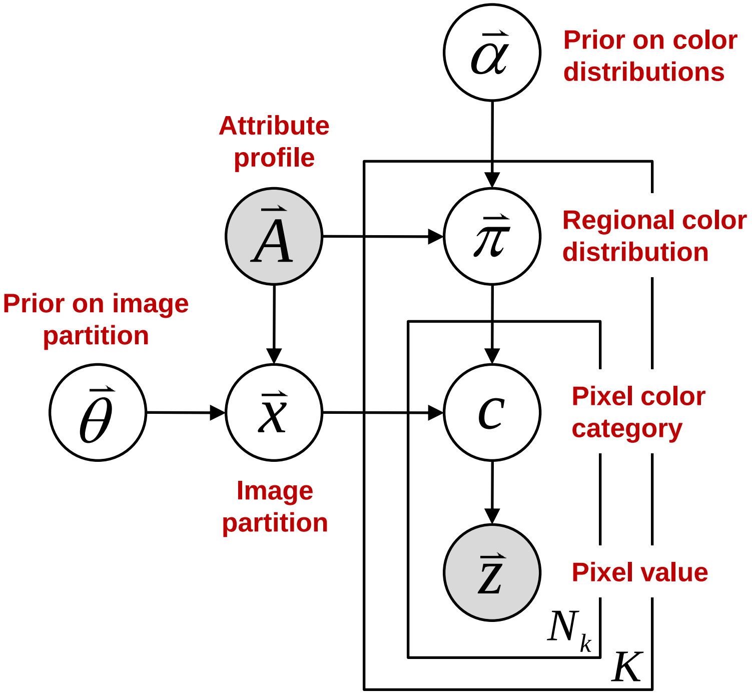

Illustration of hierarchy