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Multiple-Sensor Indoor Surveillance System

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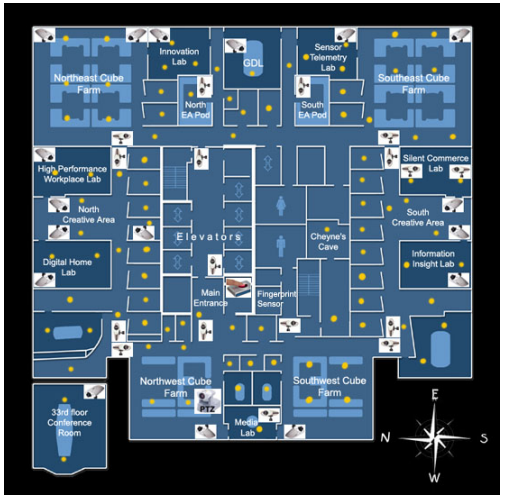
Environment

- The whole ATL floor
  - Area covered ~18,000 ft^2 (1,670 m^2)
- 32 AXIS-2100 webcams
  - ~ 3-7 Hz sampling rate
- Infrared badge system
  - 91 IR readers
- PTZ camera
- Fingerprint reader



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Multiple Sensor Indoor Surveillance Project

- MSIS Objectives:
  - Search and browsing the Event Repository database
  - Event Classification, Clustering and Visualization
    - How to visualize events captured by 32 cameras for 24 hours?
    - How to find rare events?
  - People Counting
  - People Localization -> Awareness Map
  - Real-time People Tracking
  - People recognition -> Interaction
  - Behavior and Activity Understanding

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What does a camera see?

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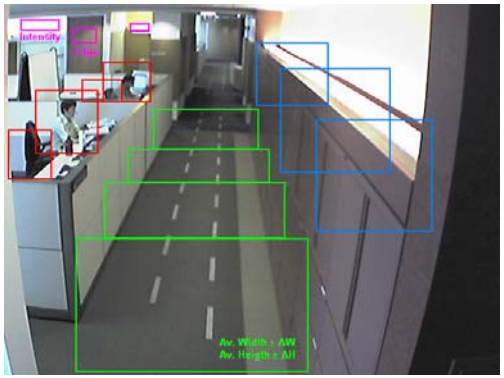
Camera Specification

- Operating Zone
- BG Model Type
  - Single Frame
  - Median Filter
- Important Areas
- Unimportant Areas
- Camera Calibration
  - Walking Zones
- Indicators
  - Edge/Intensity/Color



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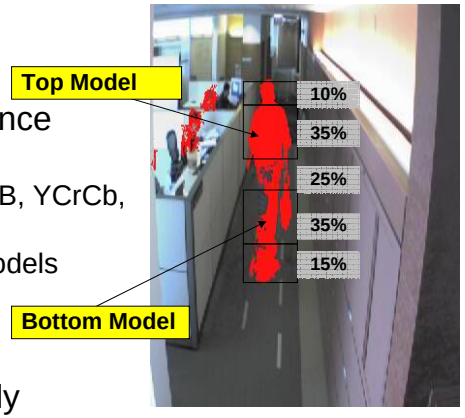
People Localization: Feature Extraction

- Features
  - Geometric features
  - Color-based Appearance Model
    - Color Histograms (RGB, YCrCb, etc.)
    - Gaussian (Mixture) Models
- Blob Extraction
  - Merging vertically
  - Separating horizontally



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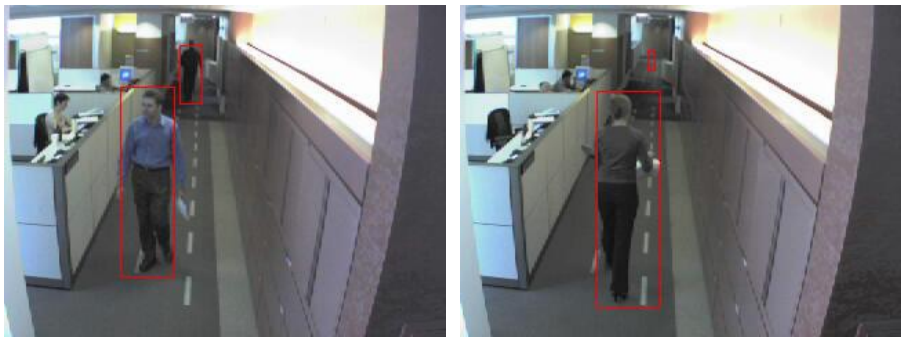
People Localization: Blob extraction

BG Model → FG Pixels → Merge Vertically



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People Localization: Blob separation

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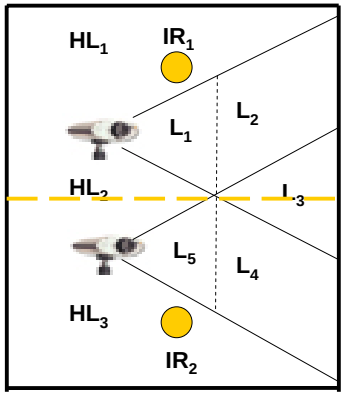
Sources of Sensorial Data

- Video cameras
  - Cover large area
  - Relatively reliable
- IR badge system
  - Covers large area
  - Rather precise
  - Unreliable
- Fingerprint station
  - Very precise
  - Rare available
- Face recognition
  - Moderately precise
  - Rare available
- Human intervention
  - Precise
  - Expensive



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People Localization: Algorithm

- $P(H_i \mid L_j)$ - probability H_i located at L_j
- $T_{ij}(H_k)$ – transition probability from L_i to L_j for H_k
- $M(H_k, L_i, C_m)$ – model for H_k at L_i and camera C_m

- *Step 1. Map regions (blobs) into locations for each camera*
  - R_q -> < C, x, y, L, e_q = { $P(R_q \mid M(H_k, L, C)$ } >
- *Step 2. Merge blobs from different cameras*
  - $E(R_q) = \{e_{q1}, e_{q2}, \ldots, e_{qQ}\}$
- *Step 3. Get related IR data, estimate likelihood function, map IR location into camera-based locations, add evidence to related objects*
  - $O = \{O_r\}$, $W = \{w_{kr}\}$ $k=1,K$, $r=1,M_0$,
  - $S_r = \{ P(R_j, L_k, C_q \mid H_{i_r}) \}$

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People Localization: Algorithm (cont.)

- *Step 4. Motion estimation*

$$\tilde{P}(H_i \mid L_j) = \frac{\left[\sum_{k=1}^{L} P(H_i \mid L_k) \cdot t_{kj}(H_i)\right] \cdot P(H_i \mid L_j)}{\sum_{l=1}^{L}\left[\sum_{k=1}^{L} P(H_i \mid L_k) \cdot t_{kj}(H_i)\right] \cdot P(H_i \mid L_l)}$$

- *Step 5. Calculate posterior probability*

$$P(H_i \mid O_r, L_k) = \frac{\tilde{P}(H_i \mid L_k) \cdot w_{kr} \cdot \prod_{P(R_j, L_k, C_q) \in S_r} P(R_j, L_k, C_q \mid H_i)}{P(O_r)}$$

$$P(O_r) = \sum_{i=1}^{N} \tilde{P}(H_i \mid L_k) \cdot w_{kr} \cdot \prod_{P(R_j, L_k, C_q) \in S_r} P(R_j, L_k, C_q \mid H_i)$$

- *Step 6. Normalize over locations*

$$P(H_i \mid L_k) = \frac{P(H_i \mid O_r, L_k)}{\sum_{k=1}^{L} P(H_i \mid O_r, L_k)}$$

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People Localization: Experimental Results

- Experiments
  - 4 hours
  - 15 cameras
  - 44 IR sensors
  - Close set
    - 15 "known" people
      - 7 with IR badges
  - Open Set
    - 15 "known" (7 with IR)
    - 10 "unknown"

	Closed Set Accuracy			Open Set Accuracy		
Person ID	Single Camera	Cameras and IR badge	Difference	Single Camera	Cameras and IR badge	Difference
1000	82.14%	87.56%	5.42%	71.39%	77.31%	5.92%
1002	99.27%	99.51%	0.24%	94.54%	95.81%	1.27%
*1003	86.88%	91.07%	4.19%	81.91%	86.10%	4.19%
1005	74.32%	81.69%	7.37%	62.73%	70.59%	7.86%
*1006	45.98%	69.68%	23.70%	43.78%	58.58%	14.80%
*1015	44.08%	41.12%	-2.96%	26.32%	26.58%	0.26%
1020	67.03%	76.71%	9.68%	60.75%	69.24%	8.49%
*1023	64.43%	60.77%	-3.66%	59.82%	58.49%	-1.33%
1024	41.26%	50.72%	9.46%	25.08%	32.78%	7.70%
*1025	69.26%	78.29%	9.03%	57.88%	66.81%	8.93%
1026	71.06%	73.66%	2.60%	41.34%	46.19%	4.85%
*1027	62.04%	73.41%	11.37%	58.13%	67.08%	8.95%
*1029	51.21%	57.88%	6.67%	51.50%	57.21%	5.71%
1064	77.81%	83.42%	5.61%	44.69%	51.69%	7.00%
1072	66.07%	74.49%	8.42%	52.53%	59.67%	7.14%
Average	**66.86%**	**73.33%**	**6.47%**	**55.49%**	**61.61%**	**6.12%**

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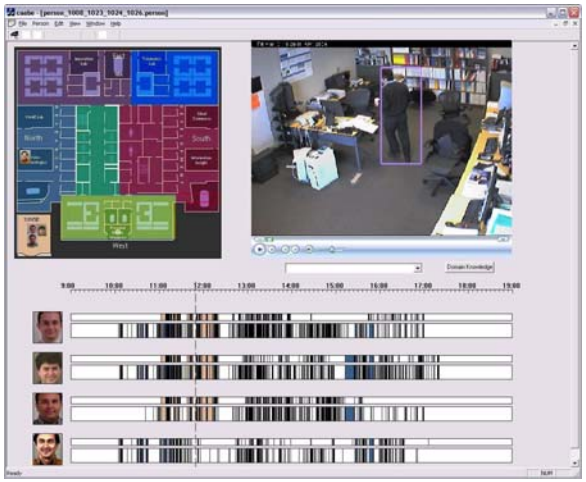
People Localization: Visualization Tool



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Summary

- People Localization
  - Multiple sensor integration
    - Video cameras
    - IR badge ID
    - Fingerprint reader
  - Camera specification
    - Interactive tool
  - Bayesian framework
  - Visualization tool

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MSIS Future Work

- Counting people on the floor
- People Tracking
- Merging different sensors for people localization
- People Recognition and Interaction
- Behavior and Activity understanding
  - Ontology of video events
  - Rare Behavior detection
  - Working place statistics
  - Instant Event Reminder

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Any questions?

- Eh???
- Merci beaucoup!

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