Probabilistic Group-Level Motion Analysis and Scenario Recognition

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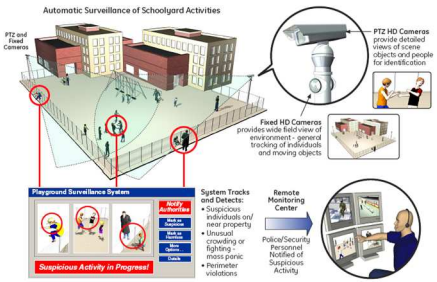
Goal: Continuous automated video-based behavior recognition in locations such as parks, schools, prison yards, public venues where continuous law enforcement presence is desirable but infeasible.

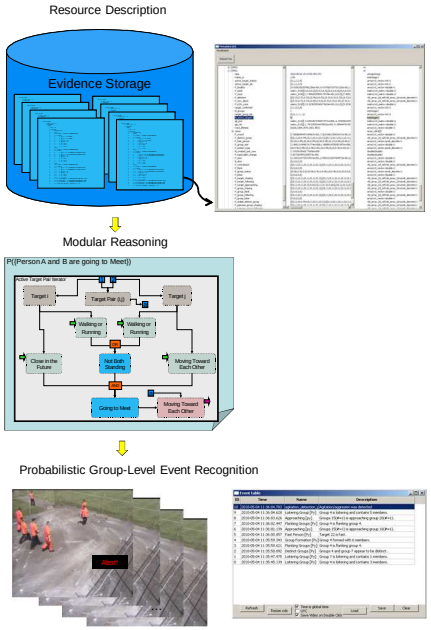


Specifically addressing issues involving **groups and crowds.**

Behaviors being detected by our system:

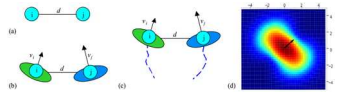
- group forming and dispersion
- running (fast) individuals
- loitering individuals or groups
- approaching / chasing / meeting
- flanking
- agitation / aggression / fighting
- customized behaviors and scenarios

Probabilistic Evidence & Reasoning



Probabilistic Soft Group Analysis

- Pairwise grouping
- Path-based connectivity



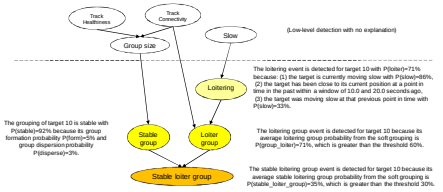
Scenario Recognition for Individuals

Track analysis	Probabilities for track i, or between tracks (i,j)
Track healthiness	$h(i)$, obtained from Kalman filter tracking confidence and lifetime
Person loitering	$p^l(i)$ {currently slow, close in the past, slow in the past}
Person motion type	$p^{mot}(M^T,i)$, $M^T=\{$ *standing, walking, running, unknown* $\}$, Fig.2(a)
Relative motion direction	$p^{mot}(M^D(i,j)$, $M^D=\{$ *same, opposite, neither* $\}$, Fig.2(b, upper)
Relative distance change	$p^{dc}(D^C(i,j)$, $D^C=\{$ *increasing, decreasing, unchanging* $\}$, Fig.2(b, lower)
Track to track pairwise metric	$p^c_t(i,j)$ incorporating front/sided-ness, velocity, and motion track history in Eq.2
Track to track path connectivity	$p^c_c(i,j)$, obtained from $p^c_t(i,j)$ after all-pair shortest path computation
Person meeting	$p^{meet}(i,j)=1-\prod_{t=t_0 \text{ to } t_f}\{1-p^c(i,j;t)\}$, where p^c is defined in Eq.11
Person following	$p^{flw}(i,j)=p(M_i^T=\textit{walking})p(M_j^T=\textit{walking})[1-\text{sigmoid}(d_{ij};\mu_{d_{flw}},\sigma_{d_{flw}})]$
Person chasing	$p^{chs}(i,j)=p(M_i^T=\textit{running})p(M_j^T=\textit{running})[1-\text{sigmoid}(d_{ij};\mu_{d_{chs}},\sigma_{d_{chs}})]$

Group-Level Scenario Recognition

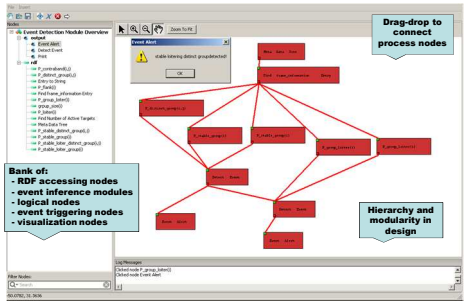
Group scenario	Probabilities for track i, or between tracks (i,j)
Group formation	$p^f_g(i)=\text{sigmoid}(y^f_g,1,0.2)$, $y^f_g=\sum_{\forall j,k,i}p^c_c(i,j;t)\cdot(1-p^c_c(i,j;t_p))\cdot\max(h(i),h(j))$
Group dispersion	$p^d_g(i)=\text{sigmoid}(y^d_g,1,0.2)$, $y^d_g=\sum_{\forall j,k,i}p^c_c(i,j;t_p)\cdot(1-p^c_c(i,j;t))\cdot\max(h(i),h(j))$
Stable group	$p^s_g(i)=1-p^l_g(i)-p^d_g(i)$
Loitering group	$p^l_g(i)=1-\prod_{\forall j}\{1-p^c_c(i,j)p^l(j)\}$
Stable loitering group	$p^{sl}_g(i)=p^s_g(i)p^l_g(i)$
Distinct groups	$p^b_g(i,j)=\prod_{\forall k}\{1-\max(p^c_c(i,k)p^c_c(k,j),p^c_c(j,k)p^c_c(k,i))\}$
Close-by groups	$p^c_g(i,j;t)=1-\sum_{k\neq i,j}(1-p^c(i,k;t))\cdot(1-p^c(k,j;t))$
Group meeting	$p^{meet}_g(i,j)=1-\prod_{t=t_0 \text{ to } t_f}\{1-p^c_g(i,j;t)\}$
Group following	$p^{flw}_g(i,j)=p^c_g(i,j)\cdot(1-\prod_k\{p^c_g(i,k)+(1-p^c_g(i,k))\cdot(1-p^{flw}(k,j))\})$
Group chasing	$p^{chs}_g(i,j)=p^c_g(i,j)\cdot(1-\prod_k\{p^c_g(i,k)+(1-p^c_g(i,k))\cdot(1-p^{chs}(k,j))\})$

Event Explanation



Scenario Modeling GUI

Allows user to easily define new scenarios using a bank of event inference modules

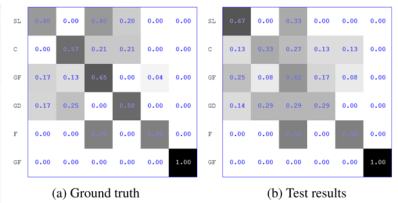


Prior Capabilities

- GE's multi-camera, multi-object surveillance tracking system
- Motion analysis, discrete group analysis
- Activity detection, social network analysis
- Active control for PTZ camera network
- Biometrics at a distance

Simulated scenarios. Data enacted by Lake Erie Correctional Officers.

Experimental Results



System Deployment & Validation

- Independent system evaluation in progress conducted by ManTech (www.mantech.com) on behalf of NIJ
- System deployed to local police department to process video feeds and control PTZ cameras for real-life applications

Conclusions

- Robust multi-camera, multi-object surveillance tracking system as the backbone
- Probabilistic representation and inference for tracking evidence and group activities
- Modular inference enables explanation of decision making for alerts
- User-friendly GUI allows law enforcement practitioners to quickly design new events and scenarios
- Integrated face capture in PTZ views
- Ongoing system deployment and validation on real-world law enforcement sites

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