A Discrete Choice Modeling Framework for Pedestrian Walking Behavior with Application to Human Tracking in Video Sequences

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  - *estimation results*
- **PART II :** Application to pedestrian tracking
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- **PART III :** Trajectory clustering for counting pedestrians
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- **Conclusions**
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Motivations

Several studies in:

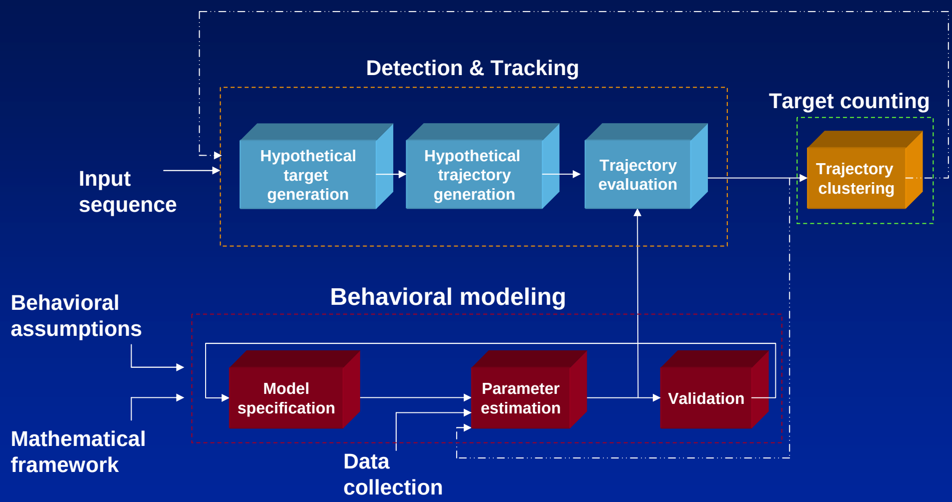
Evacuation dynamics

Space design

Transportation

Pedestrian tracking, activity recognition

Overview



What is the problem

- **Walking pedestrians behavior modeling**
- ***Normal* conditions (no panic, no evacuation)**
- **Short-term behavior (“next step” model)**
- **Fully estimable on real data**

Model framework

- the walking process is considered a sequence of choices
- individuals are assumed to be rational decision makers
- we use a microscopic modeling framework

Discrete Choice Analysis

Discrete Choice Models

DCMs are defined by 4 elements

- a set of alternatives (choice set)
- attributes describing the alternatives
- decision maker and her socio-economic characteristics
- error term

Discrete Choice Models

An individual n perceives an utility U from alternative j:

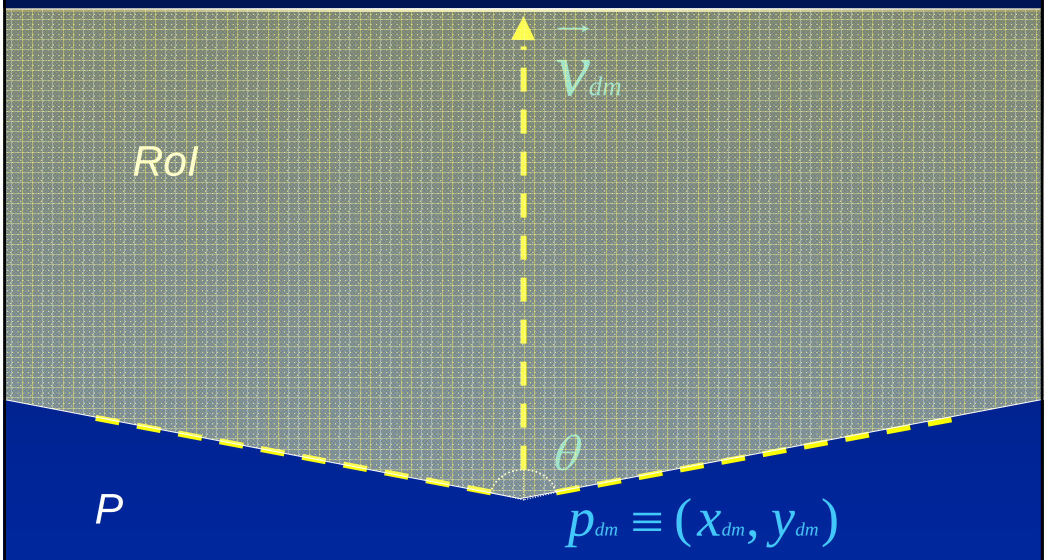
$$U_{nj} = V_{nj} + \varepsilon_{nj}$$

Under the *utility maximization* assumption we have

$$P_{ni} = \text{Prob}\,(U_{ni} > U_{nj},\ \forall j \neq i) = \text{Prob}(\varepsilon_{nj} - \varepsilon_{ni} < V_{ni} - V_{nj},\ \forall j \neq i)$$

Different DCM are obtained from different specifications of the unobserved part of the utility function

spatial discretization

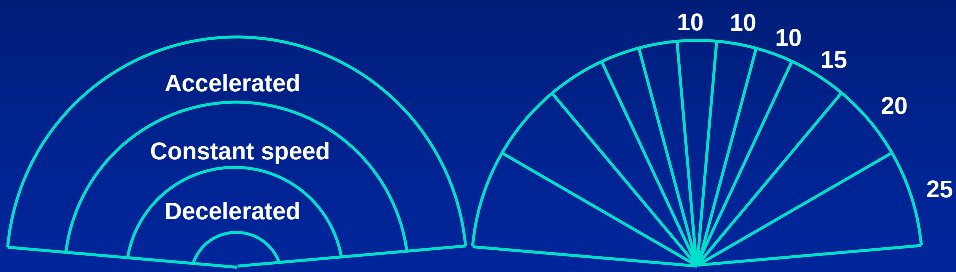


spatial discretization

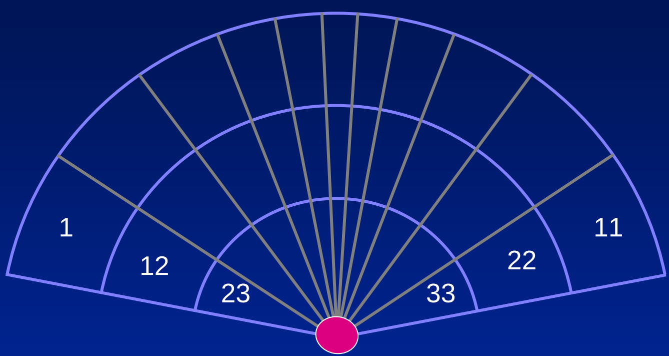
Dynamic and individual-based

↓

We discretize the space discretizing changes in speed module and direction

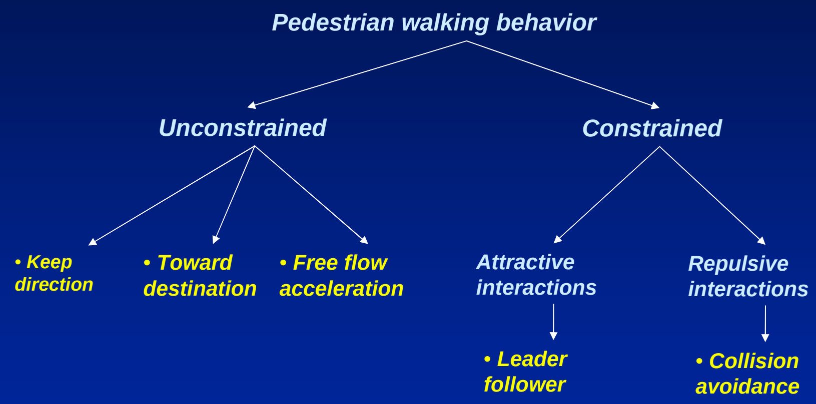


Behavioral model: choice set



$$c_{vd} = p_n + vtd \qquad U_{vdn} = V_{vdn} + \varepsilon_{vdn}$$

Behavioral model: proposed framework



Behavioral model: patterns and utilities

$$V_{vdn} = \beta_{dir} dir_{dn} + \quad \text{keep direction}$$

$$\beta_{ddist} ddist_{vdn} + \beta_{ddir} ddir_{dn} + \quad \text{toward destination}$$

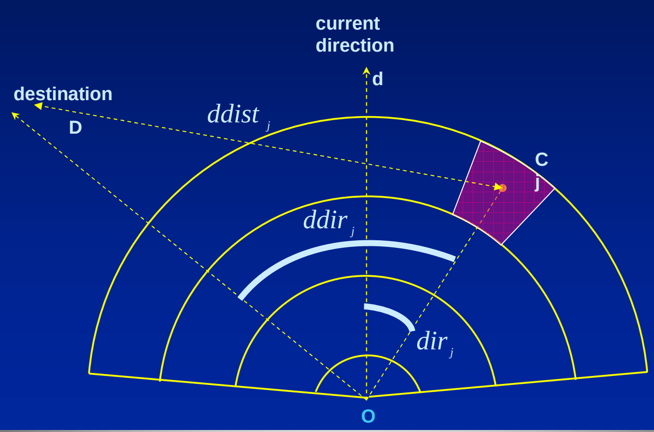
$$\beta_{acc} I_{v,acc} \left(\frac{v_n}{v_{\max}}\right)^{\lambda_{acc}} + \beta_{dec} I_{v,dec} \left(\frac{v_n}{v_{\max}}\right)^{\lambda_{dec}} + \quad \text{free flow acceleration}$$

$$I_{v,acc} I^L_{acc} \alpha^L_{acc} D_L^{\rho^L_{acc}} \Delta v_L^{\gamma^L_{acc}} \Delta \theta_L^{\delta^L_{acc}} + I_{v,dec} I^L_{dec} \alpha^L_{dec} D_L^{\rho^L_{dec}} \Delta v_L^{\gamma^L_{dec}} \Delta \theta_L^{\delta^L_{dec}} + \quad \text{leader follower}$$

$$I_{d,d_n} I_C \alpha_C e^{-\rho_C D_C} \Delta v_C^{\gamma_C} \Delta \theta_C^{\delta_C} \quad \text{collision avoidance}$$

Unconstrained patterns

$$\beta_{dir} \cdot dir_j + \beta_{ddir} \cdot ddir_j + \beta_{ddist} \cdot ddist_j$$



Unconstrained patterns

$$\beta_{acc} I_{v,\,acc} \left(\frac{v_n}{v_{\max}}\right)^{\lambda_{acc}} + \beta_{dec} I_{v,\,dec} \left(\frac{v_n}{v_{\max}}\right)^{\lambda_{dec}}$$

$$\tilde{\beta}_{acc} = I_{v,acc} \beta_{acc} \left(\frac{v_n}{v_{\max}}\right)^{\lambda_{acc}}$$

$$\tilde{\beta}_{dec} = I_{v,dec} \beta_{dec} \left(\frac{v_n}{v_{\max}}\right)^{\lambda_{dec}}$$

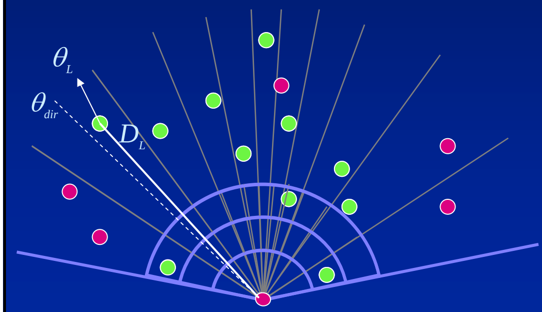
where: $$\lambda_{acc(dec)} = \frac{\partial \tilde{\beta}_{acc(dec)}}{\partial v_n} \frac{v_n}{\tilde{\beta}_{acc(dec)}}$$

Constrained patterns

$$I_{v,acc} I^{L}_{acc} \alpha^{L}_{acc} D_L^{\rho^{L}_{acc}} \Delta v_L^{\gamma^{L}_{acc}} \Delta \theta_L^{\delta^{L}_{acc}} + I_{v,dec} I^{L}_{dec} \alpha^{L}_{dec} D_L^{\rho^{L}_{dec}} \Delta v_L^{\gamma^{L}_{dec}} \Delta \theta_L^{\delta^{L}_{dec}}$$

…each direction has its potential leaders…

…which is the closest to the dm



$$leader_g = sensitivity_g \times stimulus_g$$

$g = \{\text{acc}, \text{dec}\}$

$$sensitivity = f(D_L) = \alpha^{L}_{g} D_L^{\rho^{L}_{g}}$$

$D_L = \text{dist}(p_L, p_{dm})$

$$stimulus = s(\Delta v_L, \Delta\theta_L) = \Delta v_L^{\gamma^{L}_{g}} \Delta\theta_L^{\delta^{L}_{g}}$$

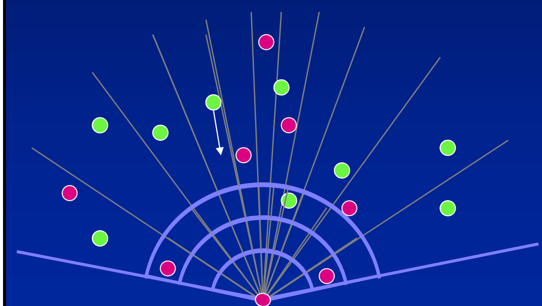
$\Delta\theta_L = |\theta_L - \theta_{dir}|$ $\quad \Delta v_L = |v_L - v_{dm}|$

Constrained patterns

$$I_{d,d_n} I_C \alpha_C e^{-\rho_C D_C} \Delta v_C^{\gamma_C} \Delta\theta_C^{\delta_C}$$

…each direction has its potential colliders…

…which is caused by the max angle θ_C



$$coll = sensitivity \times stimulus$$

$$sensitivity = f(D_C) = \alpha_C e^{-\rho_C D_C}$$

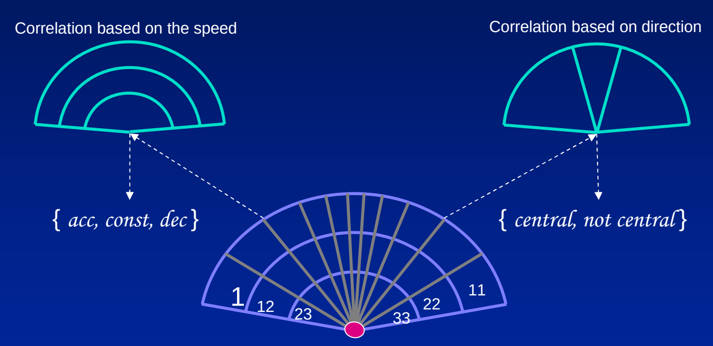
$D_C = \text{dist}(p_C, p_{Cj})$

$$stimulus = s(\Delta v_C, \Delta\theta_C) = \Delta v_C^{\gamma_C} \Delta\theta_C^{\delta_C}$$

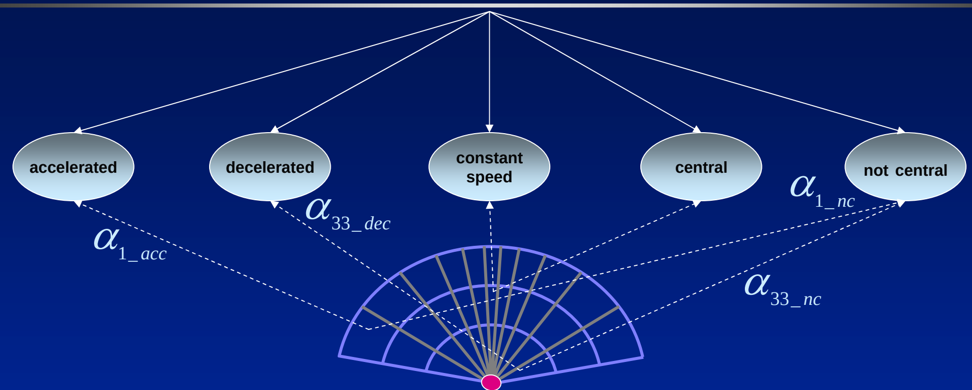
$\Delta v_C = v_C + v_{dm}$ $\quad \Delta\theta_C = |\theta_C - \theta_{dm}|$

Behavioral model : the CNL

GEV models (D.McFadden, 1978)



Behavioral model : the CNL



$$P(i|C) = \sum_{m=1}^{M} \frac{\left(\sum_{j \in C} \alpha_{jm}^{\mu_m/\mu} y_j^{\mu_m}\right)^{\frac{\mu}{\mu_m}}}{\sum_{n=1}^{M} \left(\sum_{j \in C} \alpha_{jn}^{\mu_n/\mu} y_j^{\mu_n}\right)^{\frac{\mu}{\mu_n}}} \frac{\alpha_{im}^{\mu_m/\mu} y_i^{\mu_m}}{\sum_{j \in C} \alpha_{jm}^{\mu_m/\mu} y_j^{\mu_m}}$$

Estimation results: CNL

Var	val	t-t 0	t-t 1
β_{dir}	-0.027	-11.342	
β_{ddir}	-0.061	-19.066	
β_{ddist}	-1.614	-1.9749	
β_{acc}	-19.822	-5.847	
β_{dec}	-2.069	-2.651	
λ_{acc}	0.969	26.880	
α_C	-0.0058	-4.639	
ρ_C	-0.313	-6.748	
γ_C	0.781	3.318	
μ_{const}	1.597	32.413	12.119
$\mu_{not\_central}$	1.487	15.765	5.160

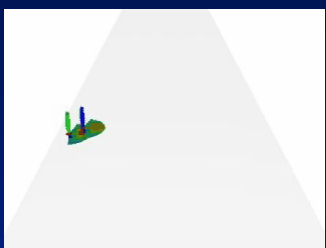
Var	val	t-t 0	t-t 1
α^L_{acc}	4.883	3.368	
α^L_{dec}	4.061	6.278	
ρ_{acc}	-0.657	-3.034	
ρ_{dec}	-0.481	-4.280	
γ_{acc}	0.869	9.877	
γ_{dec}	0.524	90.89	
δ_{dec}	-0.892	-1.642	
μ^{JTB}	1.0000	--	--
μ^{Flon}	0.591	--	-8.565

$$\alpha_C e^{\rho_C d_C} \Delta v_C^{\gamma_C} \Delta \theta_C^{\delta_C}$$

$$\alpha^L_g d_L^{\rho^L_g} \Delta v_L^{\gamma^L_g} \Delta \theta_L^{\delta^L_g}$$

null log_lik. = -37702.8 *Final log_lik. = -22572.7*

Validation: a first pedestrian simulator

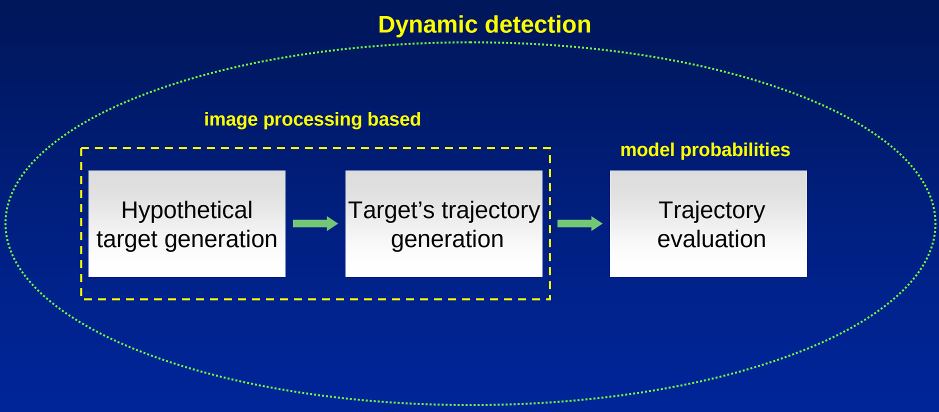


PART I : conclusions

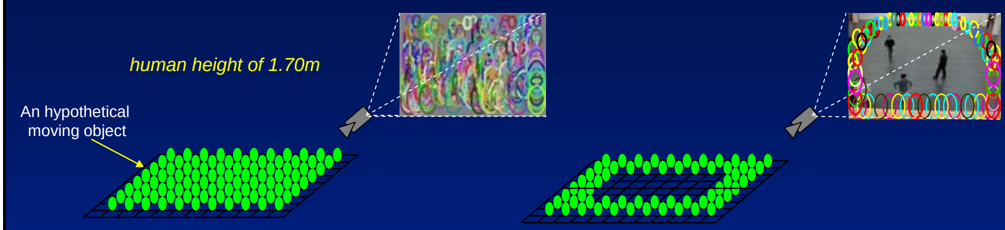
- DCA provides a robust statistical framework for pedestrian walking behavior;
- Microscopic model with agent-based simulation;
- Constrained and unconstrained patterns has been successfully modeled;
- Adaptive spatial discretization;
- Work finalized with one paper *in press* and one under review (Transportation Research Part B)

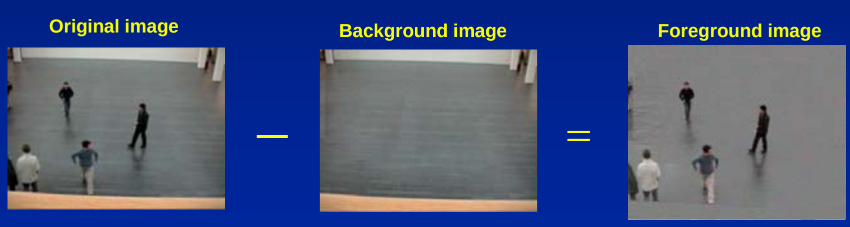
Application: pedestrian detection and tracking in video sequences

Overview



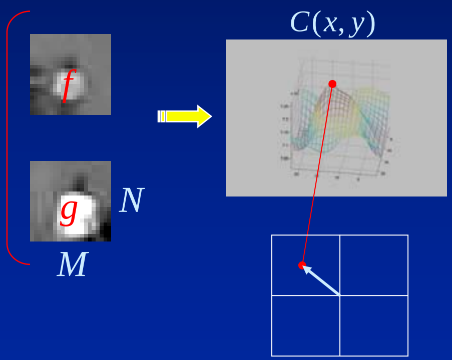
Initialization

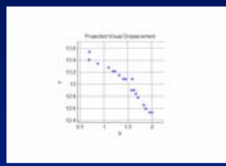


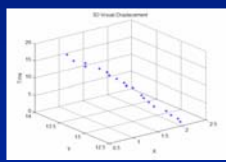


Trajectory generation

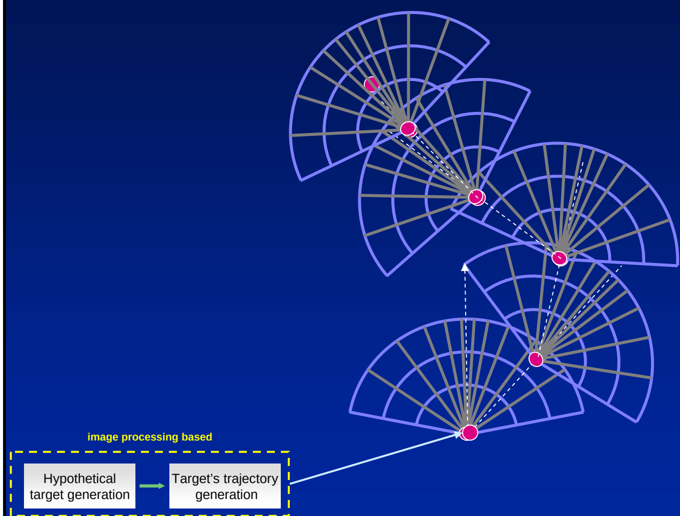
$$C(x,y)=\frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)g(x+m,y+n)$$







Dynamic detection

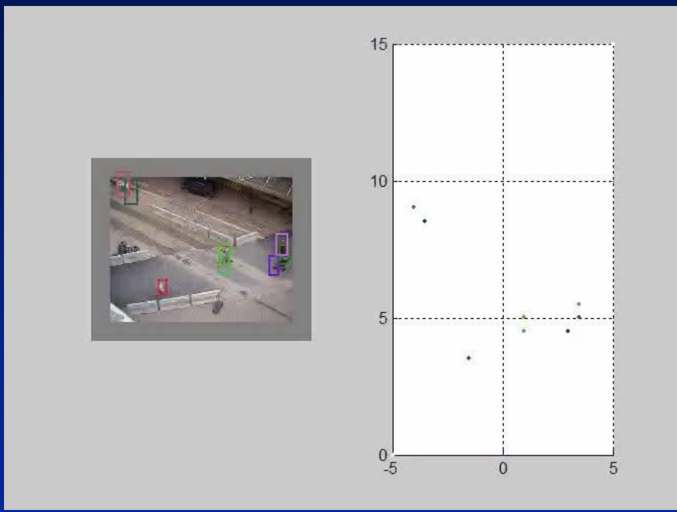


$$P_{nj}^{t_1} \quad P_{nj}^{t_2} \quad \cdots \quad P_{nj}^{t_N}$$

$$\text{if} \quad TS_n = \frac{\sum_{i=1, j\in C}^{N} P_{nj}^{t_i}}{\sum_{i=1, j\in C}^{N} \max_{j\in C} P_{nj}^{t_i}} \geq T_h$$

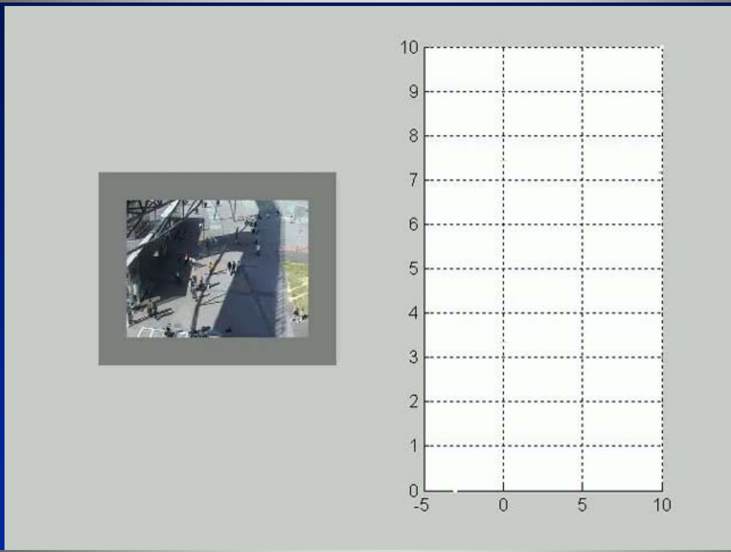
Pedestrian n is detected

Pedestrian tracking

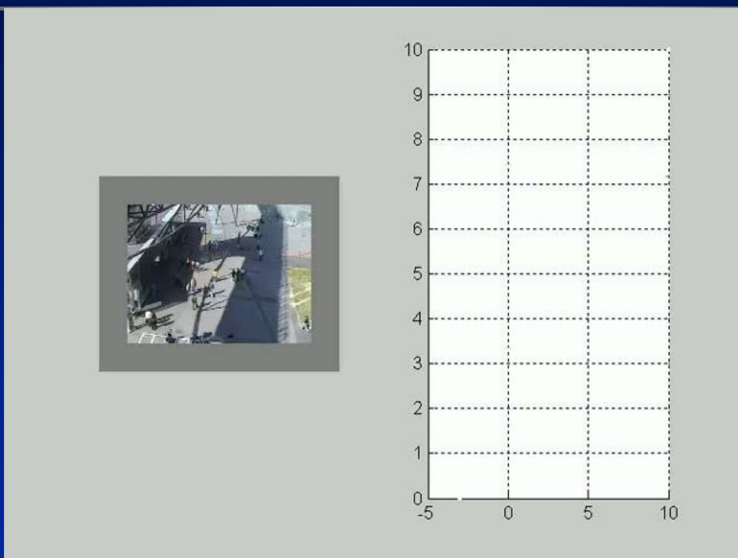


Pedestrian tracking

Pedestrian tracking



Pedestrian tracking



PART II : conclusions

- A methodology to integrate behavioral information for detection and tracking has been defined;
- The dynamic detection approach allows to avoid complex segmentation-based tasks for target detection;
- The proposed method can be integrated with any more sophisticated detection-tracking scheme;
- Over-estimation of the targets number ….
- Work finalized with one paper *in press* with IJCV

Research Summary

Main contributions

- **New model for pedestrian walking behavior based on discrete choice analysis**
  - **adaptive spatial discretization;**
  - **general framework modeling constrained and unconstrained patterns;**
  - **model calibrated on real data;**
  - **behavioral interpretation of the model parameters;**
- **Behavioral and image information are integrated in a detection-tracking context**
  - **simple initialization scheme;**
  - **dynamic detection;**
  - **deterministic and probabilistic tracking;**
- **Counting pedestrians based on trajectory clustering**
  - **different data representations and metrics are compared under a common hierarchical clustering framework**

Future works

Modeling part:

- Integrated DCA framework (strategic, tactic, operational);
- Controlled experimental conditions to take into account socio-economic characteristics;
- Group, panic and evacuation behaviors;
- Integration of spatial information (architecture, obstacles);

Integration:

- Use of more sophisticated initialization and tracking schemes;
- Multimodal sensory input (not only video);
- Integration of sensory inputs with '*scenario*' simulators;