Specification, estimation and validation of a pedestrian walking behavior model

Th. Robin, M. Bierlaire, G. Antonini and J. Cruz
EPFL Technical report (2007)

2008/11/5 (Wed)

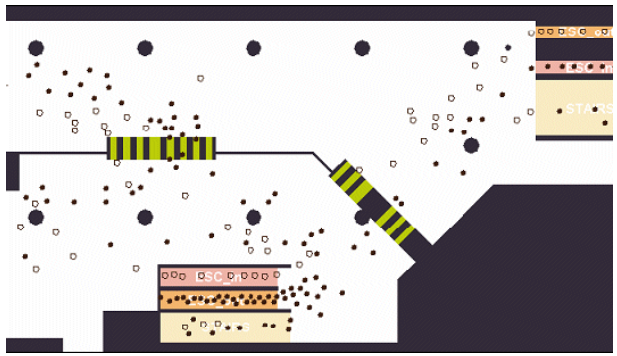
M2 濱上洋平

目的

- 数理モデルによる歩行者行動の予測
- 実データを用いたパラメータ推定
- 推定に使用していないデータでのモデル検証

↓

- 歩行者行動シミュレーション
- 歩行者トラッキング



3段階の決定

Strategical

- 目的地，出発時刻，活動パターン

Tactical

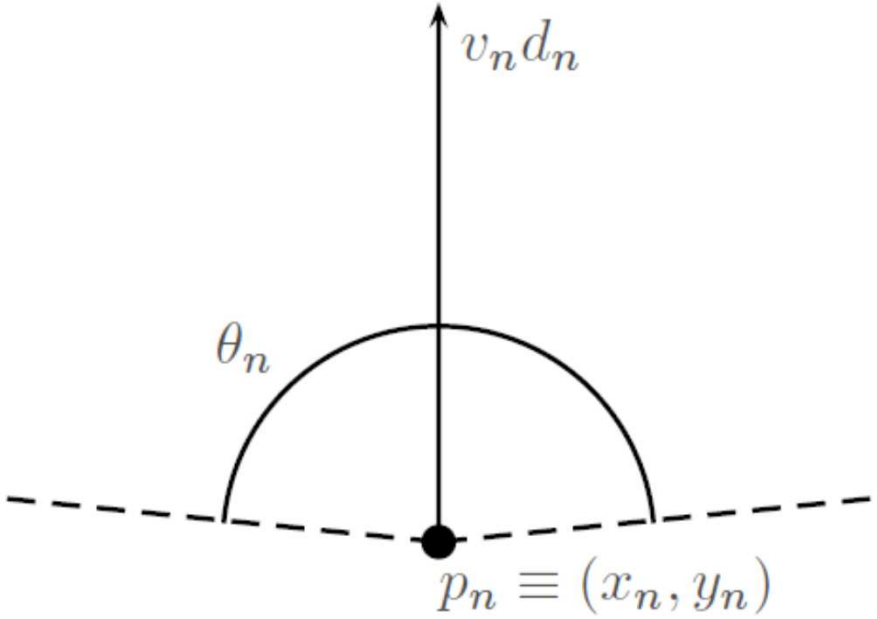
- 活動スケジュール，活動エリア，経路選択

Operational

- 歩行挙動
  - 次の一歩
  - 速度，角度
  - 衝突回避
  - 追従

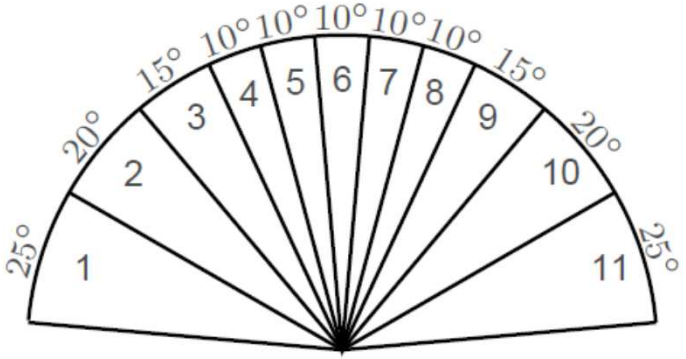
設定

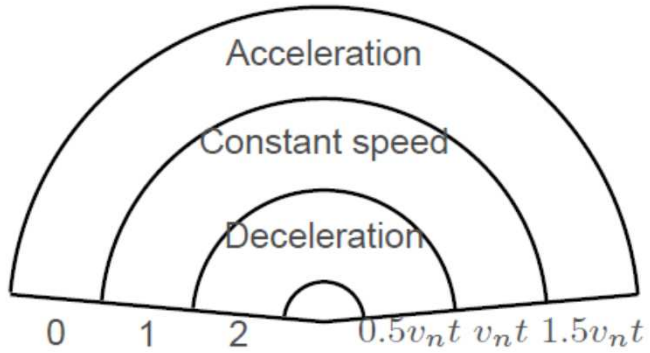
- 現在地　$p_n=(x_n, y_n)$
- 現在の速度　v_n
- 進行方向　d_n　, $\| d_n \| =1$
- 視認角　$\theta_n=170°$

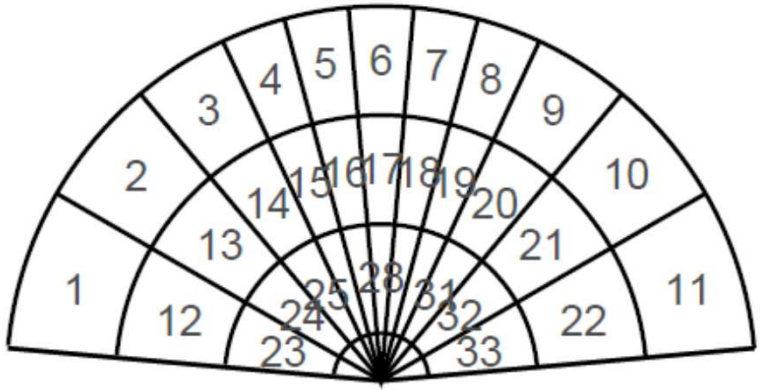


選択肢集合 C_n

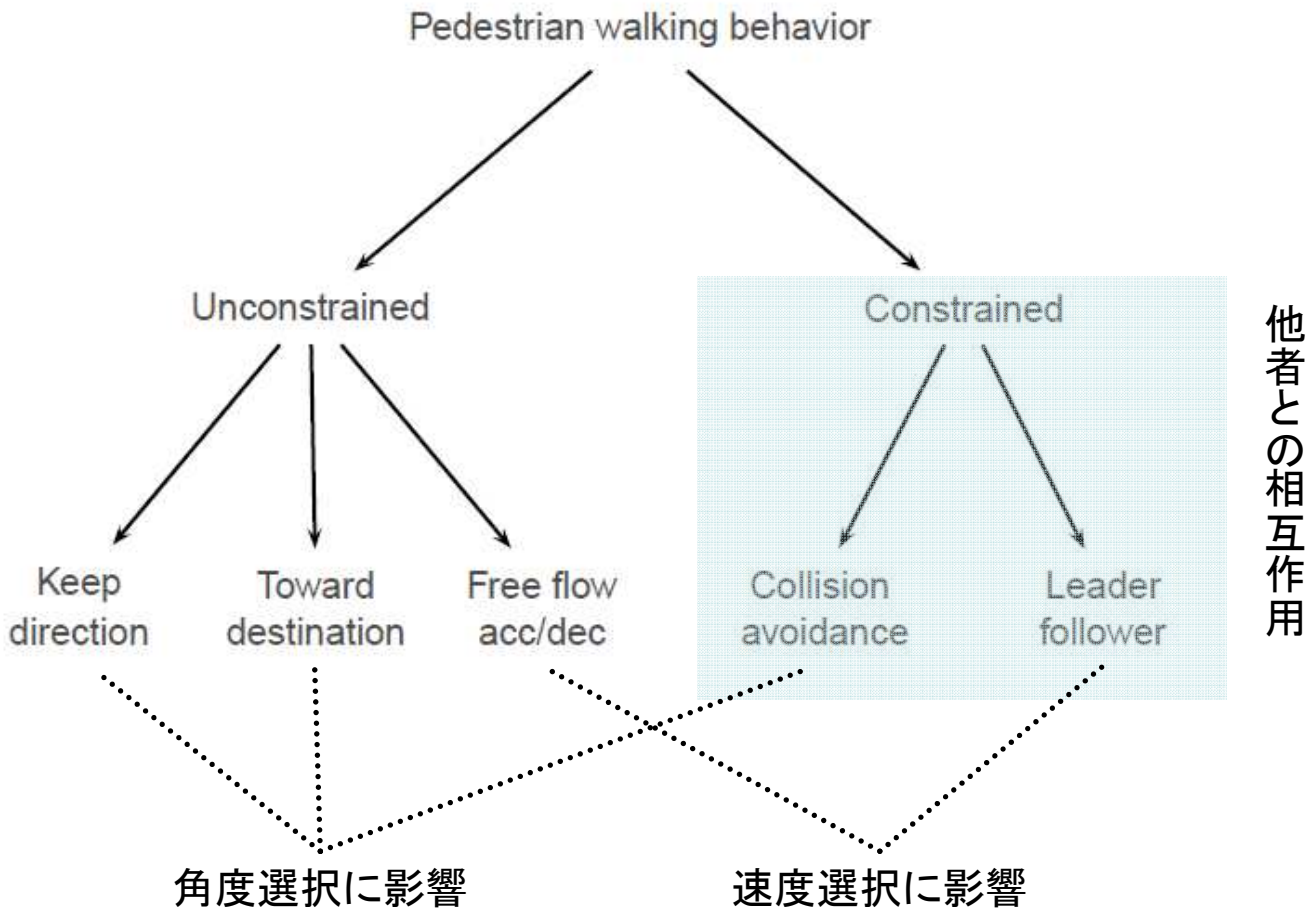
- 角度:11
- 速度:3($0.5v_n$, v_n, $1.5v_n$)
- 選択肢:33







行動要素


Pedestrian walking behavior
Unconstrained
Constrained
Keep direction
Toward destination
Free flow acc/dec
Collision avoidance
Leader follower
他者との相互作用
角度選択に影響
速度選択に影響

モデルの特定化

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

$$
\begin{aligned}
V_{vdn} = {} & \beta_{dir\_central}\, dir_{dn}\, I_{d,central} + \\
& \beta_{dir\_side}\, dir_{dn}\, I_{d,side} + \\
& \beta_{dir\_extreme}\, dir_{dn}\, I_{d,extreme} + \\
& \beta_{ddist}\, ddist_{vdn} + \\
& \beta_{ddir}\, ddir_{dn} + \\
& \beta_{dec}\, I_{v,dec} (v_n / v_{max})^{\lambda_{dec}} + \\
& \beta_{accLS}\, I_{n,LS}\, I_{v,acc} (v_n / v_{maxLS})^{\lambda_{accLS}} + \\
& \beta_{accHS}\, I_{n,HS}\, I_{v,acc} (v_n / v_{max})^{\lambda_{accHS}} + \\
& I_{v,acc}\, I^{L}_{d,acc}\, \alpha^{L}_{acc}\, D_L^{\rho^{L}_{acc}}\, \Delta v_L^{\gamma^{L}_{acc}}\, \Delta\theta_L^{\delta^{L}_{acc}} + \\
& I_{v,dec}\, I^{L}_{d,dec}\, \alpha^{L}_{dec}\, D_L^{\rho^{L}_{dec}}\, \Delta v_L^{\gamma^{L}_{dec}}\, \Delta\theta_L^{\delta^{L}_{dec}} + \\
& I_{d,d_n}\, I_{d,C}\, \alpha_C e^{\rho_C D_C}\, \Delta v_C^{\gamma_C}\, \Delta\theta_C^{\delta_C}
\end{aligned}
$$

keep direction

toward destination

free flow acceleration

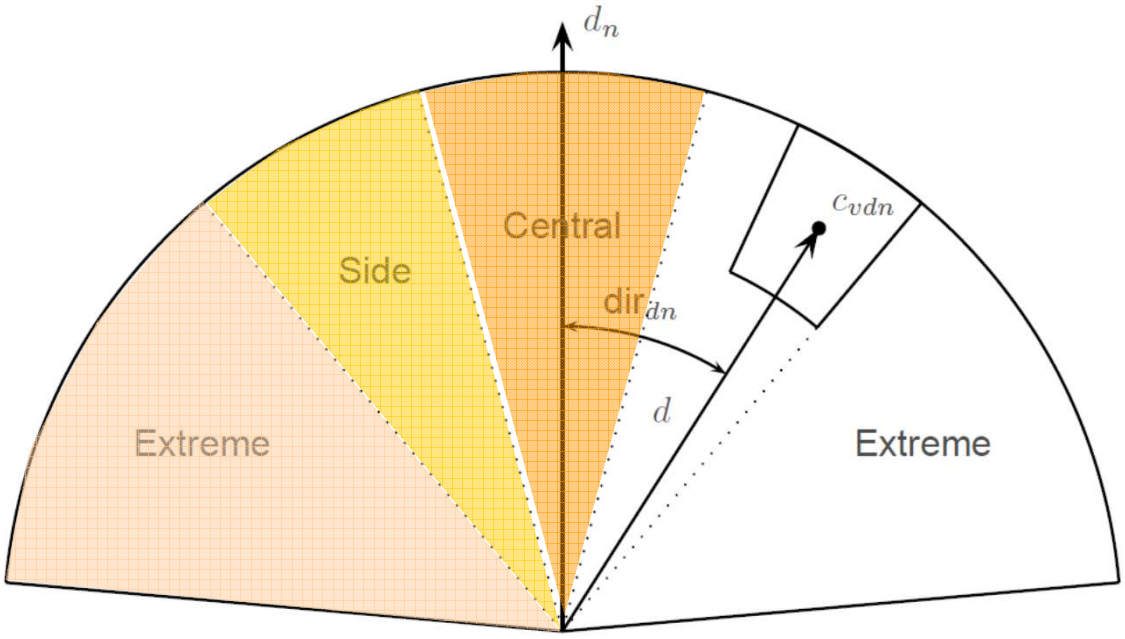
leader-follower

collision avoidance

Keep direction

- 角度変動大→効用低
- 角度と効用が比例するとは限らない
  （今までは　$\beta_{dir} dir_{dn}$ ）

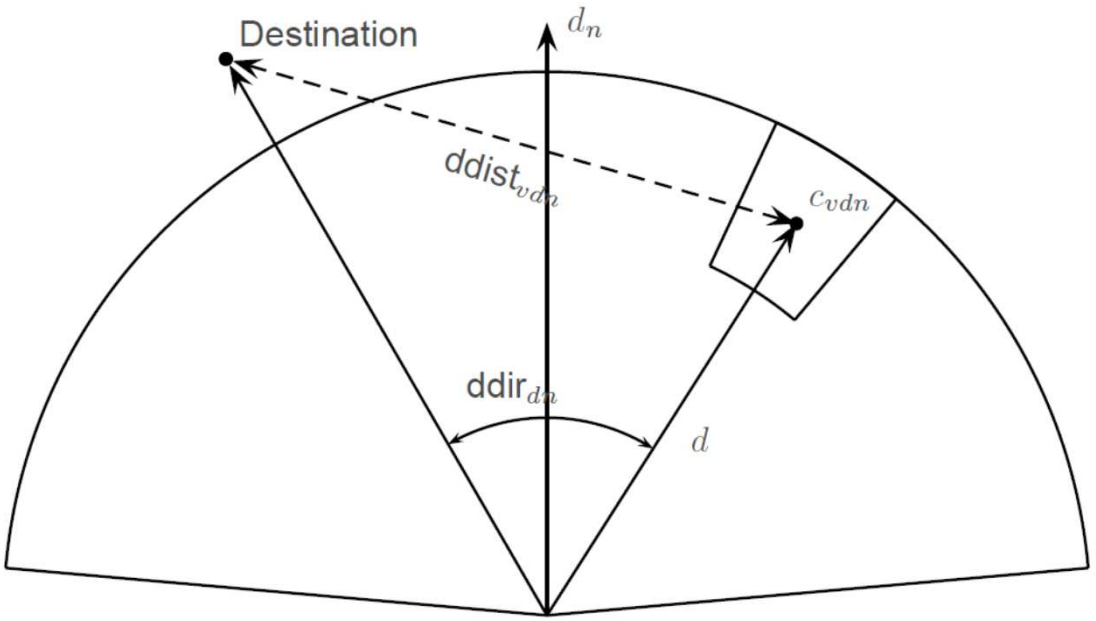
$$\beta_{\text{dir\_central}} \text{dir}_{dn} I_{\text{central}} + \beta_{\text{dir\_side}} \text{dir}_{dn} I_{\text{side}} + \beta_{\text{dir\_extreme}} \text{dir}_{dn} I_{\text{extreme}}$$



Toward destination

- 目的地は既知
- 目的地までの距離を長くする，目的地方向から大きく外れるといった選択はしにくい．

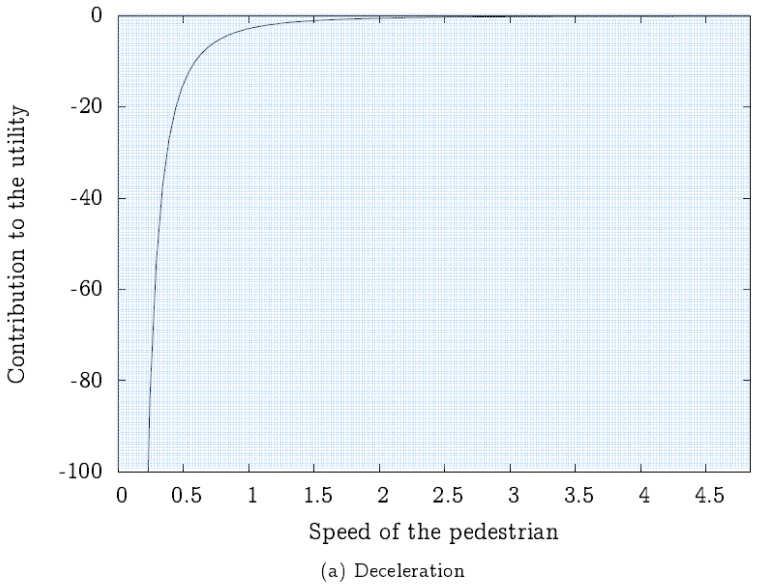
$$\beta_{\text{ddist}}\text{ddist}_{vdn} + \beta_{\text{ddir}}\text{ddir}_{dn}$$



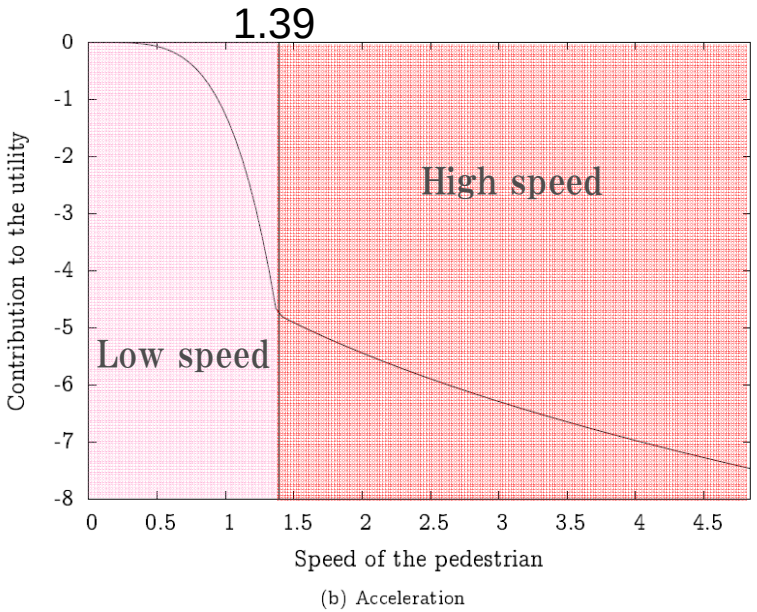
Free flow acceleration

- 速度一定が最も快適
- 希望速度を得るため加速，減速を行う
- 希望速度は未知
- 速度低→減速を選択しにくい
- 速度高→加速を選択しにくい

$$\beta_{\text{dec}} I_{\text{v,dec}} (v_n / v_{\text{max}})^{\lambda_{\text{dec}}} +$$
$$\beta_{\text{accLS}} I_{\text{LS}} I_{\text{v,acc}} (v_n / v_{\text{maxLS}})^{\lambda_{\text{accLS}}} +$$
$$\beta_{\text{accHS}} I_{\text{HS}} I_{\text{v,acc}} (v_n / v_{\text{max}})^{\lambda_{\text{accHS}}}$$



(a) Deceleration



(b) Acceleration

Figure 6: Impact of the free flow acceleration terms on the utility

Leader-follower

- 同方向の歩行者を追従
- leaderは最近接の歩行者
- 加速，減速で影響が異なる

$$\begin{cases} \text{if } d_l \le d_k \le d_r \ \text{(is in the cone)}, \\ \text{and } 0 < D_k \le D_{th} \ \text{(not too far)}, \\ \text{and } 0 < |\Delta\theta_k| \le \Delta\theta_{th} \ \text{(walking in almost the same direction)} \end{cases}$$

$$I_{\mathrm{V,acc}} I^L_{\mathrm{acc}} \alpha^L_{\mathrm{acc}} D_L^{\rho^L_{\mathrm{acc}}} \Delta v_L^{\gamma^L_{\mathrm{acc}}} \Delta\theta_L^{\delta^L_{\mathrm{acc}}} + I_{\mathrm{V,dec}} I^L_{\mathrm{dec}} \alpha^L_{\mathrm{dec}} D_L^{\rho^L_{\mathrm{dec}}} \Delta v_L^{\gamma^L_{\mathrm{dec}}} \Delta\theta_L^{\delta^L_{\mathrm{dec}}}.$$

感度　　刺激

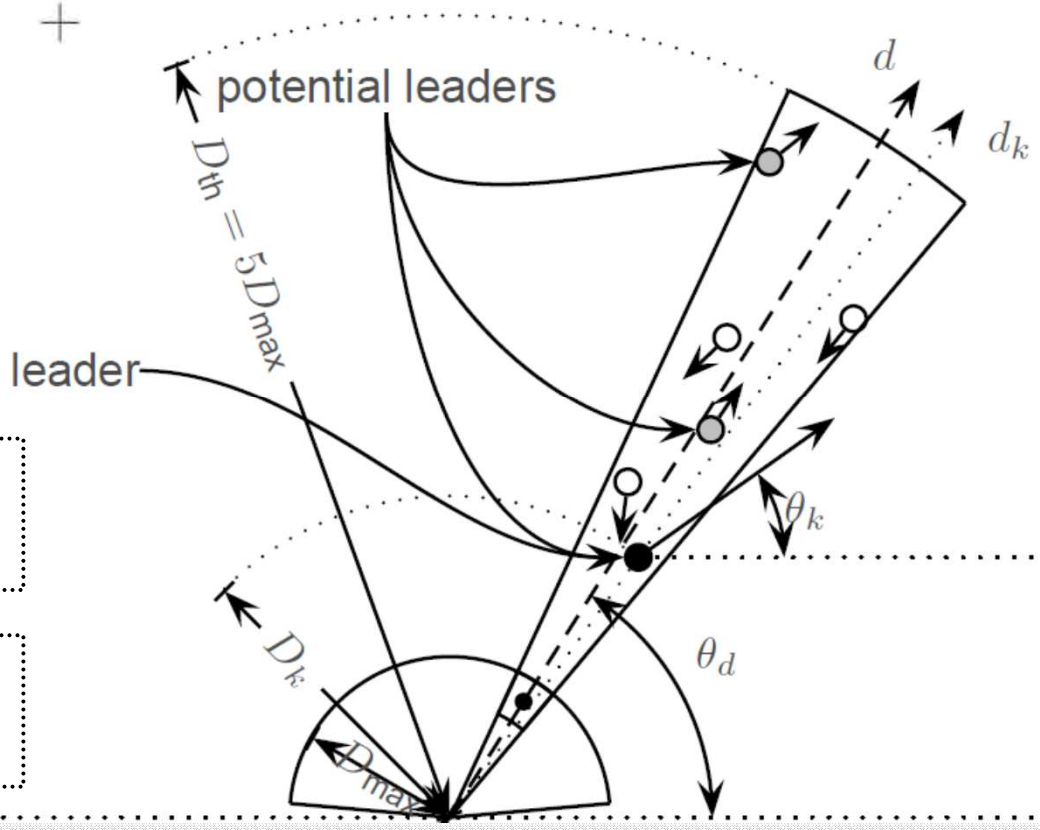
$$\Delta v_L = |v_L - v_n|$$
$$\Delta\theta_L = \theta_L - \theta_d$$

$I^L_{\mathrm{d,acc}}$

コーンdに存在し且つv_nより速い場合→1
それ以外→0

$I^L_{\mathrm{d,dec}}$

コーンdに存在し且つv_nより遅い場合→1
それ以外→0



Collision avoidance

- 対向する歩行者を避ける
- colliderは最も対向する歩行者

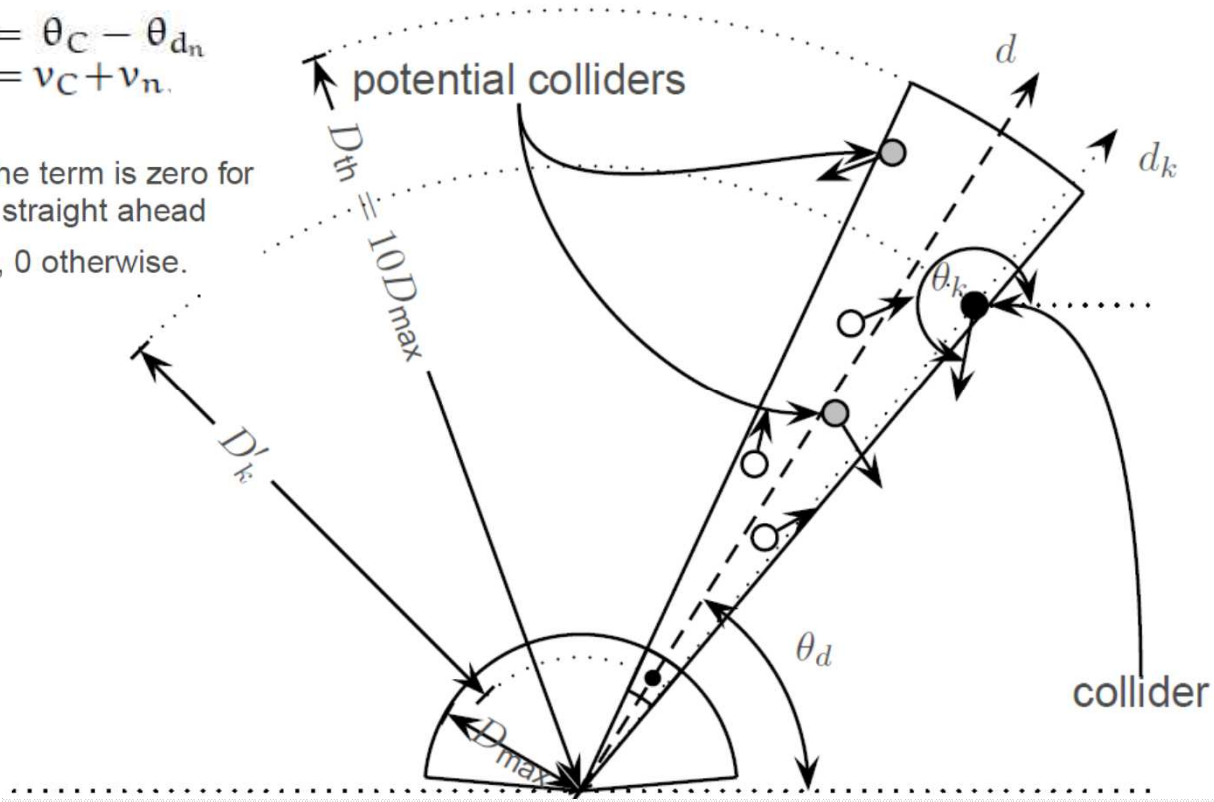
$$\begin{cases} \text{if } d_l \le d_k \le d_r \text{ (is in the cone),} \\ \text{and } 0 < D_k \le D'_{th} \text{ (not too far),} \\ \text{and } \frac{\pi}{2} \le |\Delta\theta_k| \le \pi \text{ (walking in the other direction)} \end{cases}$$

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

感度　　刺激

$$\Delta\theta_C = \theta_C - \theta_{d_n}$$
$$\Delta v_C = v_C + v_n.$$

- I_{d}, d_n = 1 if $d \neq d_n$, otherwise, that is the term is zero for alternatives corresponding to walking straight ahead
- I_C = 1 if there is a collider in the cone, 0 otherwise.



$$
\begin{aligned}
V_{vdn} = {} & \beta_{dir\_central}\, dir_{dn}\, I_{d,central} + \\
& \beta_{dir\_side}\, dir_{dn}\, I_{d,side} + \\
& \beta_{dir\_extreme}\, dir_{dn}\, I_{d,extreme} + \\
& \beta_{ddist}\, ddist_{vdn} + \\
& \beta_{ddir}\, ddir_{dn} + \\
& \beta_{dec}\, I_{v,dec}\, (v_n / v_{max})^{\lambda_{dec}} + \\
& \beta_{accLS}\, I_{n,LS}\, I_{v,acc}\, (v_n / v_{maxLS})^{\lambda_{accLS}} + \\
& \beta_{accHS}\, I_{n,HS}\, I_{v,acc}\, (v_n / v_{max})^{\lambda_{accHS}} + \\
& I_{v,acc}\, I^{L}_{d,acc}\, \alpha^{L}_{acc}\, D_{L}^{\rho^{L}_{acc}}\, \Delta v_{L}^{\gamma^{L}_{acc}}\, \Delta\theta_{L}^{\delta^{L}_{acc}} + \\
& I_{v,dec}\, I^{L}_{d,dec}\, \alpha^{L}_{dec}\, D_{L}^{\rho^{L}_{dec}}\, \Delta v_{L}^{\gamma^{L}_{dec}}\, \Delta\theta_{L}^{\delta^{L}_{dec}} + \\
& I_{d,d_n}\, I_{d,C}\, \alpha_{C} e^{\rho_C D_C}\, \Delta v_{C}^{\gamma_C}\, \Delta\theta_{C}^{\delta_C}
\end{aligned}
$$

keep direction

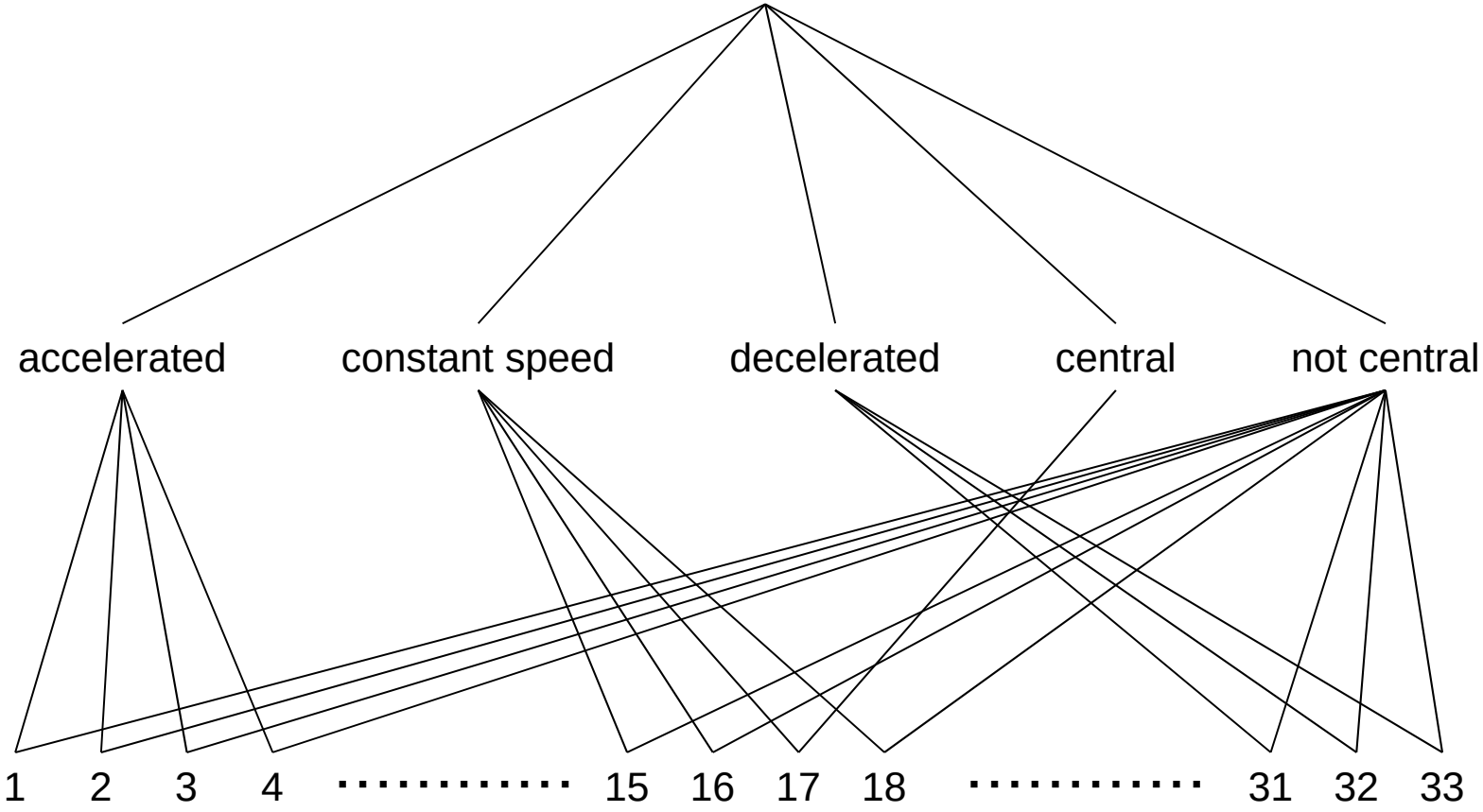
toward destination

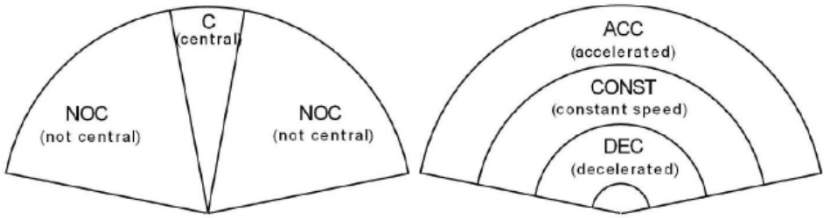
free flow acceleration

leader-follower

collision avoidance

CNLモデル


accelerated
constant speed
decelerated
central
not central
1
2
3
4
15
16
17
18
31
32
33


C
(central)
NOC
(not central)
NOC
(not central)
ACC
(accelerated)
CONST
(constant speed)
DEC
(decelerated)

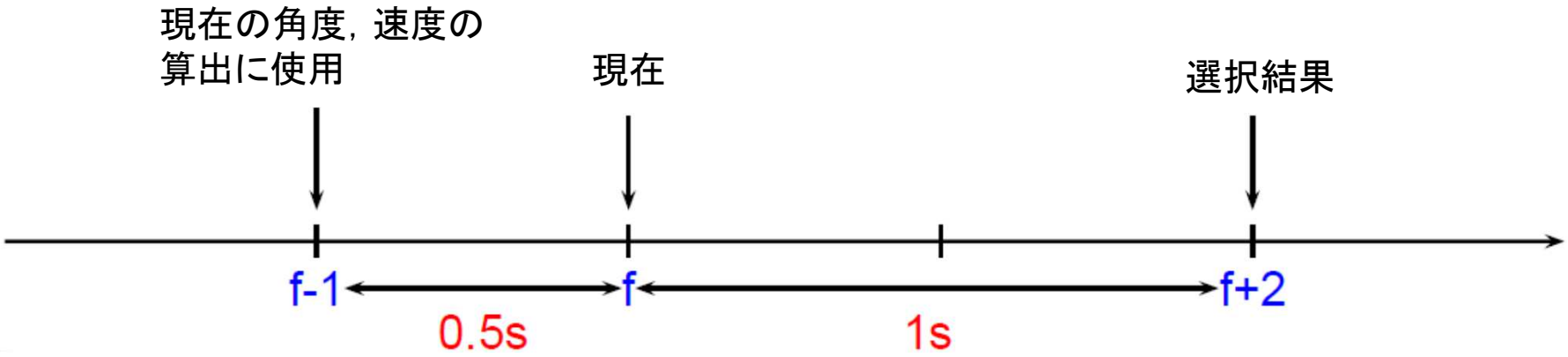
使用データ

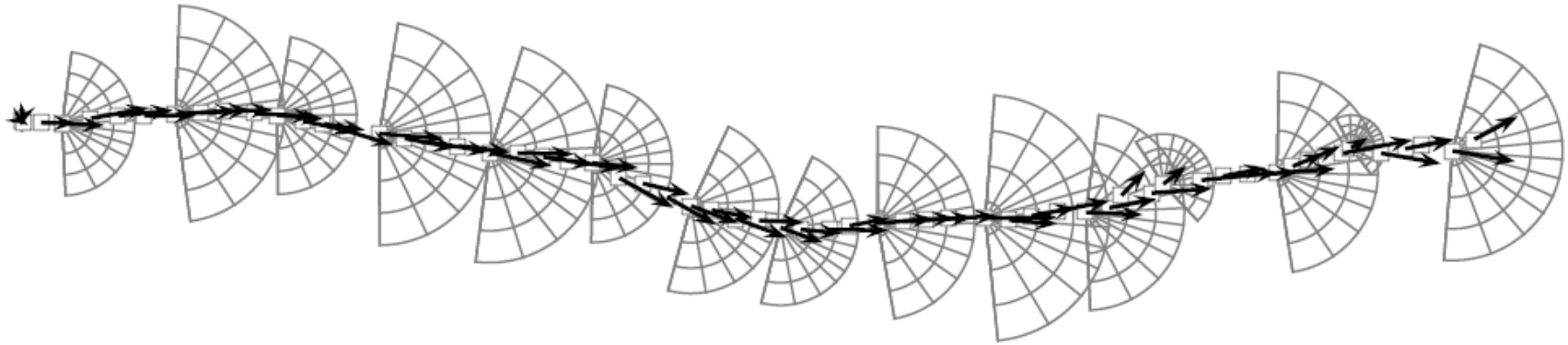
Data1：Japanese(real)

- K.Teknomo(2000)
- 190 pedestrian
- 10200 points
- データ取得間隔：0.5s

Data2：Experimental

- Hoogendorn&Daaman(2001)
- 47481 points
- データ取得間隔：0.5s


現在の角度，速度の
算出に使用
現在
選択結果
f-1
f
f+2
0.5s
1s



推定結果

Variable name	Coefficient estimate	t test 0	Variable name	Coefficient estimate	t test 0	t test 1
β_{ddir}	-0.0790	-24.53	ρ^L_{acc}	-0.489	-2.19	
β_{ddist}	-1.55	-11.66	γ^L_{acc}	0.625	2.87	
$\beta_{dir\_extreme}$	-0.0326	-9.30	α^L_{dec}	3.69	6.90	
β_{dir_side}	-0.0521	-21.87	ρ^L_{dec}	-0.663	-7.11	
$\beta_{dir\_central}$	-0.0252	-8.74	γ^L_{dec}	0.652	6.19	
β_{accLS}	-4.97	-22.61	δ^L_{acc}	-0.171	-2.33	
β_{accHS}	-7.47	-5.21	α_C	-0.00639	-9.82	
β_{dec}	-0.0630	-2.40	ρ_C	-0.239	-8.28	
λ_{accLS}	4.16	15.94	μ_{acc}	1.66	9.73	3.88
λ_{accHS}	0.358	2.09	μ_{const}	1.50	13.46	4.48
λ_{dec}	-2.41	-8.43	$\mu_{central}$	2.35	1.93	1.11
α^L_{acc}	0.942	2.28	$\mu_{not\_central}$	1.75	9.46	4.04
Sample size = 9281			Init log-likelihood = -32451			
Nbr of estimated parameters = 24			Final log-likelihood = -13997.27			
$\bar{\rho}^2 = 0.568$			Likelihood ratio test = 36907			

Table 3: **CNL** estimation results for the Japanese data set

推定結果

Variable name	Coefficient estimate	t test 0	Variable name	Coefficient estimate	t test 0	t test 1
β_{ddir}	-0.0790	-24.53	ρ^L_{acc}	-0.489	-2.19	
β_{ddist}	-1.55	-11.66	γ^L_{acc}	0.625	2.87	
$\beta_{dir\ extreme}$	-0.0326	-9.30	α^L_{dec}	3.69	6.90	
$\beta_{dir\ side}$	-0.0521	-21.87	ρ^L_{dec}	-0.663	-7.11	
$\beta_{dir\ central}$	-0.0252	-8.74	γ^L_{dec}	0.652	6.19	
β_{accLS}	-4.97	-22.61	δ^L_{acc}	-0.171	-2.33	
β_{accHS}	-7.47	-5.21	α_C	-0.00639	-9.82	
β_{dec}	-0.0630	-2.40	ρ_C	-0.239	-8.28	
λ_{accLS}	4.16	15.94	μ_{acc}	1.66	9.73	3.88
λ_{accHS}	0.358	2.09	μ_{const}	1.50	13.46	4.48
λ_{dec}	-2.41	-8.43	$\mu_{central}$	2.35	1.93	1.11
α^L_{acc}	0.942	2.28	$\mu_{not\ central}$	1.75	9.46	4.04
Sample size = 9281			Init log-likelihood = -32451			
Nbr of estimated parameters = 24			Final log-likelihood = -13997.27			
$\bar{\rho}^2 = 0.568$			Likelihood ratio test = 36907			

Table 3: **CNL** estimation results for the Japanese data set

$$
\begin{aligned}
V_{vdn} = {} & \beta_{dir\ central}\, dir_{dn}\, I_{d,central} + \\
& \beta_{dir\ side}\, dir_{dn}\, I_{d,side} + \\
& \beta_{dir\ extreme}\, dir_{dn}\, I_{d,extreme} + \\
& \beta_{ddist}\, ddist_{vdn} + \\
& \beta_{ddir}\, ddir_{dn} + \\
& \beta_{dec}\, I_{v,dec} (v_n / v_{max})^{\lambda_{dec}} + \\
& \beta_{accLS}\, I_{n,LS}\, I_{v,acc} (v_n / v_{maxLS})^{\lambda_{accLS}} + \\
& \beta_{accHS}\, I_{n,HS}\, I_{v,acc} (v_n / v_{max})^{\lambda_{accHS}} + \\
& I_{v,acc}\, I^L_{d,acc}\, \alpha^L_{acc}\, D_L^{\rho^L_{acc}}\, \Delta v_L^{\gamma^L_{acc}}\, \Delta\theta_L^{\delta^L_{acc}} + \\
& I_{v,dec}\, I^L_{d,dec}\, \alpha^L_{dec}\, D_L^{\rho^L_{dec}}\, \Delta v_L^{\gamma^L_{dec}}\, \Delta\theta_L^{\delta^L_{dec}} + \\
& I_{d,d_n}\, I_{d,C}\, \alpha_C e^{\rho_C D_C}\, \Delta v_C^{\gamma_C}\, \Delta\theta_C^{\delta_C}
\end{aligned}
$$

keep direction (dir terms)

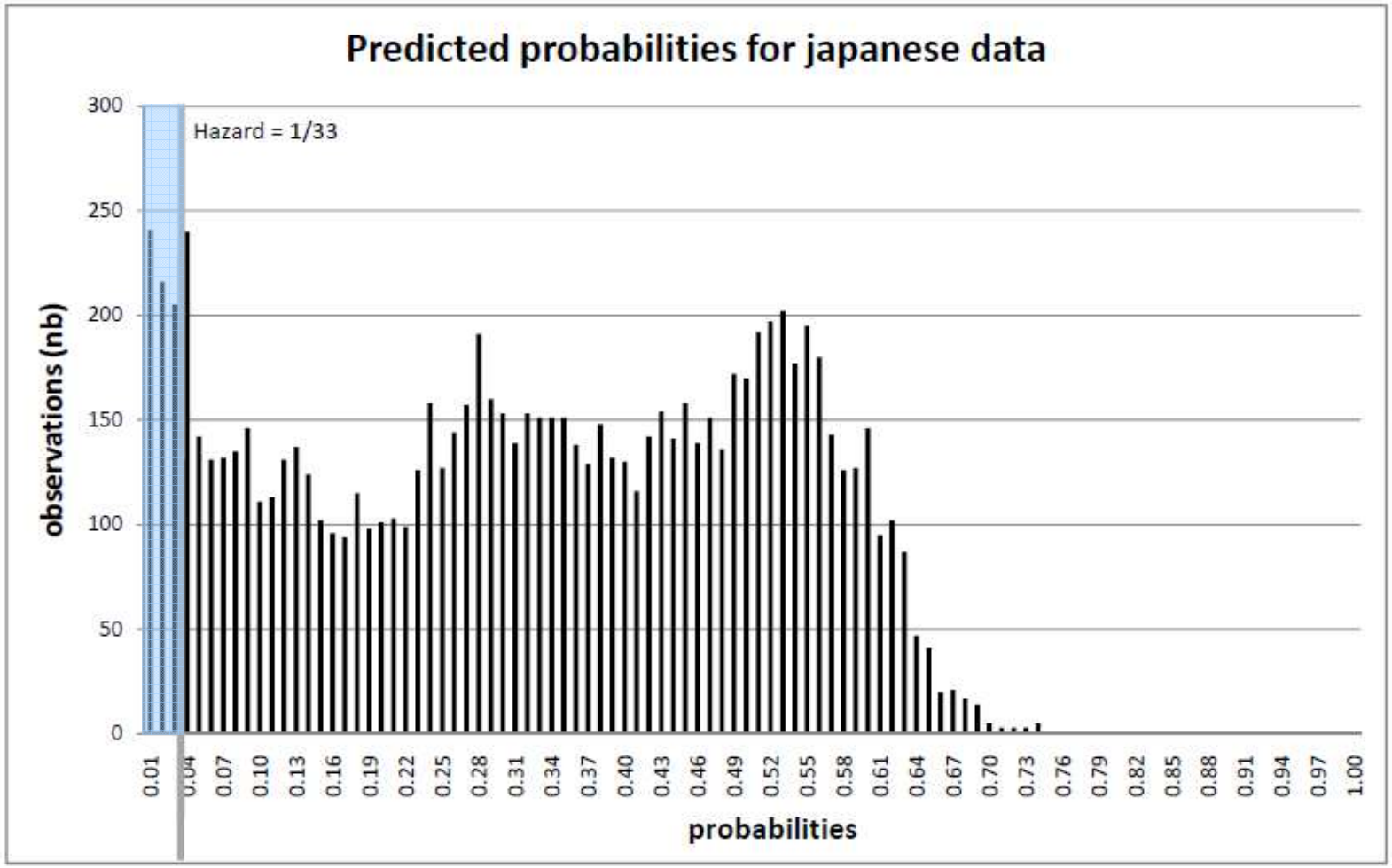
toward destination (ddist, ddir terms)

free flow acceleration (dec, accLS, accHS terms)

leader-follower (acc, dec terms)

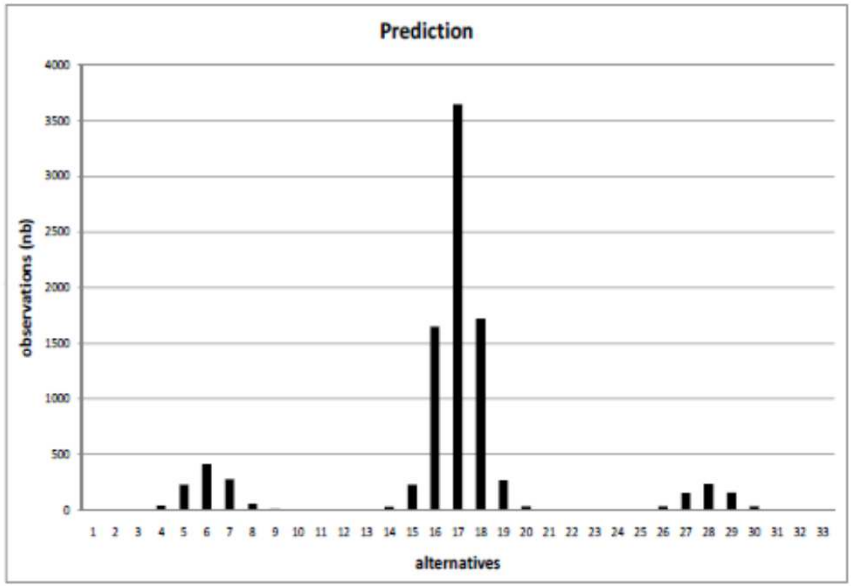
collision avoidance (C terms)

Data1：real

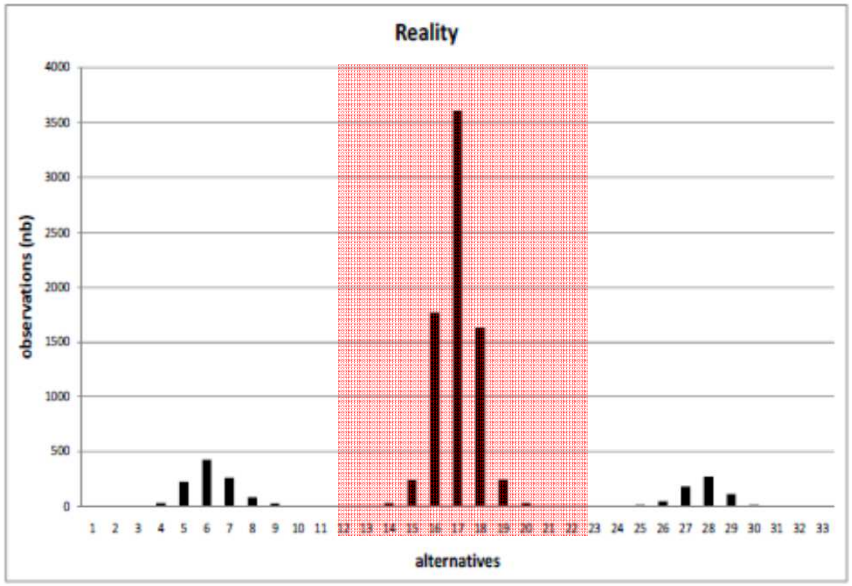


7.13%

Data1：real



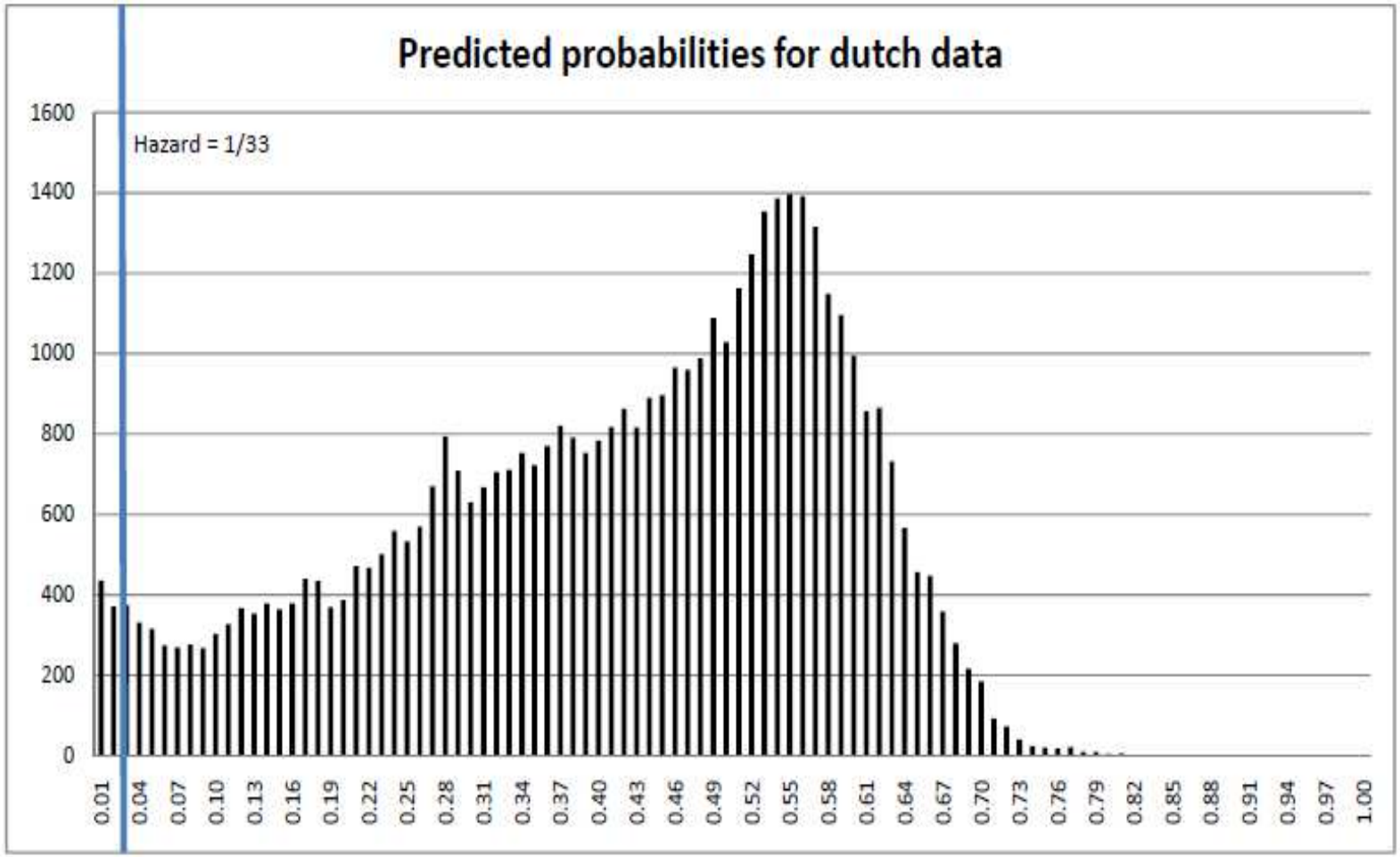
Predicted



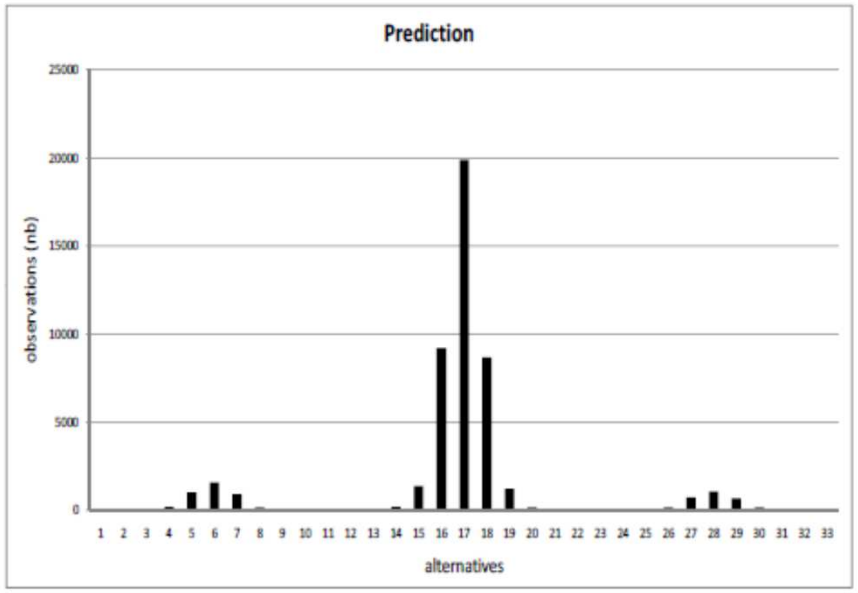
Observed

constant-only model: 19.90%

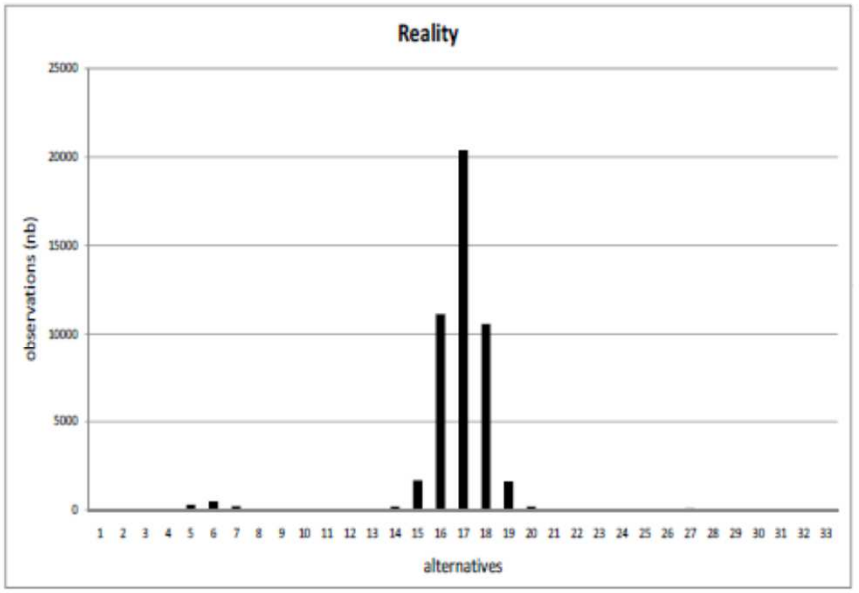
Data2：Experimental



Data2：Experimental



Predicted



Observed

結論

- 歩行者行動モデルに関する新しい方法論のフレームワークを示した（離散選択モデル）
- 実データを使用しモデルを作成
- 作成モデルは，実験データにおいても首尾よく推定された.