

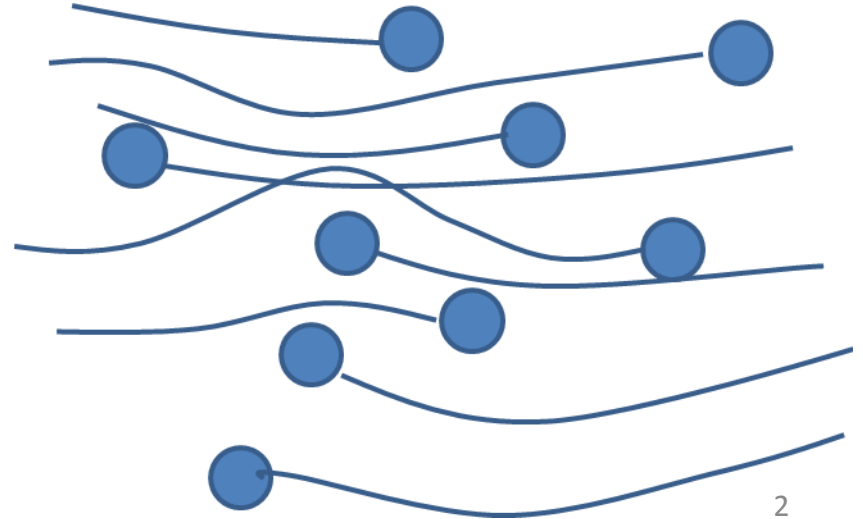
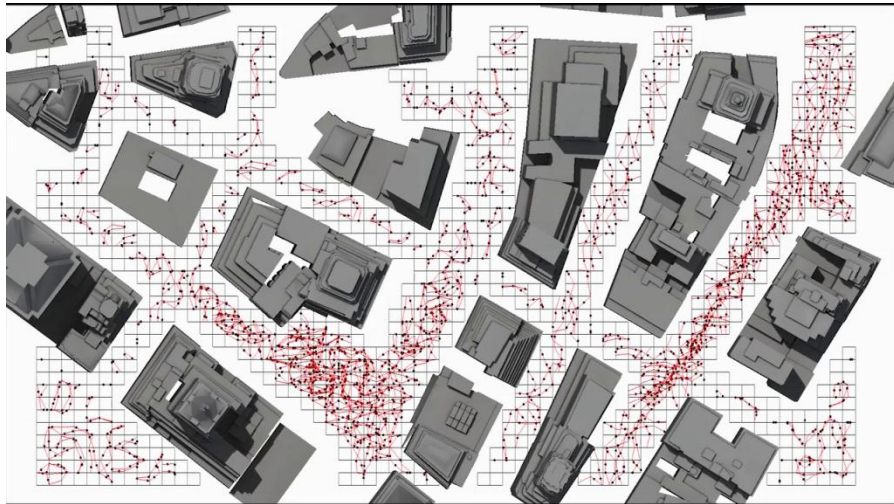
Simuler les foules et peupler les mondes virtuels

Julien Pettré

Mondes virtuels



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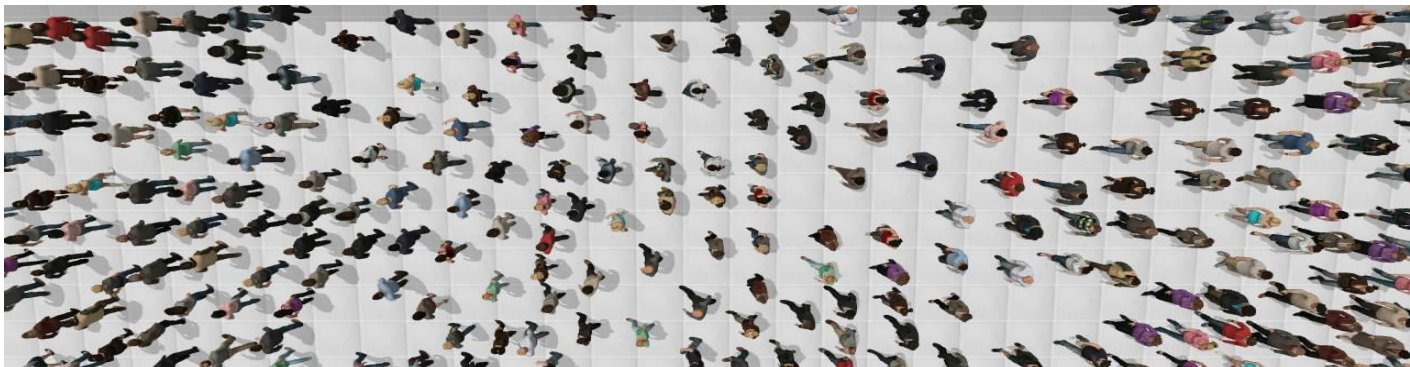


SIMULATION DE FOULE

Simulation de foule

Wikipedia (version anglaise, 2015) :

*“La **simulation de foule** est le procédé par lequel est calculé le mouvement d’un grand nombre d’entités ou de personnages; elle est fréquemment utilisée en animation graphique pour la réalisation de films”*



Sujet vaste

- Applications :
 - Architecture,
 - Sécurité,
 - Entraînement,
 - Surveillance,
 - Etc.



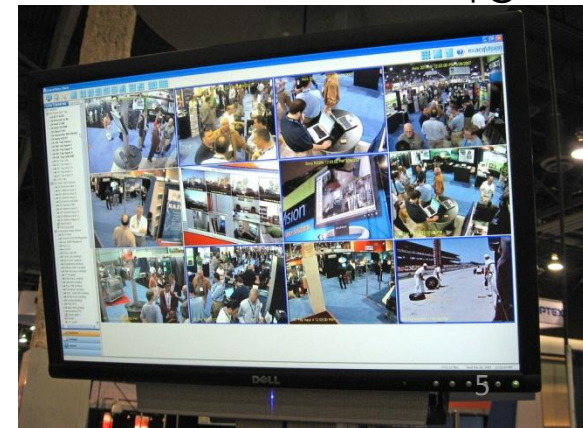
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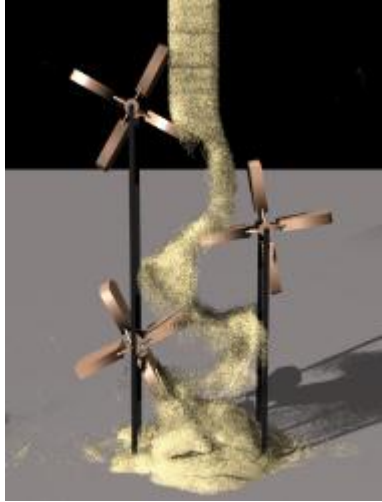


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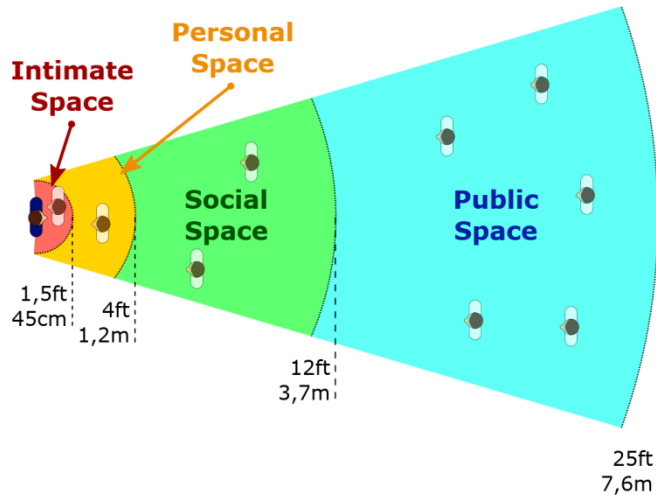
Sujet pluridisciplinaire



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- Disciplines :
 - Informatique,
 - Physique,
 - Mathématiques,
 - Psycho-sociologie,
 - Sciences du Transport,
 - Etc.

Deux approches



Microscopique



Macroscopique

Approches microscopiques



Approches microscopiques

- Agent :
 - Individu
 - Déplacement
 - Buts & motivations
 - Contraintes



Approches microscopiques

- Agent
- Voisinage :
 - Sous-ensemble d'agents
 - Influence



Approches microscopiques

- Agent
- Voisinage
- Interaction :
 - Influence sur la trajectoire
 - Type : éviter, suivre, fuir, etc.
 - Facteurs : physiques, sociologiques, psychologiques, etc.



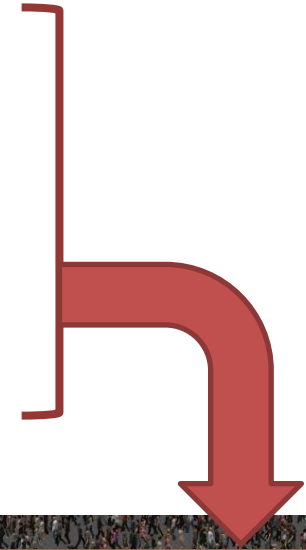
Approches microscopiques



- Agent
- Voisinage
- Interaction
- Combinaison :
 - Cumulation et ordonnancement d'interactions
 - Types d'interactions identiques ou différents

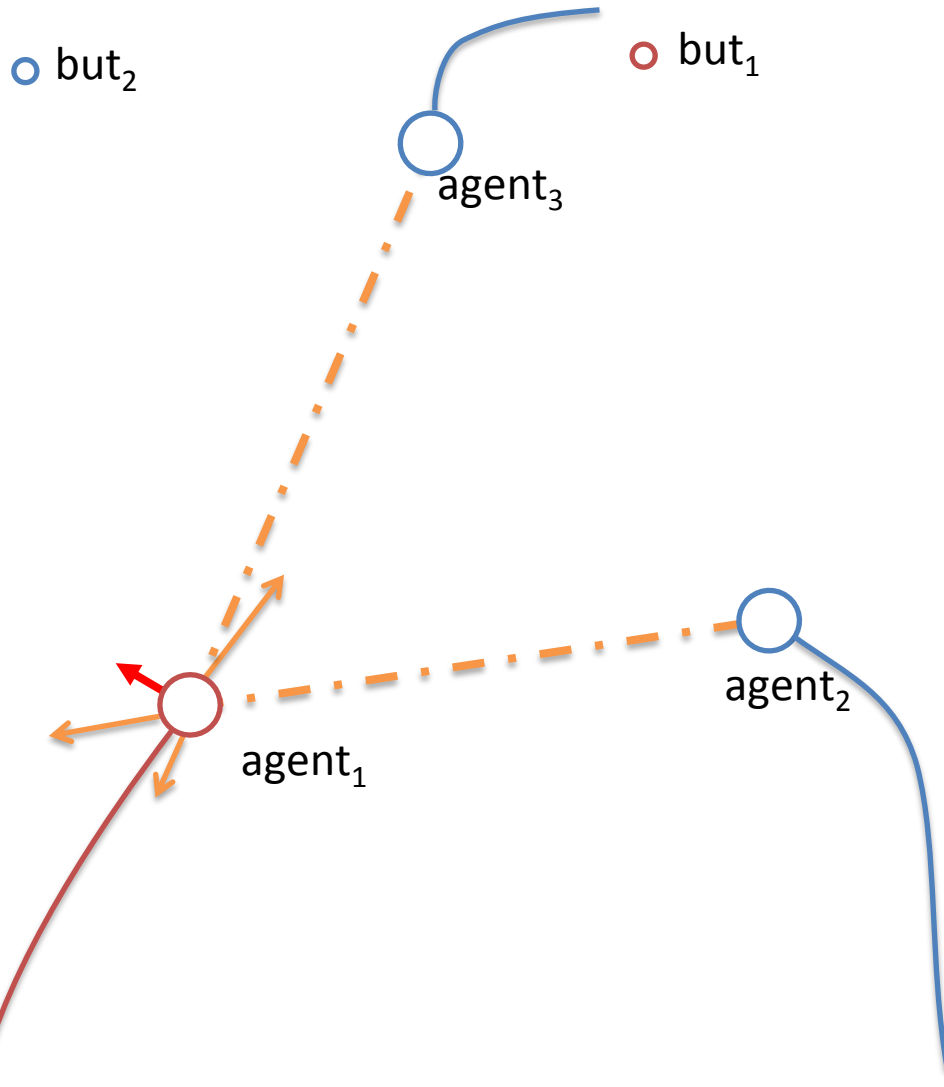
Approches microscopiques

- Agent
- Voisinage
- Interaction
- Combinaison



INTERACTIONS LOCALES: ÉVITEMENT DE COLLISION

Modèles d'évitement de collision



- Modèle « en position » (Forces sociales)

- Evitement:

$$d > s$$

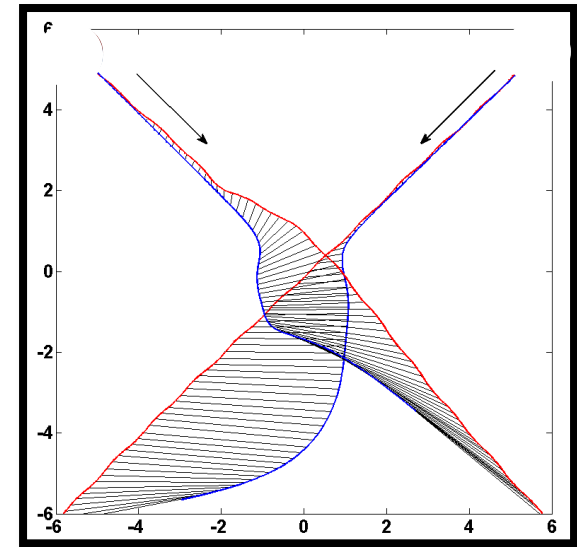
- Répulsion:

$$\vec{F}_{1,i} = r(d) \cdot \frac{\overrightarrow{P_i P_1}}{\|P_i P_1\|}$$

- Mouvement:

$$\vec{a}_1 = \overrightarrow{F_{1,but_1}} + \sum_i \vec{F}_{1,i}$$

Etude expérimentale

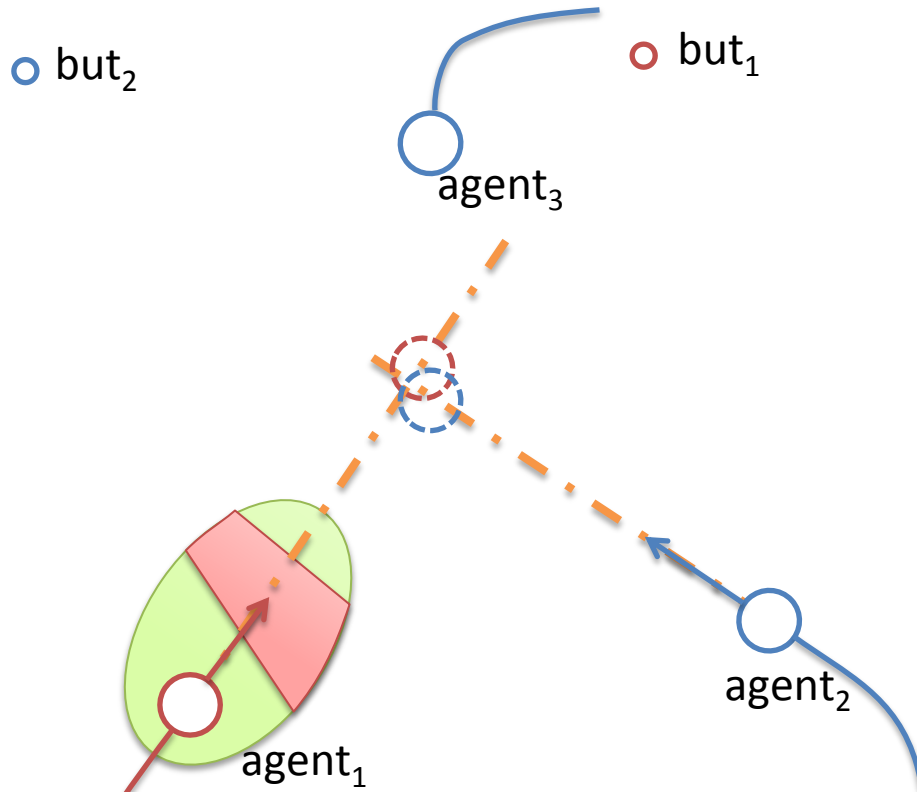


— Trajectoires réelles
— Trajectoires simulées

Olivier, A. H., Marin, A., Crétual, A., & Pettré, J. (2012). **Minimal predicted distance: A common metric for collision avoidance during pairwise interactions between walkers.** *Gait & posture*, 36(3), 399-404.

Olivier, A. H., Marin, A., Crétual, A., Berthoz, A., & Pettré, J. (2013). **Collision avoidance between two walkers: Role-dependent strategies.** *Gait & posture*, 38(4), 751-756.

Modèles d'évitement



- Modèle « en vitesse »

- Evitement:

$$d(t_{futur}) > s$$

- Mouvement à vitesse constante

- Distance minimum d'approche

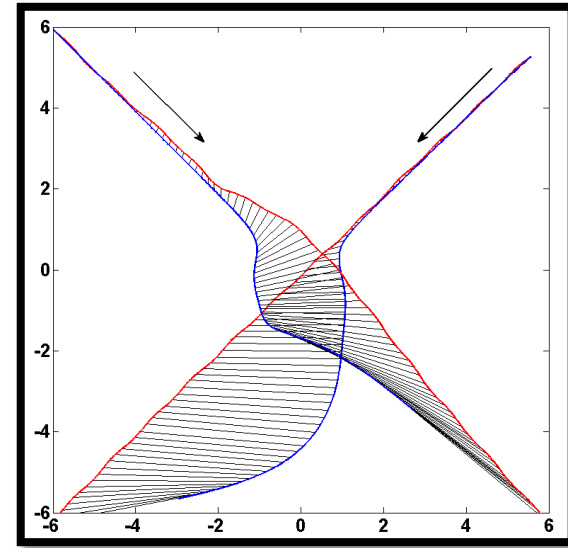
- Vitesse admissible:

$$\forall A_{1|2} = \{\vec{v}_1 | \forall t \in [t_0, t_0 + \tau], d(t) > r\}$$

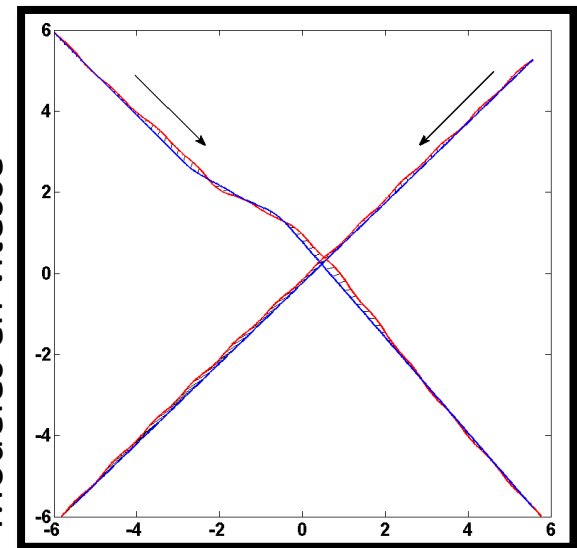
Paris, S., Pettré, J., & Donikian, S. (2007, September). **Pedestrian reactive navigation for crowd simulation: a predictive approach**. In *Computer Graphics Forum* (Vol. 26, No. 3, pp. 665-674).

Pettré, J., Ondřej, J., Olivier, A. H., Cretual, A., & Donikian, S. (2009). **Experiment-based modeling, simulation and validation of interactions between virtual walkers**. In *Proc. of the ACM SIGGRAPH / Eurographics Symposium on Computer Animation* (pp. 189-198). ACM.

Etude expérimentale



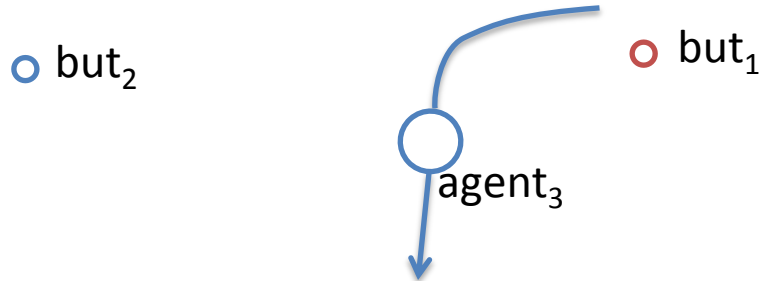
Modèles en position



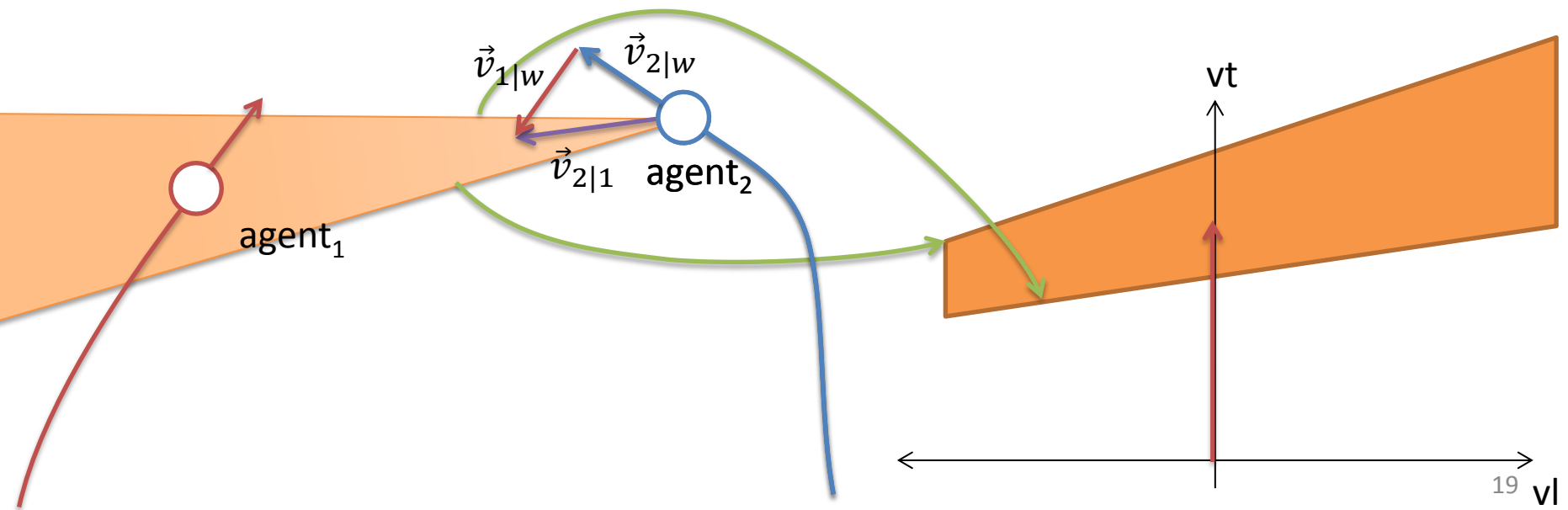
Modèles en vitesse

- Trajectoires réelles
- Trajectoires simulées

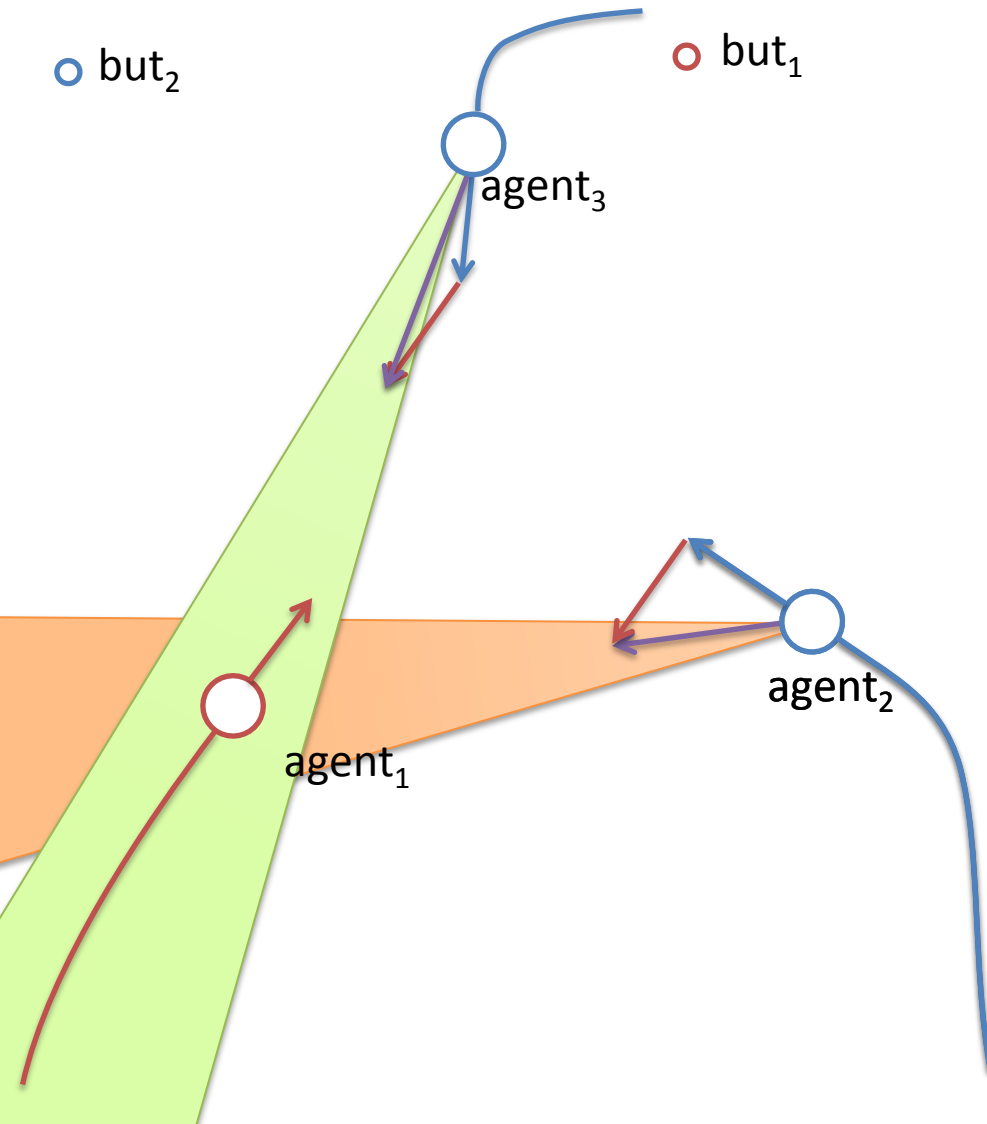
Modèles d'évitement



- Vitesse relative:
 $\vec{v}_{2|1} = \vec{v}_{2|w} - \vec{v}_{1|w}$
- Contraintes de distance d'approche
- Espace des vitesses atteignables

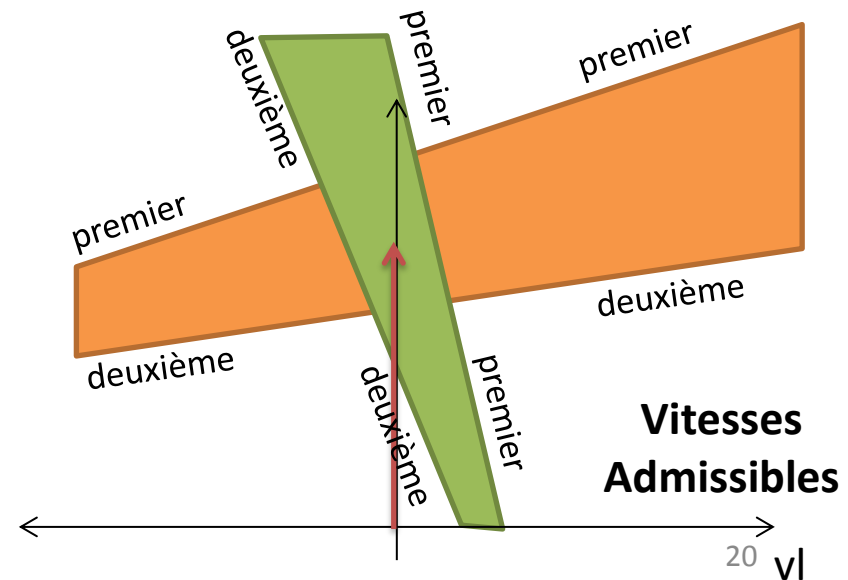


Modèles d'évitement



- Vitesse relative:

$$\vec{v}_{2|1} = \vec{v}_{2|w} - \vec{v}_{1|w}$$
- Contraintes de distance d'approche
- Espace des vitesses atteignables
- Combinaisons



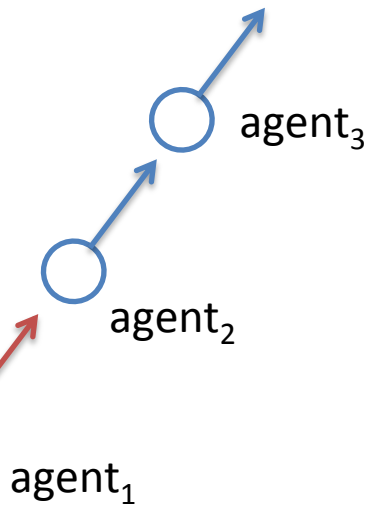
Exemple



INTERACTIONS LOCALES: SUIVI

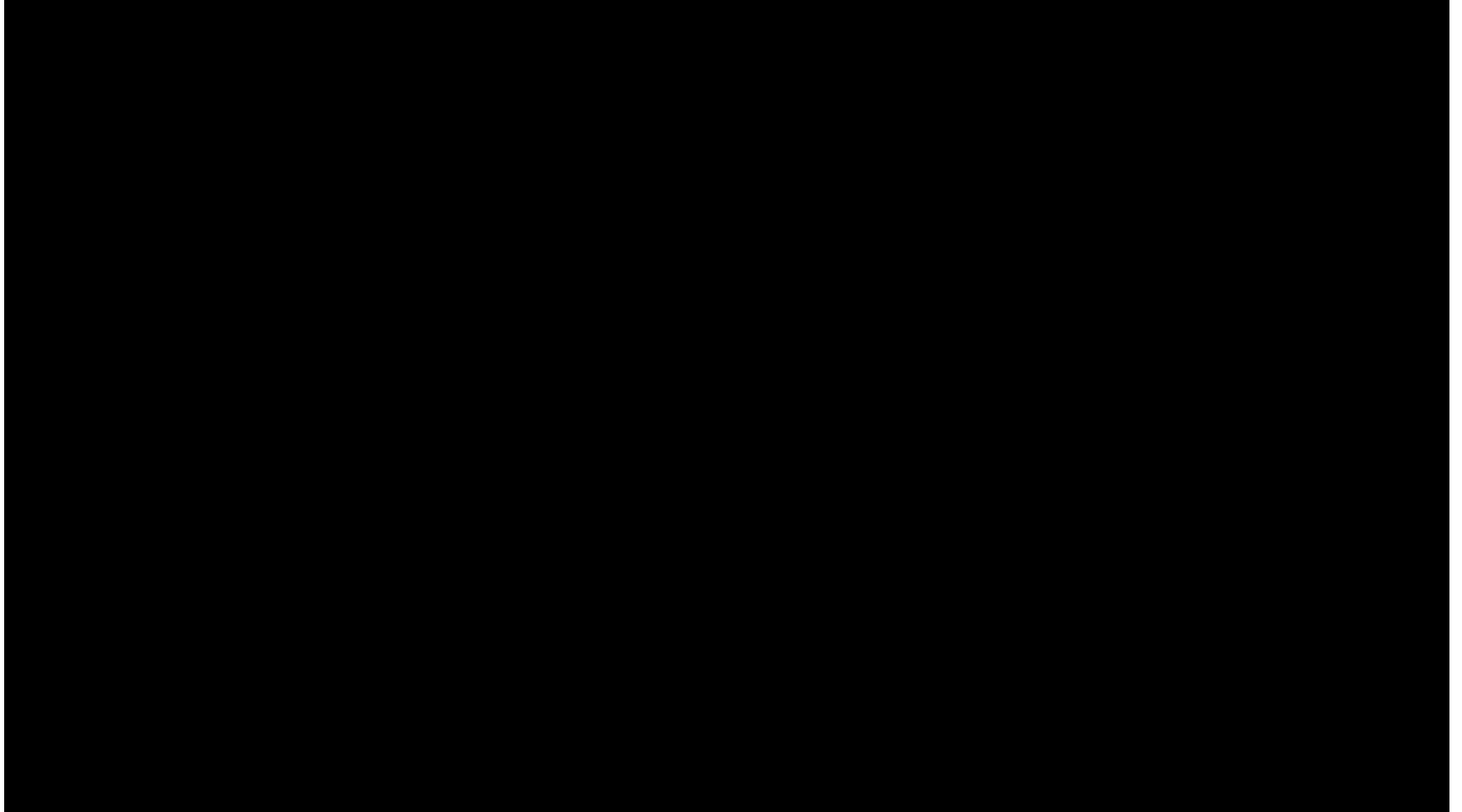
Modèles de suivi

but₁
but₂
but₃

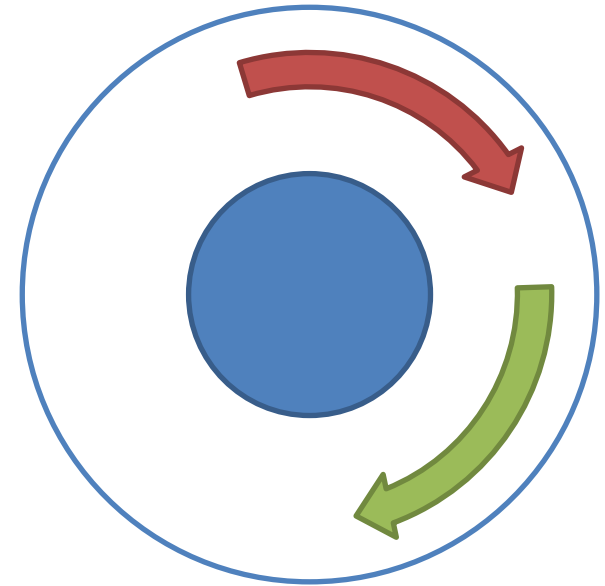
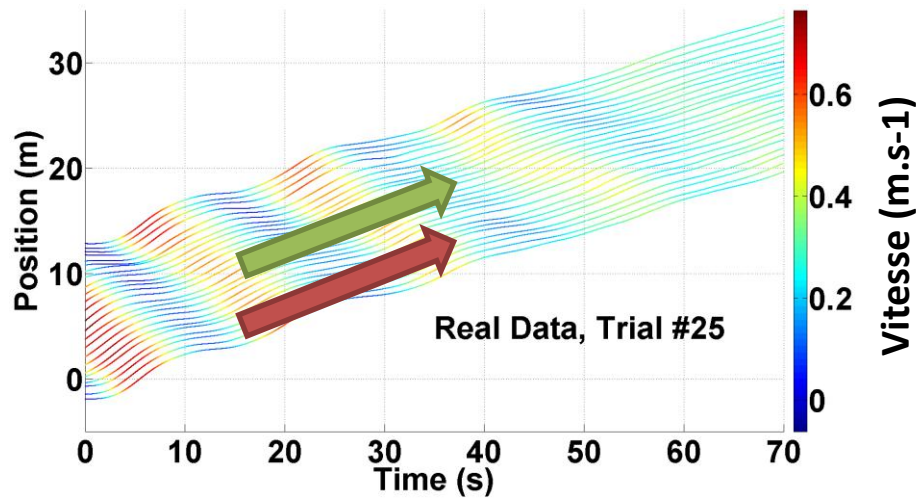


- Contrôle unidimensionnel du mouvement
- Peu étudié
- Similitudes avec la conduite automobile
- Phénomènes collectifs émergents

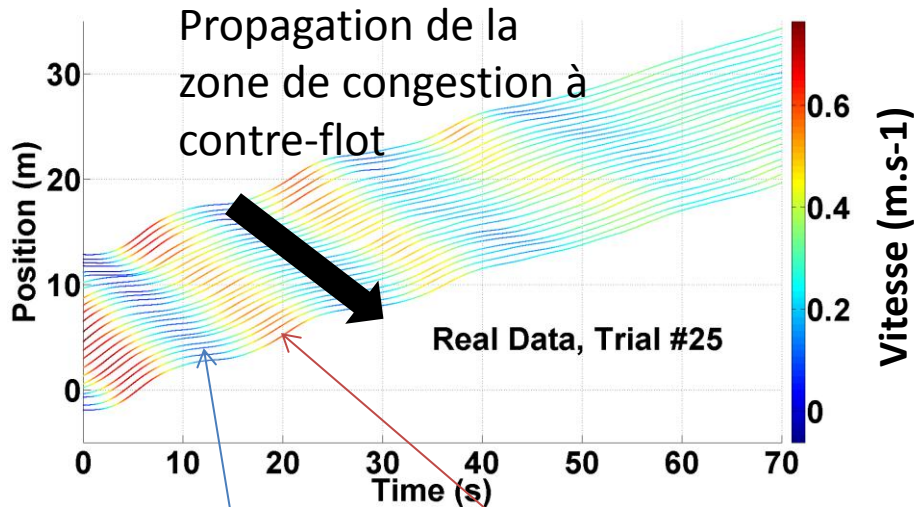
Etude circulation unidimensionnelle



Etude circulation unidimensionnelle

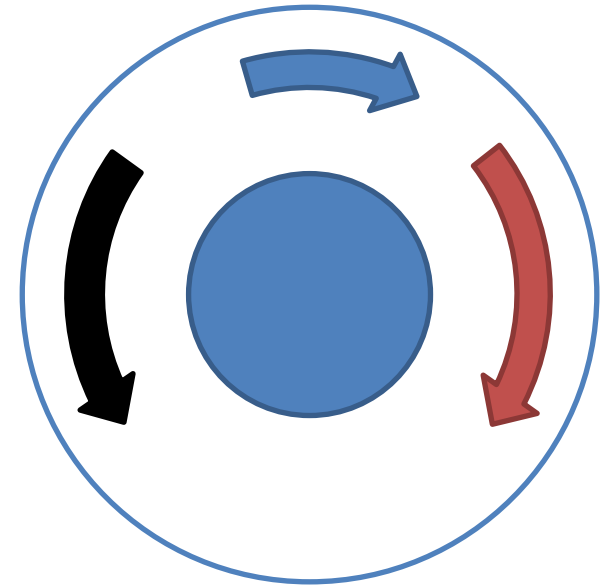


Etude circulation unidimensionnelle

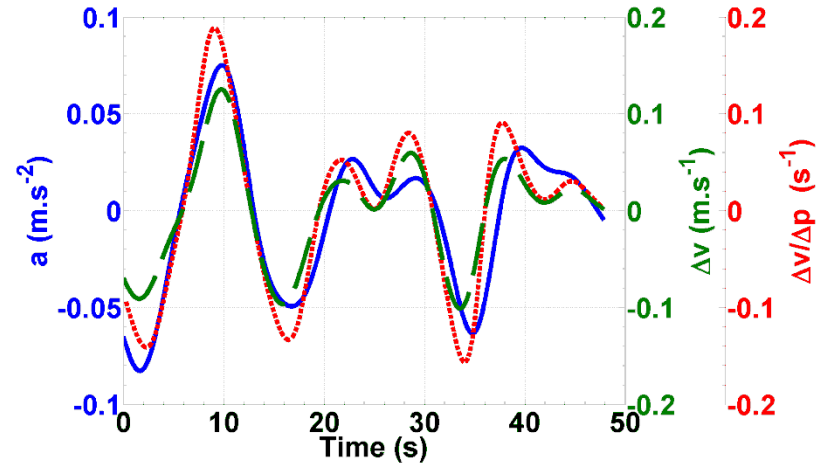
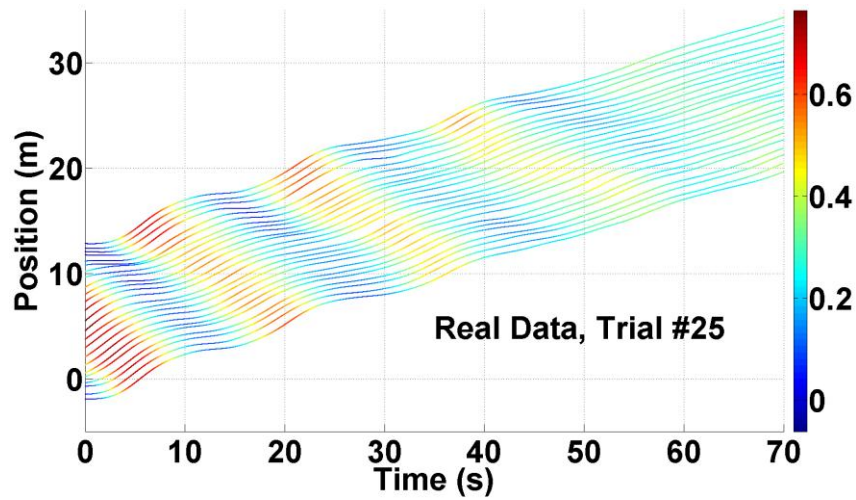


Phase de vitesse rapide

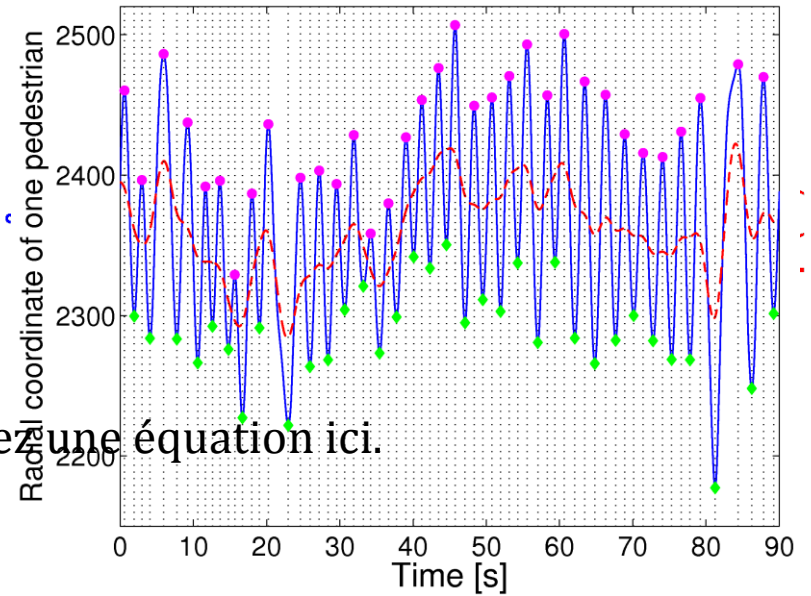
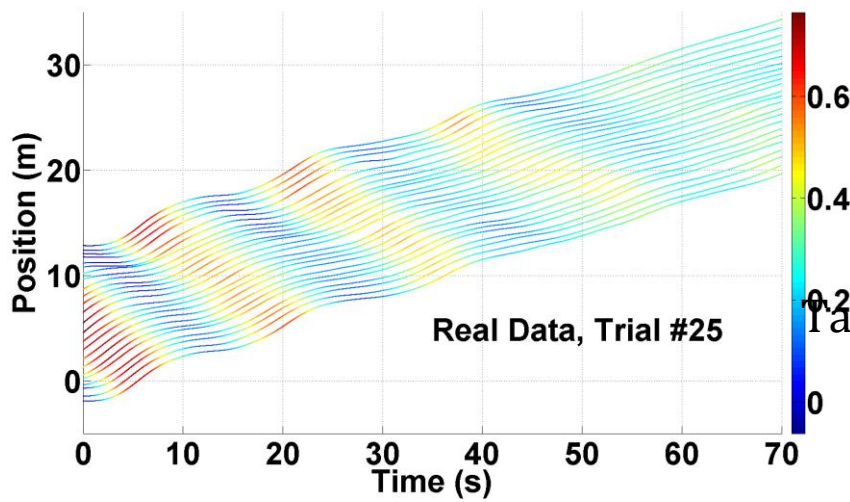
Phase de vitesse lente



Etude circulation unidimensionnelle



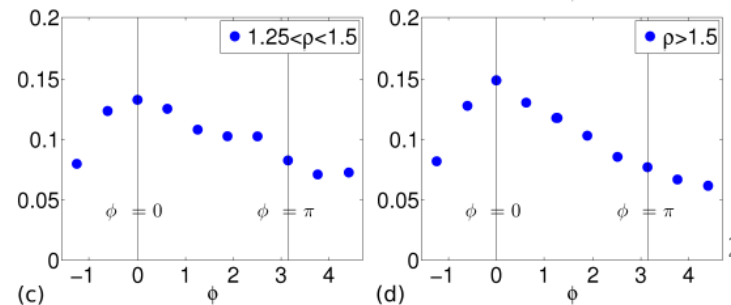
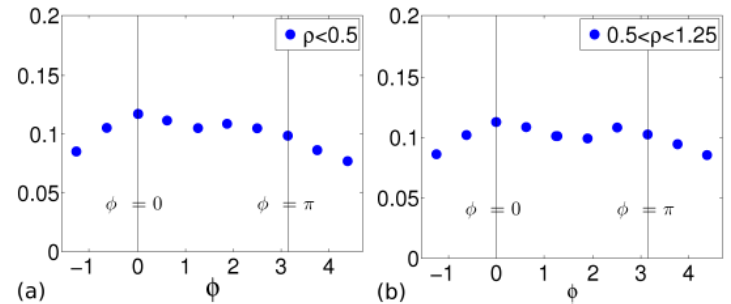
Etude circulation unidimensionnelle



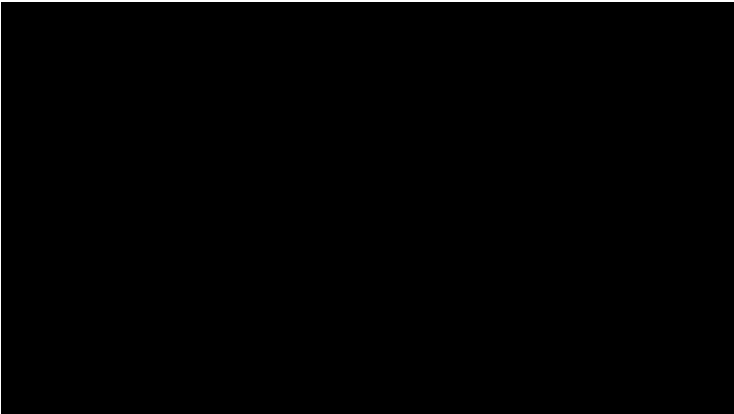
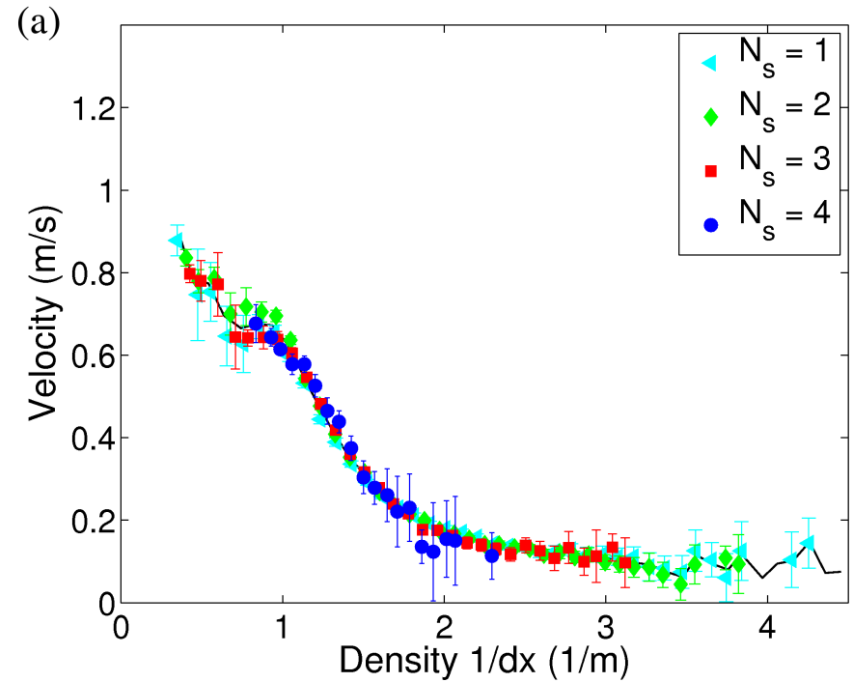
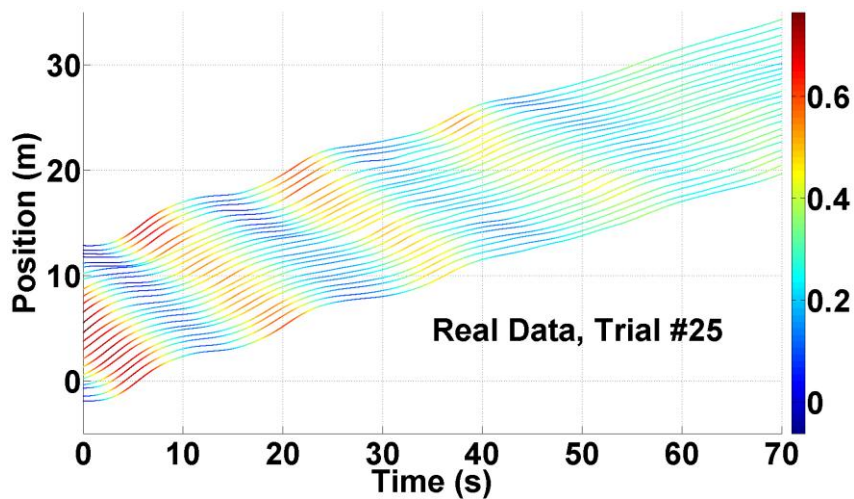
$\phi = 0$



$\phi = \pi$



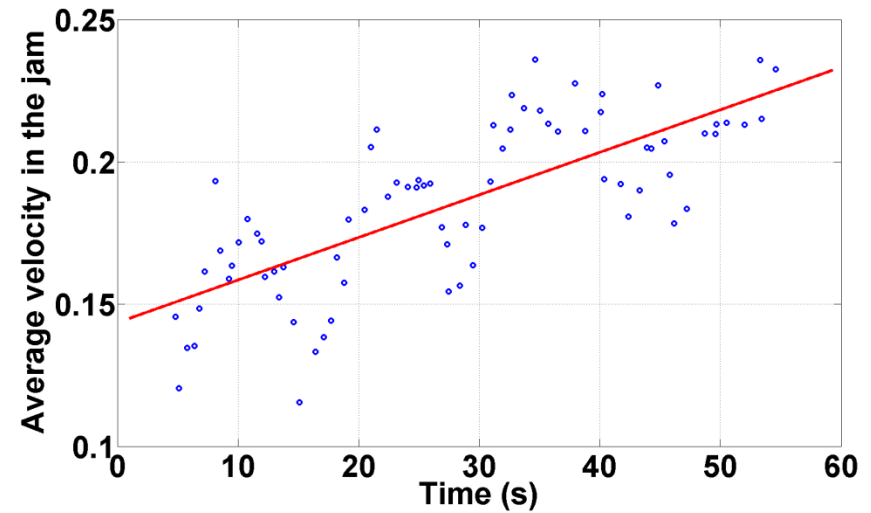
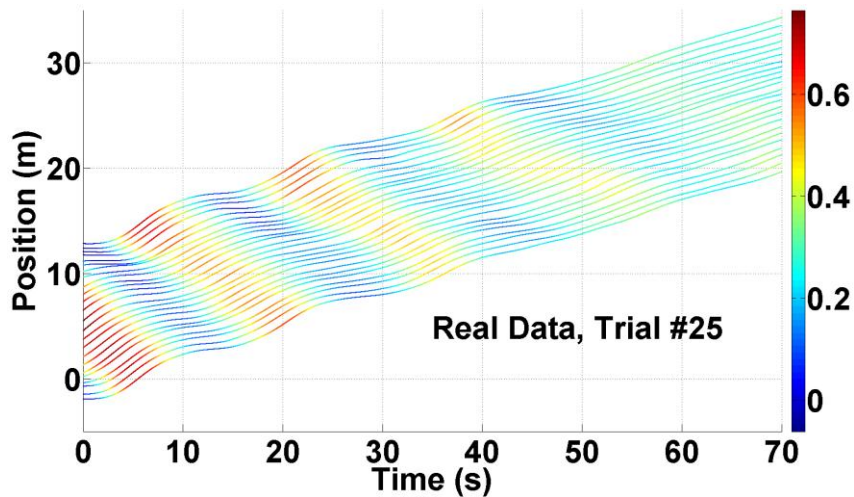
Etude circulation unidimensionnelle



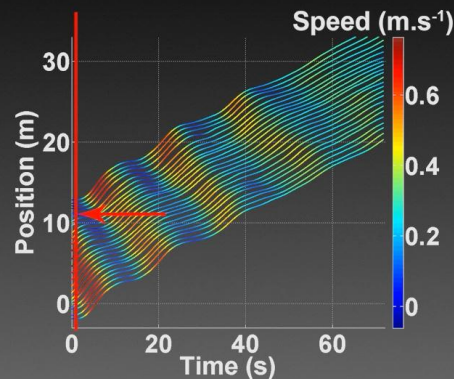
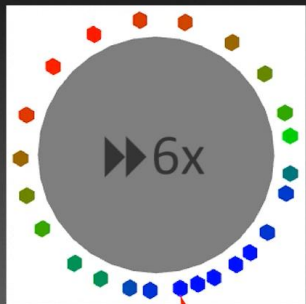
Jelić, A.; Appert-Rolland, C.; Lemerrier, S. & Pettré, J. (2012), 'Properties of pedestrians walking in line: Fundamental diagrams', *Physical Review E* 85(3).

Jelić, A.; Appert-Rolland, C.; Lemerrier, S. & Pettré, J. (2012), 'Properties of pedestrians walking in line: stepping behaviors', *Physical Review E* 85(3).

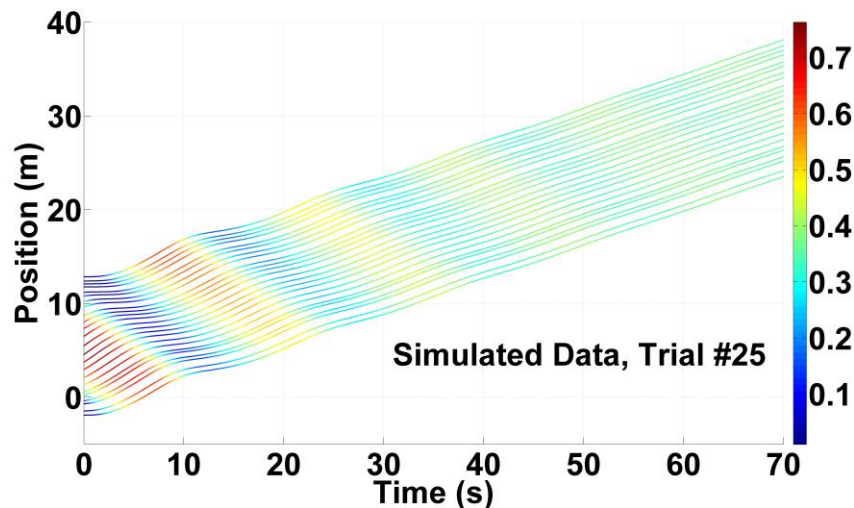
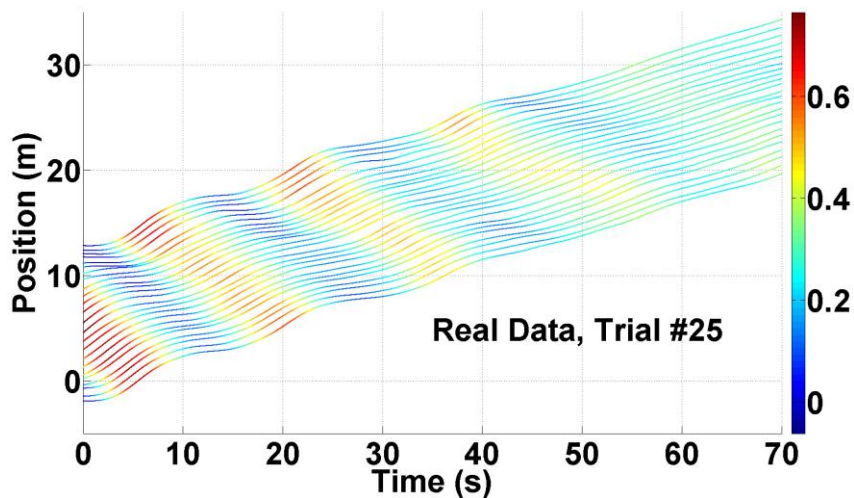
Etude circulation unidimensionnelle



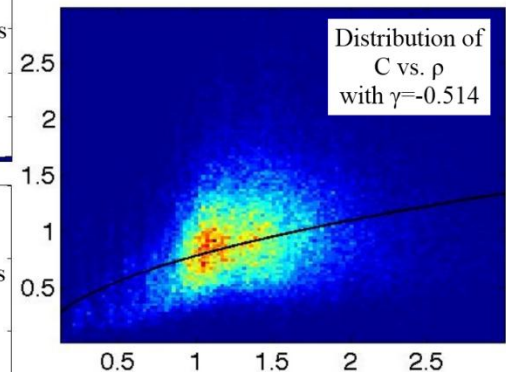
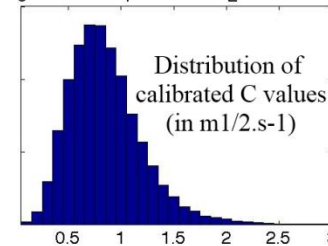
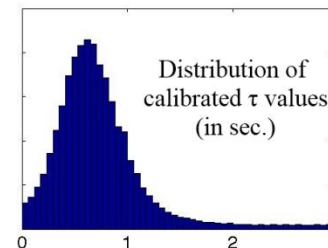
Example of experimental data:
trial #25



Etude circulation unidimensionnelle



- Elaboration d'un modèle de simulation
$$a = C \Delta v(t + \tau) \cdot \rho^{-\gamma}$$
- Calage des paramètres sur les données:



Exemple

Realistic following behaviors
for crowd simulation

ID 1030

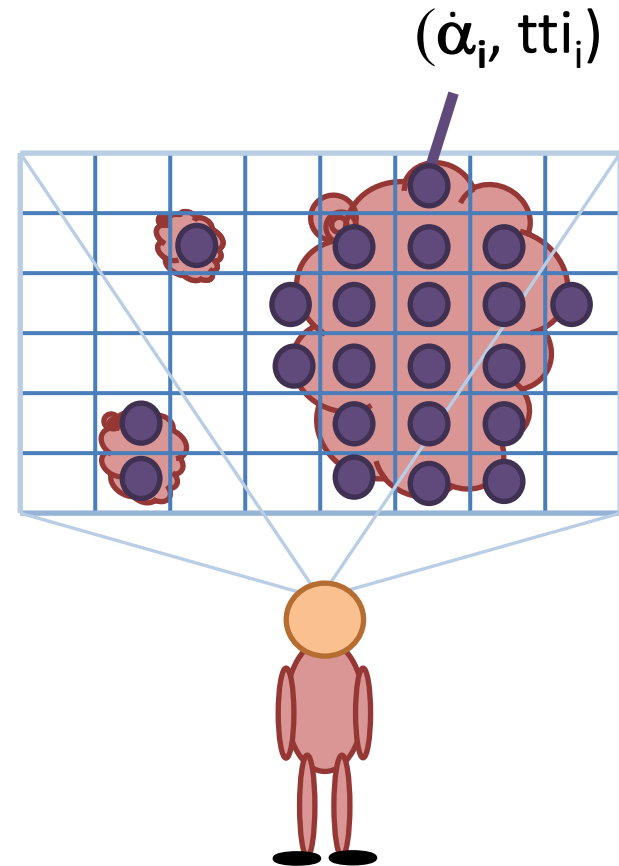
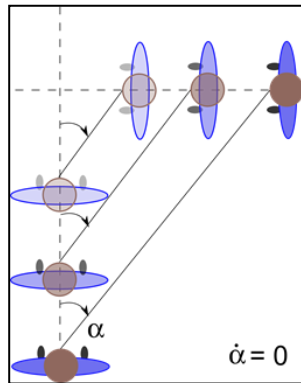
Eurographics 2012

AGENTS SENSORIMOTEURS

Contrôle visuel du mouvement

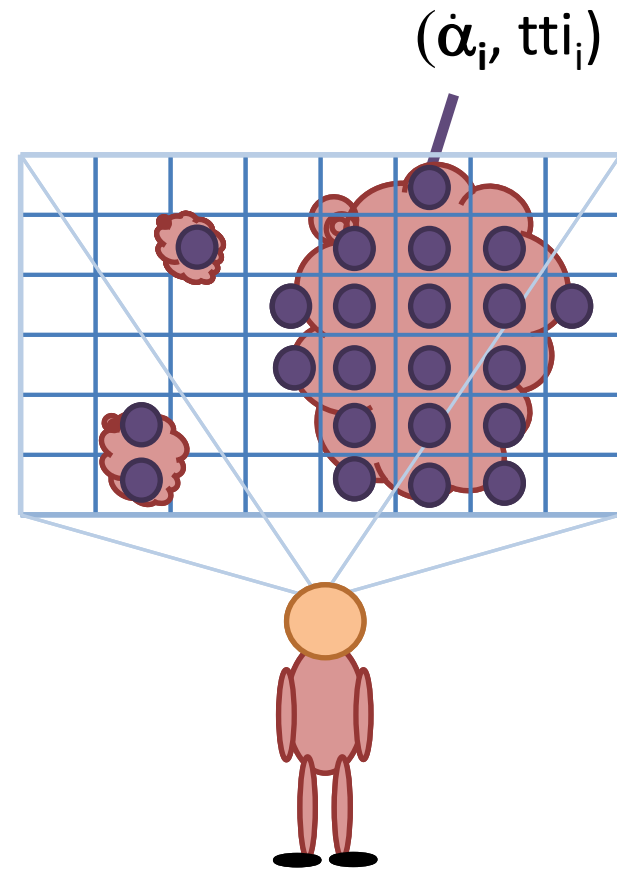
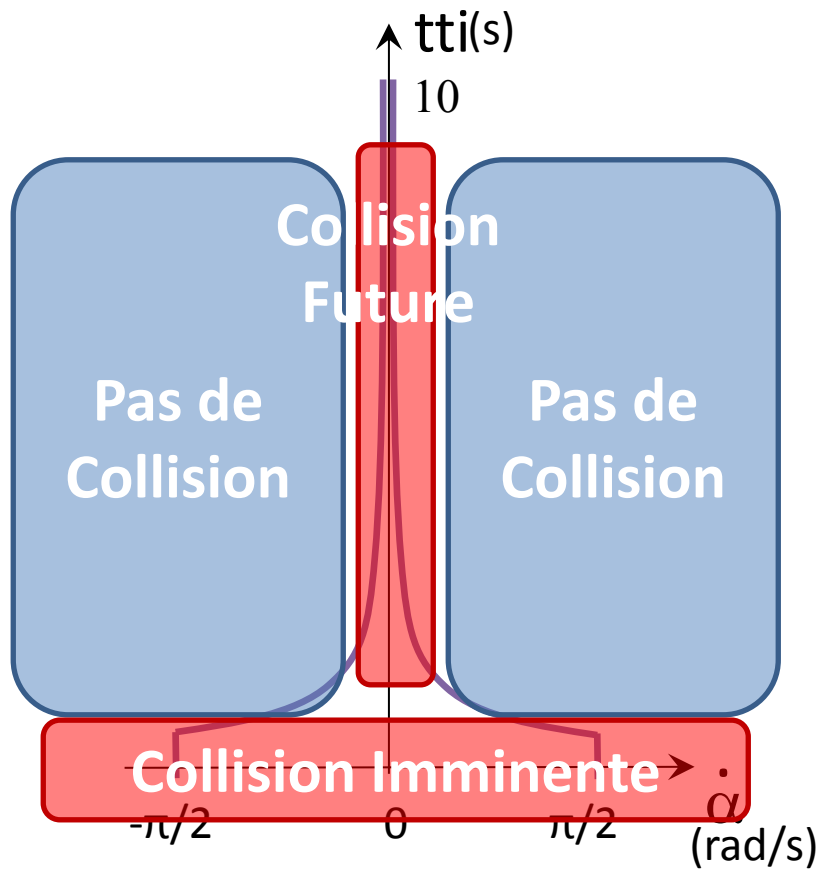


Contrôle visuel du mouvement



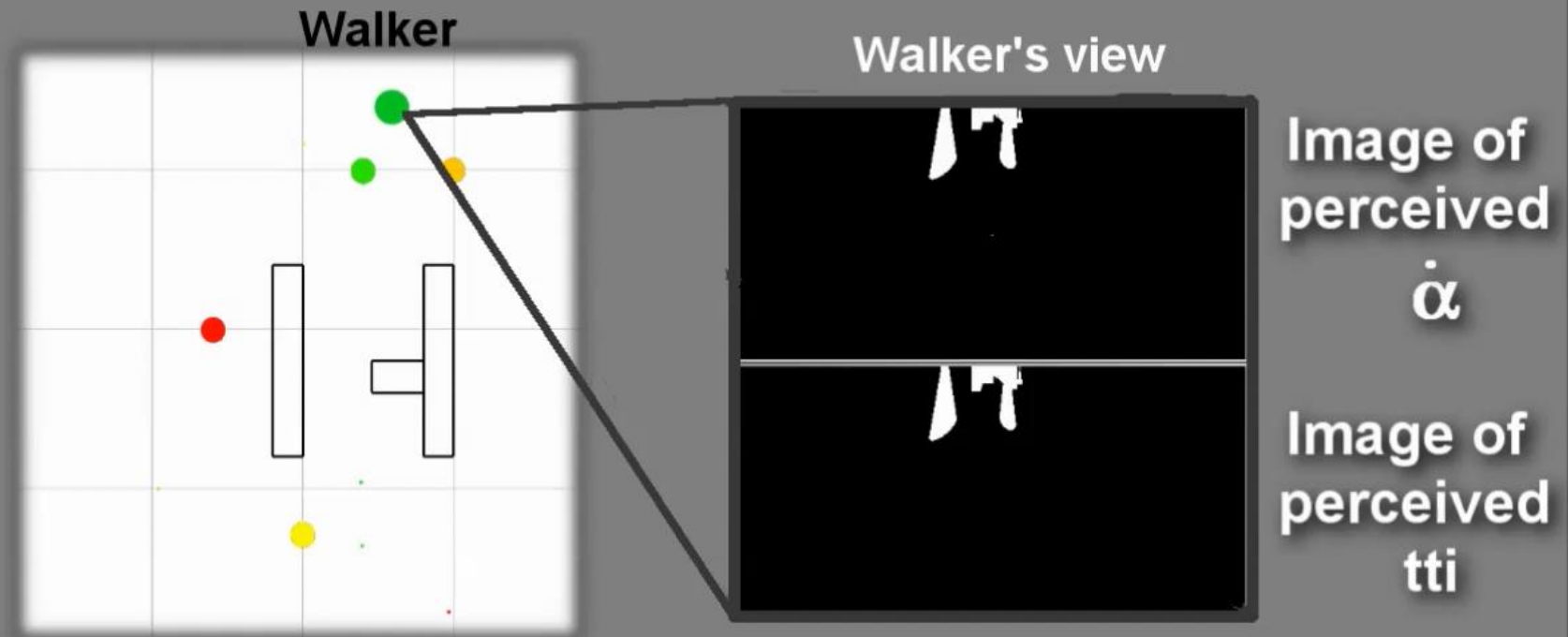
Ondřej, J., Pettré, J., Olivier, A. H., & Donikian, S. (2010, July). A synthetic-vision based steering approach for crowd simulation. In *ACM Transactions on Graphics (TOG)* (Vol. 29, No. 4, p. 123). ACM.

Contrôle visuel du mouvement



Contrôle visuel du mouvement

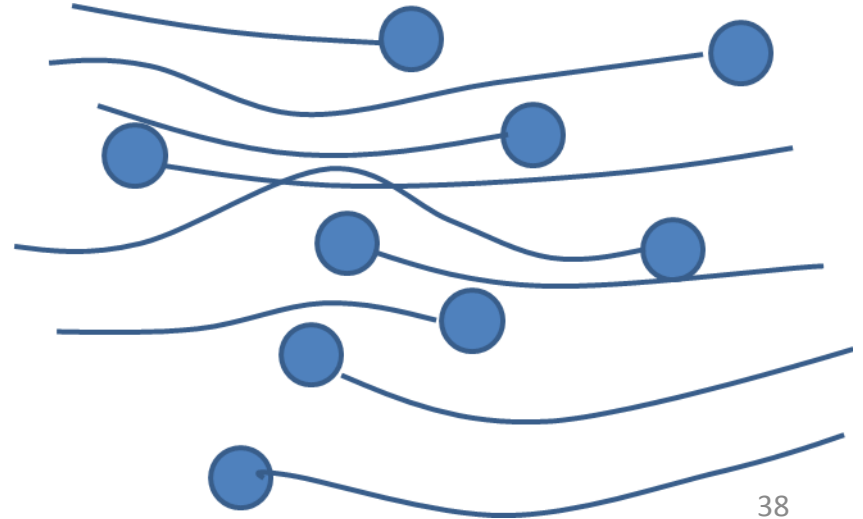
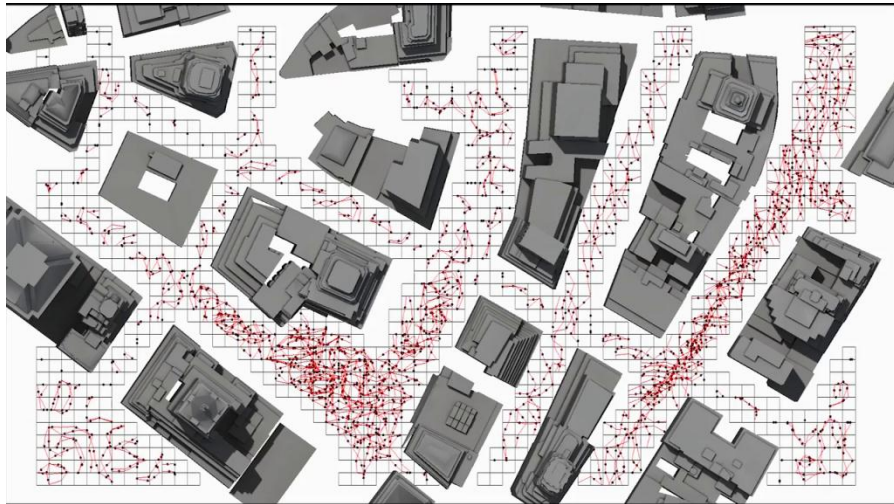
Walkers react to perceived points $p_i(\dot{\alpha}_i, tti_i)$



Mondes virtuels



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Mondes virtuels

- Simulation de foule :
 - Complexité algorithmique
 - Modélisation des comportements
 - Réglage des paramètres

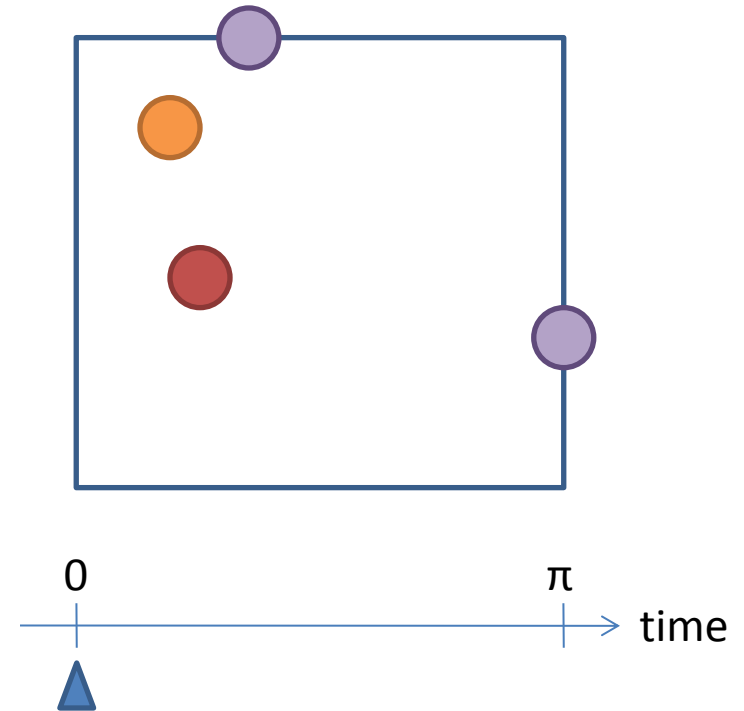
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- Alternatives nécessaires
 - Conception haut niveau
 - Contrôle intuitif
 - Hautes performances
 - Haute qualité

TEXTURES DE FOULE

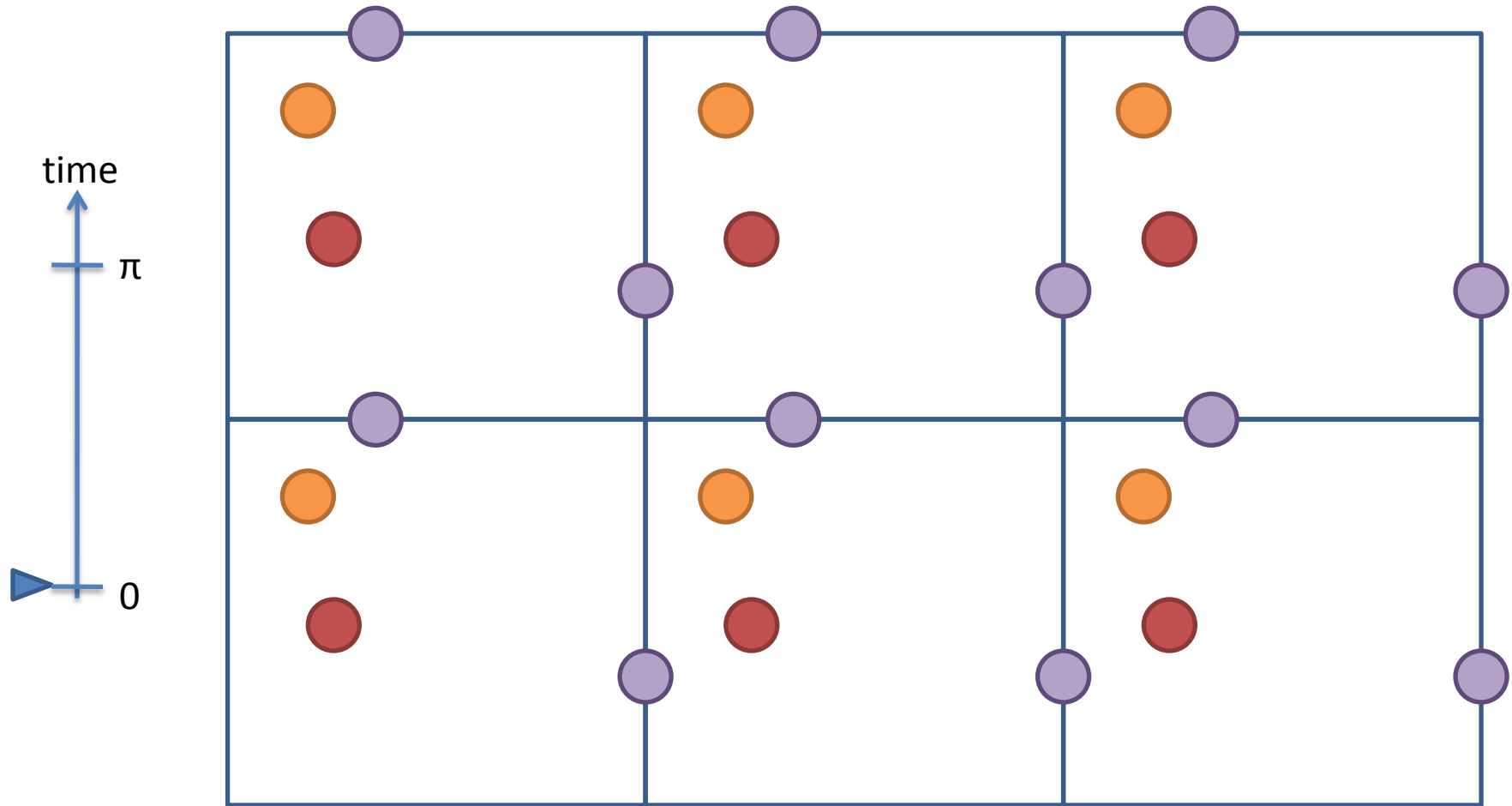
Textures de foule

- Textures 3D animées
- Animation Π -périodiques
- Points de passages spatiotemporels
- Conditions aux limites compatibles pour connection

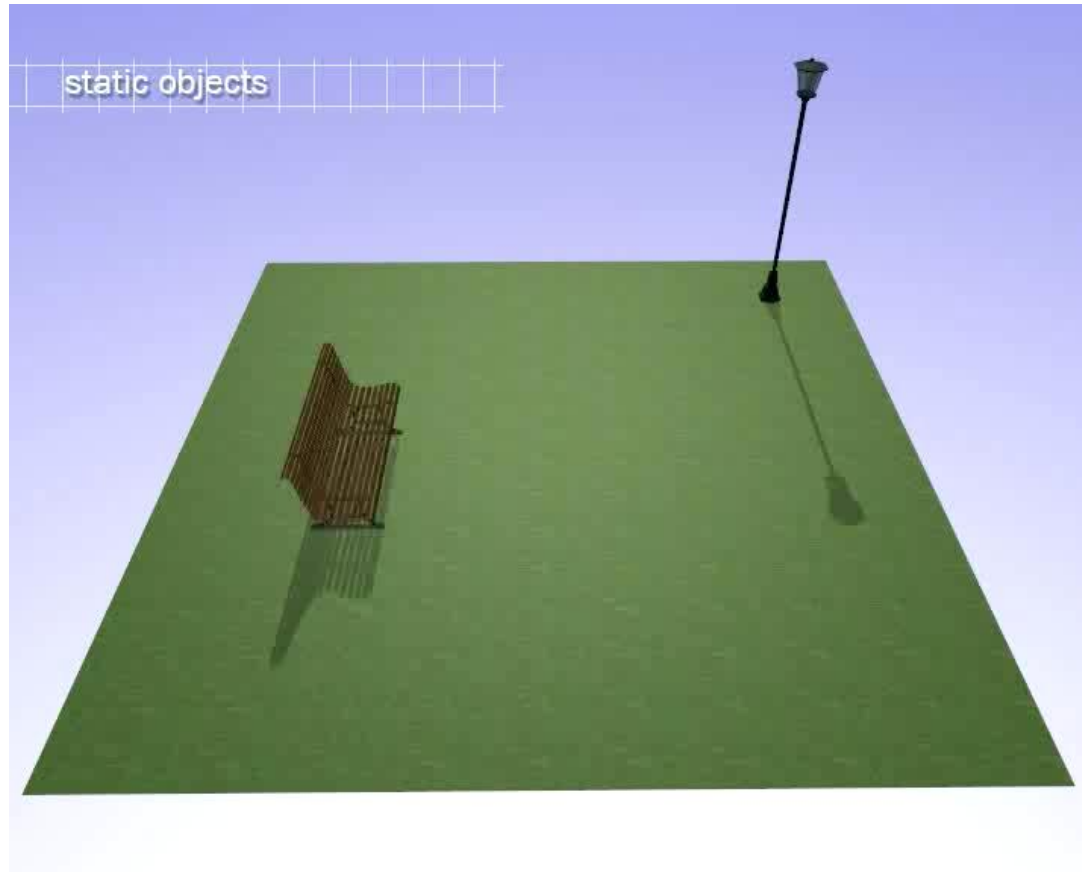


Yersin, B., Maïm, J., Pettré, J., & Thalmann, D. (2009, February). **Crowd patches: populating large-scale virtual environments for real-time applications.** In *Proceedings of the 2009 symposium on Interactive 3D graphics and games* (pp. 207-214). ACM.

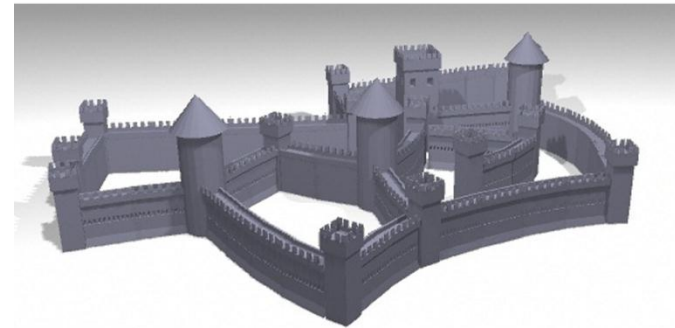
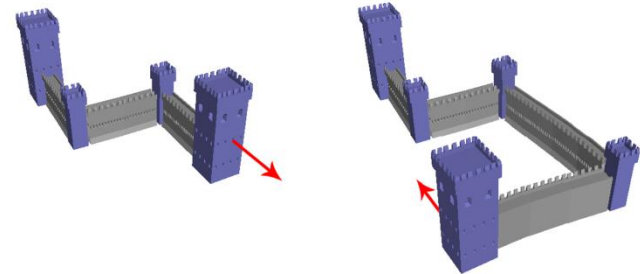
Textures de foule



Vidéo d'illustration



Sculpture d'animation de foule



Jordao, K., Pettré, J., Christie, M., & Cani, M. P. (2014). **Crowd sculpting: A space-time sculpting method for populating virtual environments.** In *Computer Graphics Forum* (Vol. 33, No. 2, pp. 351-360).

Sculpture d'animation de foule

Crowd Sculpting:
a space-time method
to populate
environments

ID 1067

Eurographics 2014

CONCLUSION

Conclusions et perspectives

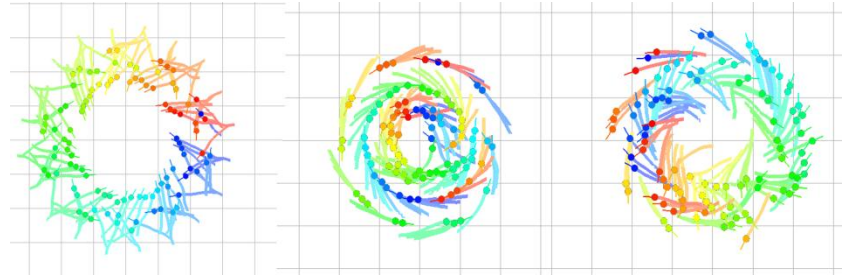
Algorithmes microscopiques de simulation de foule



Lien avec des observations expérimentales



Agents sensorimoteurs



Peuplement efficace d'environnements

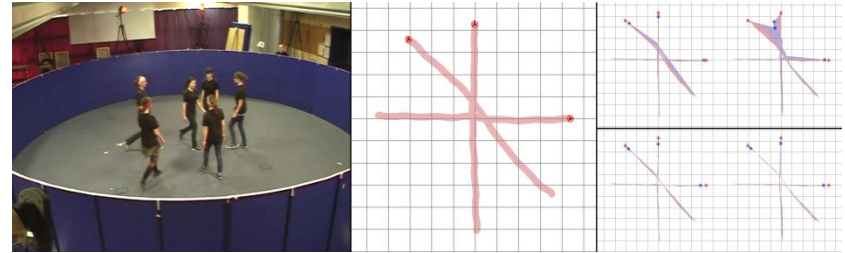


Perspectives

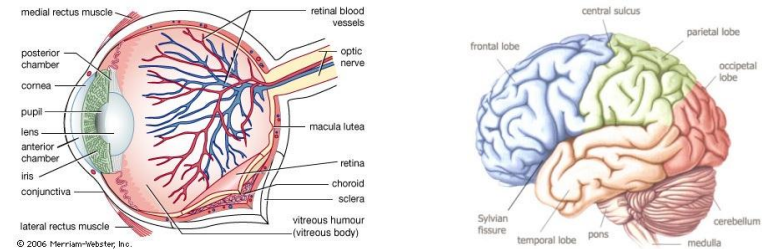
Etudes expérimentales



Calibrage d'algorithmes



Agents sensorimoteurs



Peuplement efficace
d'environnements



Merci

- (Post-)doctorants :

- Julien Bruneau
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- Kevin Jordao
- Samuel Lemercier
- Yi Li
- Ricardo Marques
- Jan Ondrej
- Zhiguo Ren
- Steve Tonneau
- David Wolinski
- Yijiang Zhang

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- Cecile Appert-Rolland
- Alain Berthoz
- Marie-Paule Cani
- Marc Christie
- Armel Crétual
- Pierre Degond
- Stéphane Donikian
- Richard Kulpa
- Anne-Hélène Olivier
- Daniel Thalmann



Merci

