Toward realistic and efficient virtual crowds

Julien Pettré

-

June 25, 2015

Habilitation à Diriger des Recherches

A short Curriculum

- **2003**
  - PhD degree from the University of Toulouse III
  - Locomotion planning for digital actors
- **2005**
  - Post-doc at EPFL, Switzerland
  - Crowd animation, motion planning for crowds
- **2006**
  - Researcher position at Inria
  - Crowd modeling and simulation

Virtual Crowds

To understand, reproduce or predict the behaviour of real human crowds

Virtual Crowds


Transportation systems design

Safety procedures


Event planning


Urban design


Movie industry


Game industry

…

Virtual Crowds

Introduction

To observe the behaviour of real human crowds

Macroscopic

Microscopic

Timeline

- **2007-10**
  - ANR LOCANTHROPE
  - EU TANGO
  - ANR PEDIGREE
- **2012**
  - Olivier et al., '**Minimal predicted distance**', *Gait & Posture*
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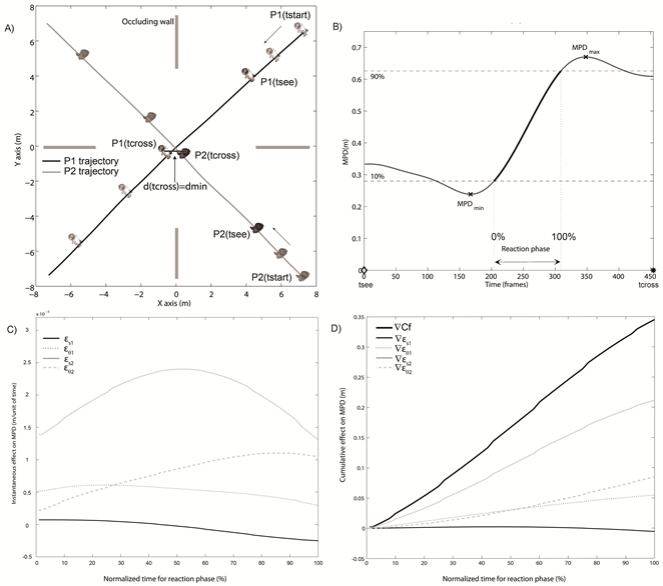
- **2015**
  - Bruneau et al., '**Going through, going around: A study on individual avoidance of groups**', *IEEE VR*

Collision avoidance between 2 walkers



[Olivier *G&P* 2013]

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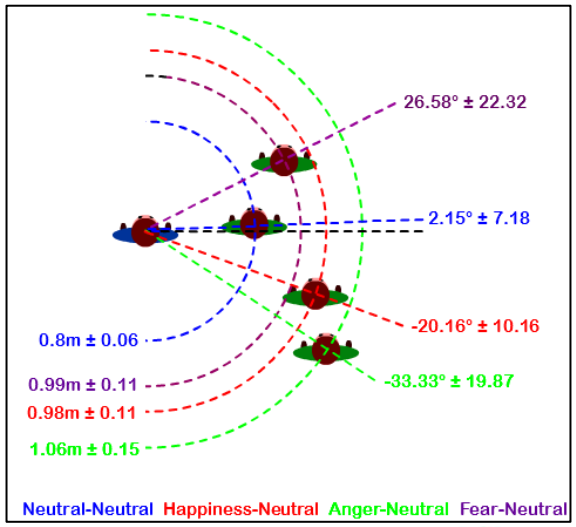
Influence of psychological factors



[Perrinet et al. *SAP* 2013]

Timeline

Using Virtual Reality to control experimental conditions

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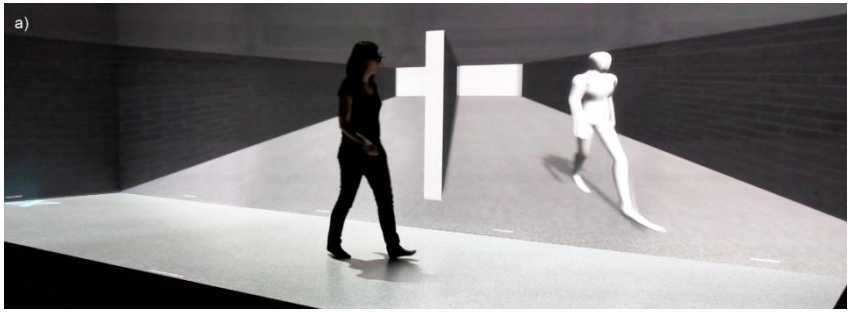

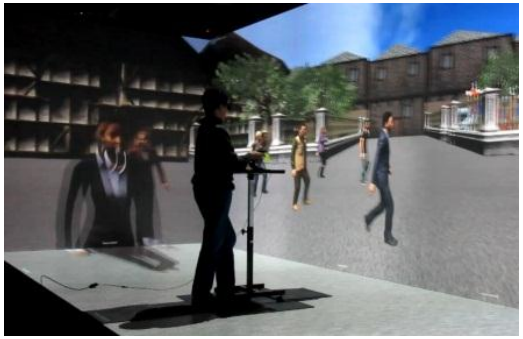

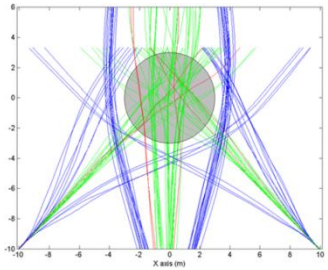

[Bruneau et al. *IEEE VR* 2015]

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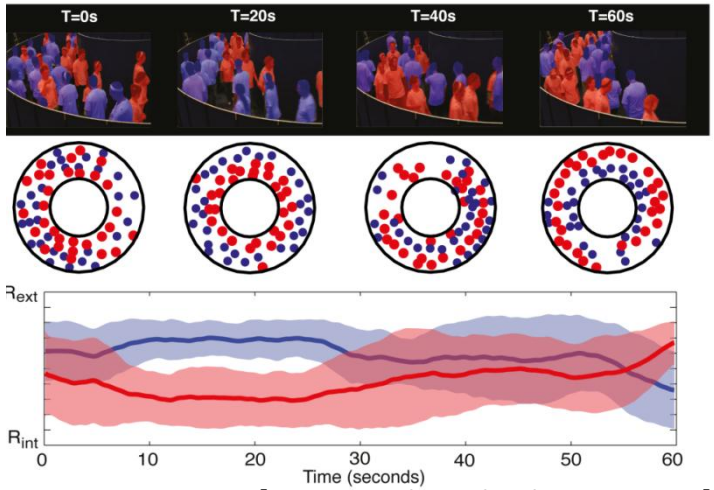
Observe emergent traffic patterns

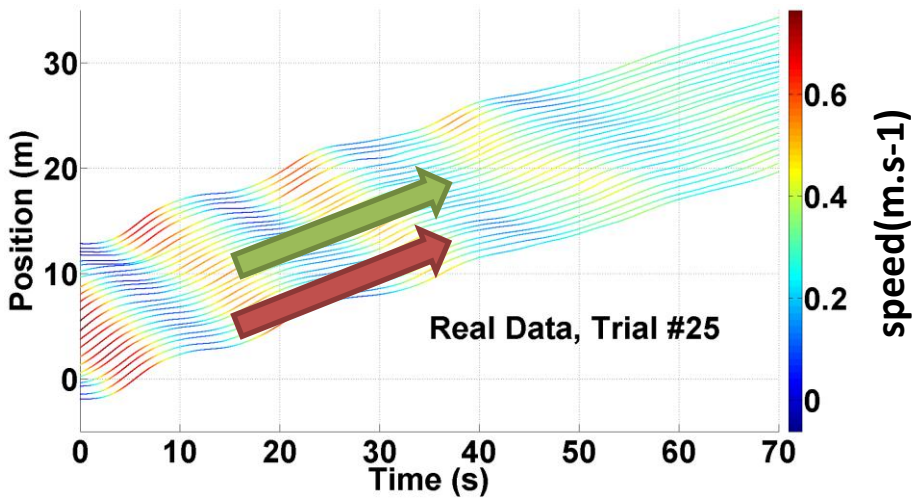


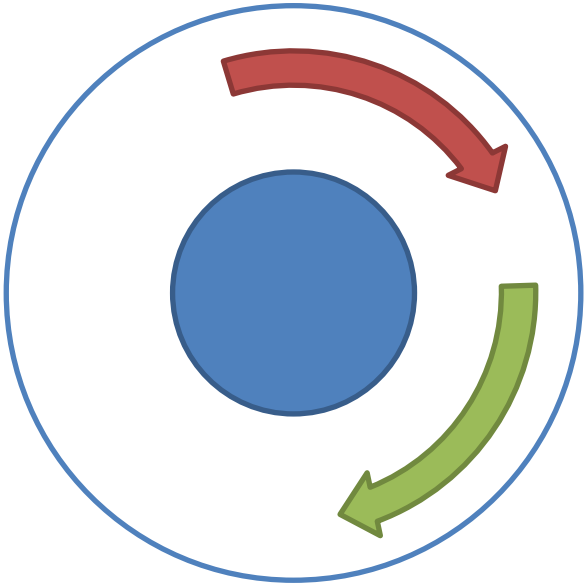
[Moussaid et al. *Plos CB* 2012]

Following behaviors

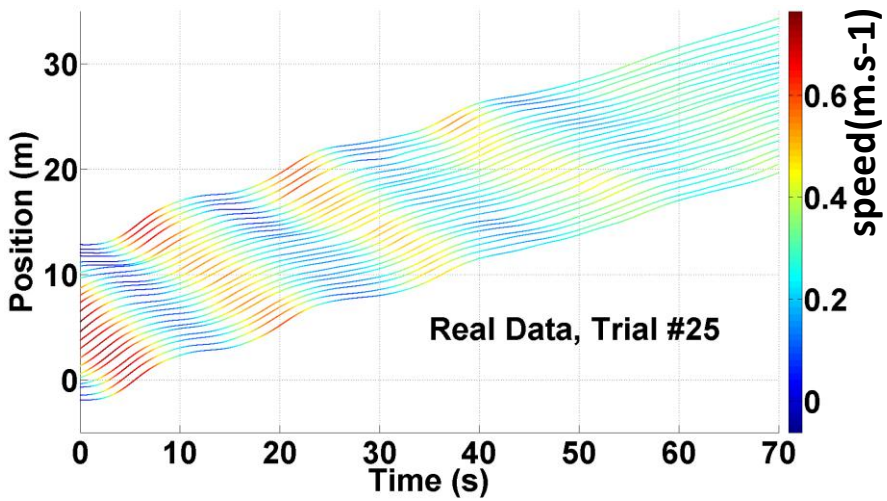
[Lemercier et al. *Eurographics* 2012]

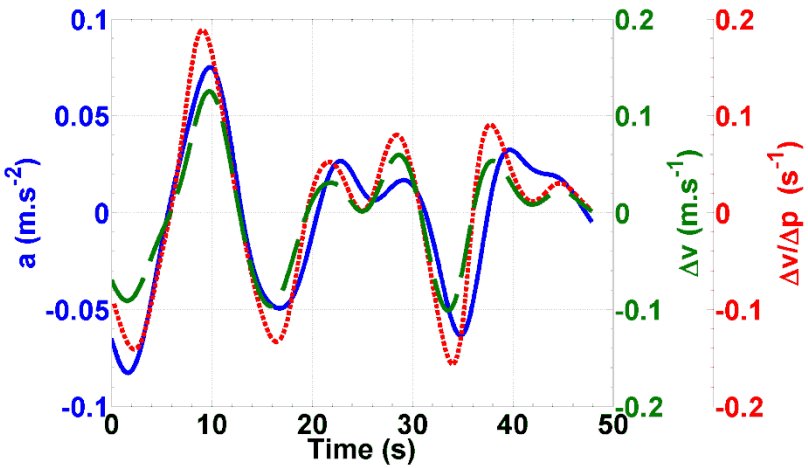
Following behaviors



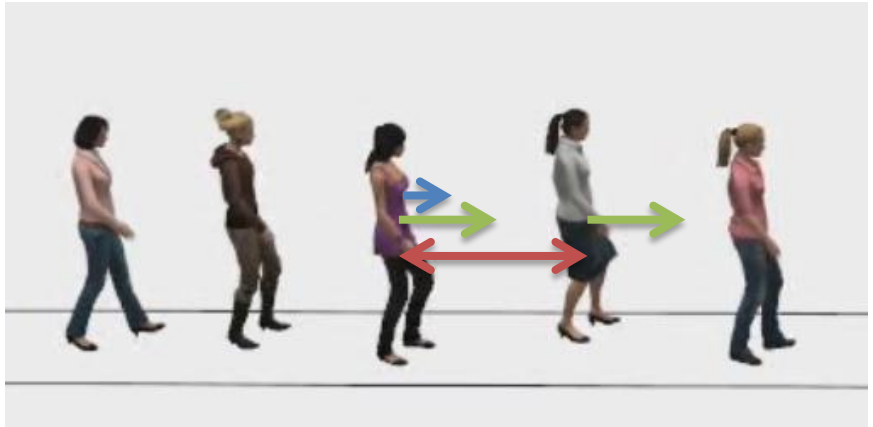


Following behaviors





[Lemercier et al. *Eurographics* 2012]



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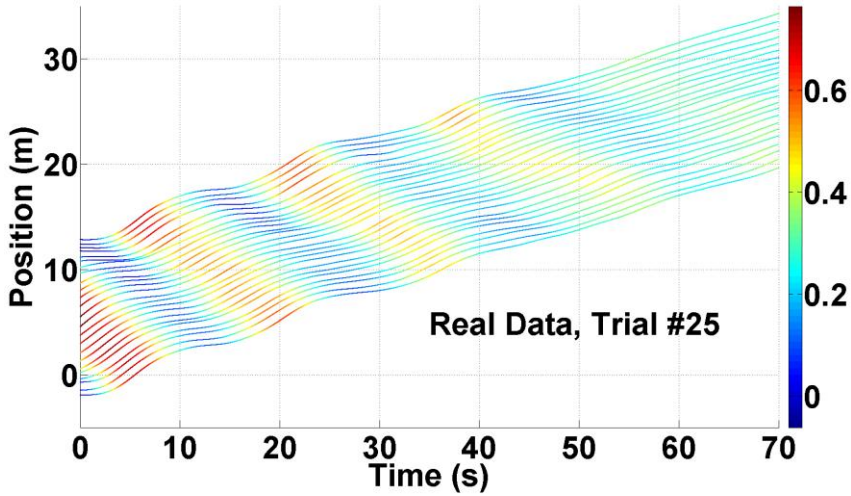
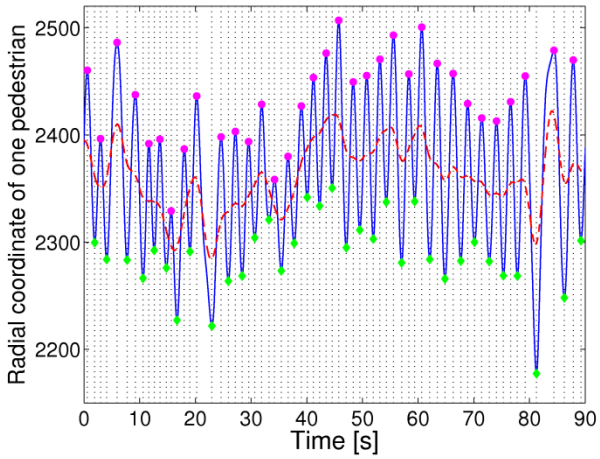
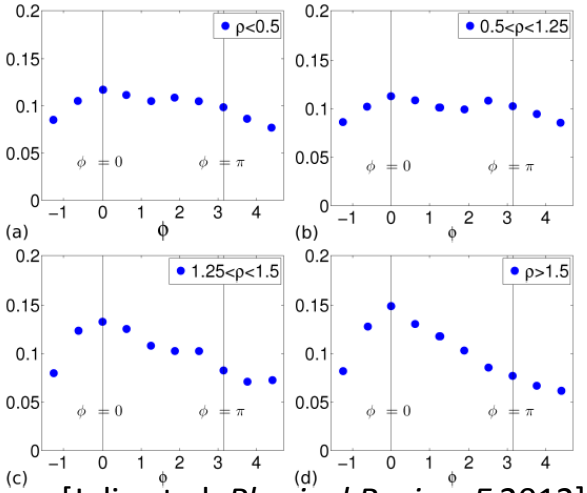




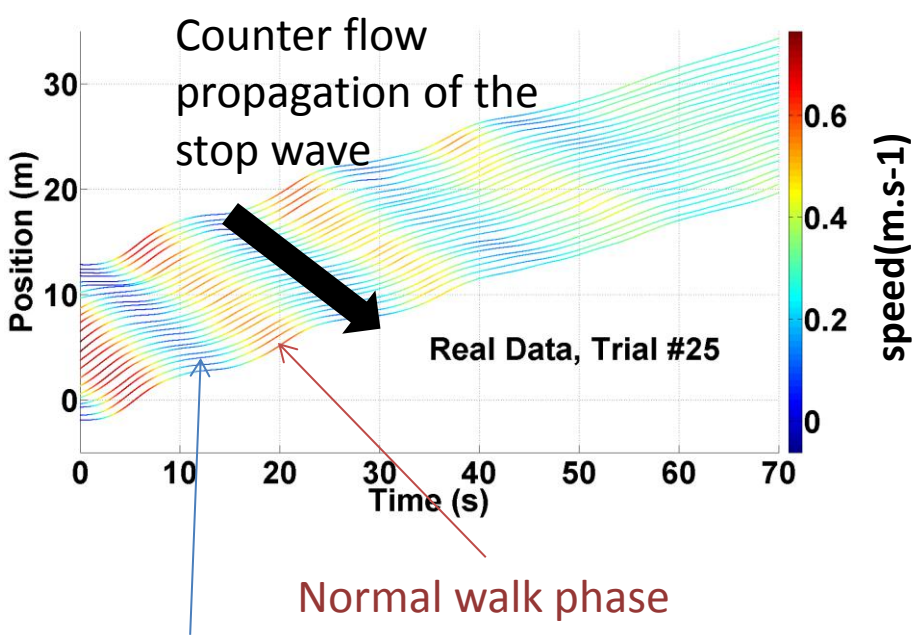
$\phi = 0$

$\phi = \pi$

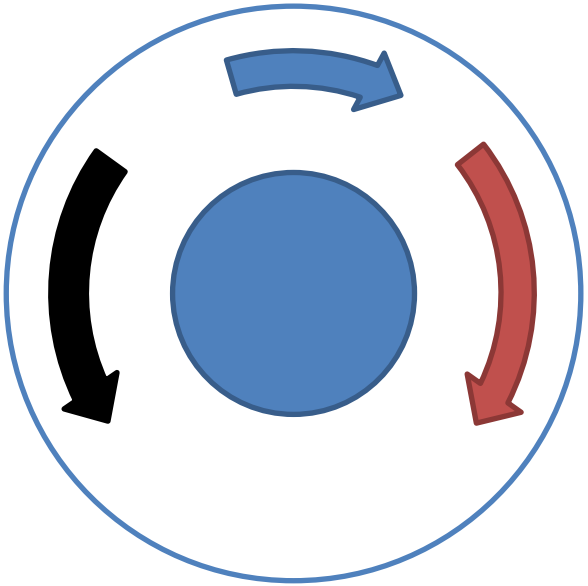


[Jelic et al. *Physical Review E* 2012]

Following behaviors



Slow walk phase



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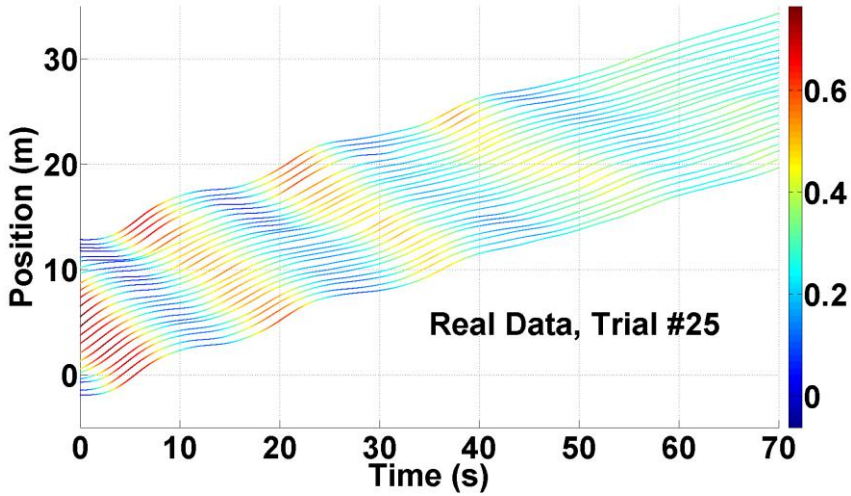

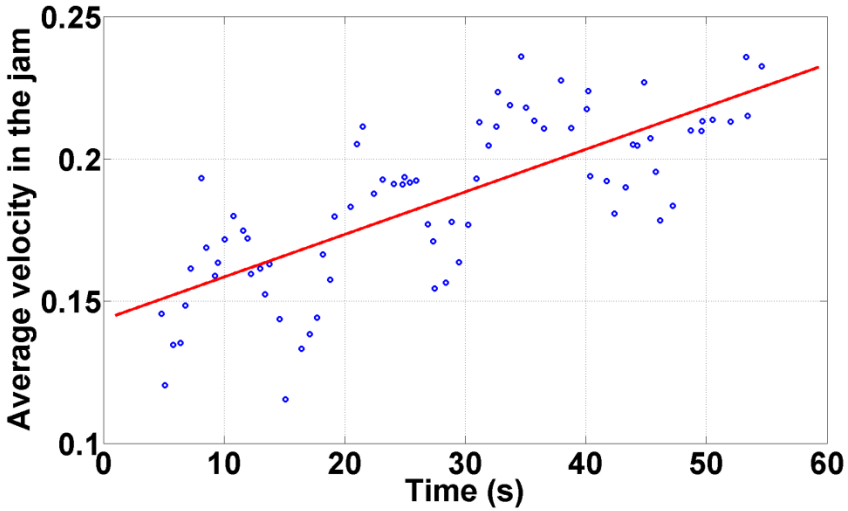

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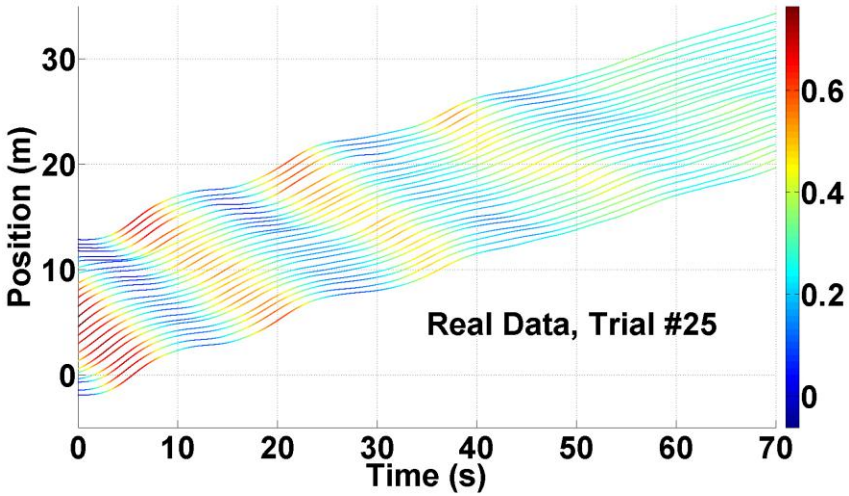

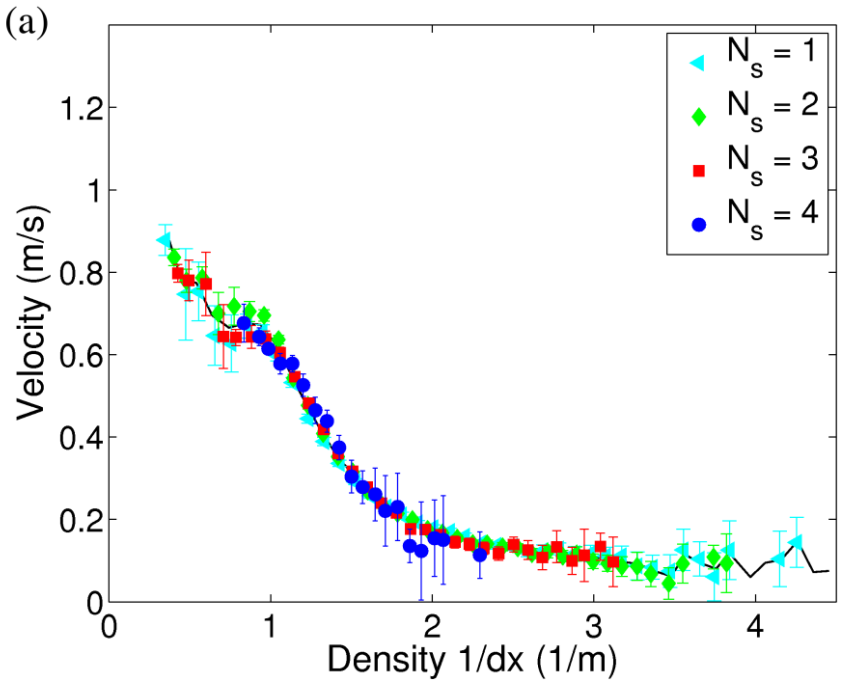

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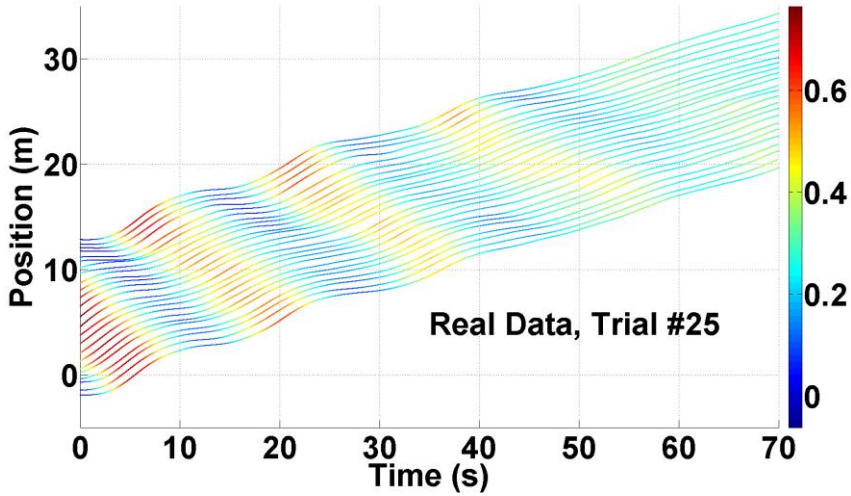
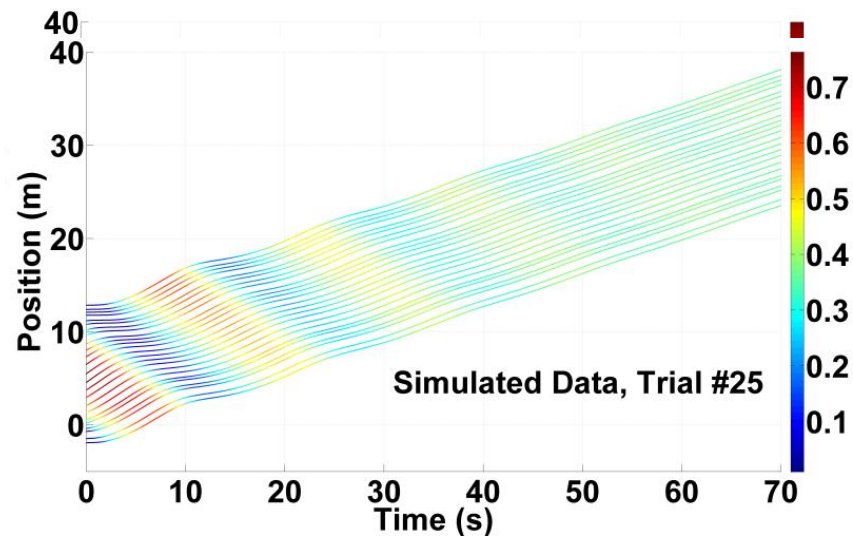
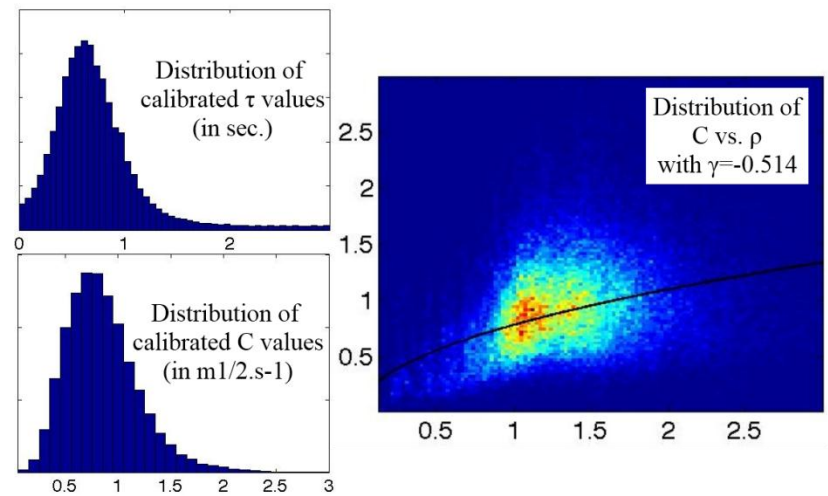




Derived simulation model

$$a = C\Delta v(t+\tau).\rho^{-\gamma}$$

Parameter estimation on experimental data:



[Lemercier et al. *Eurographics* 2012]

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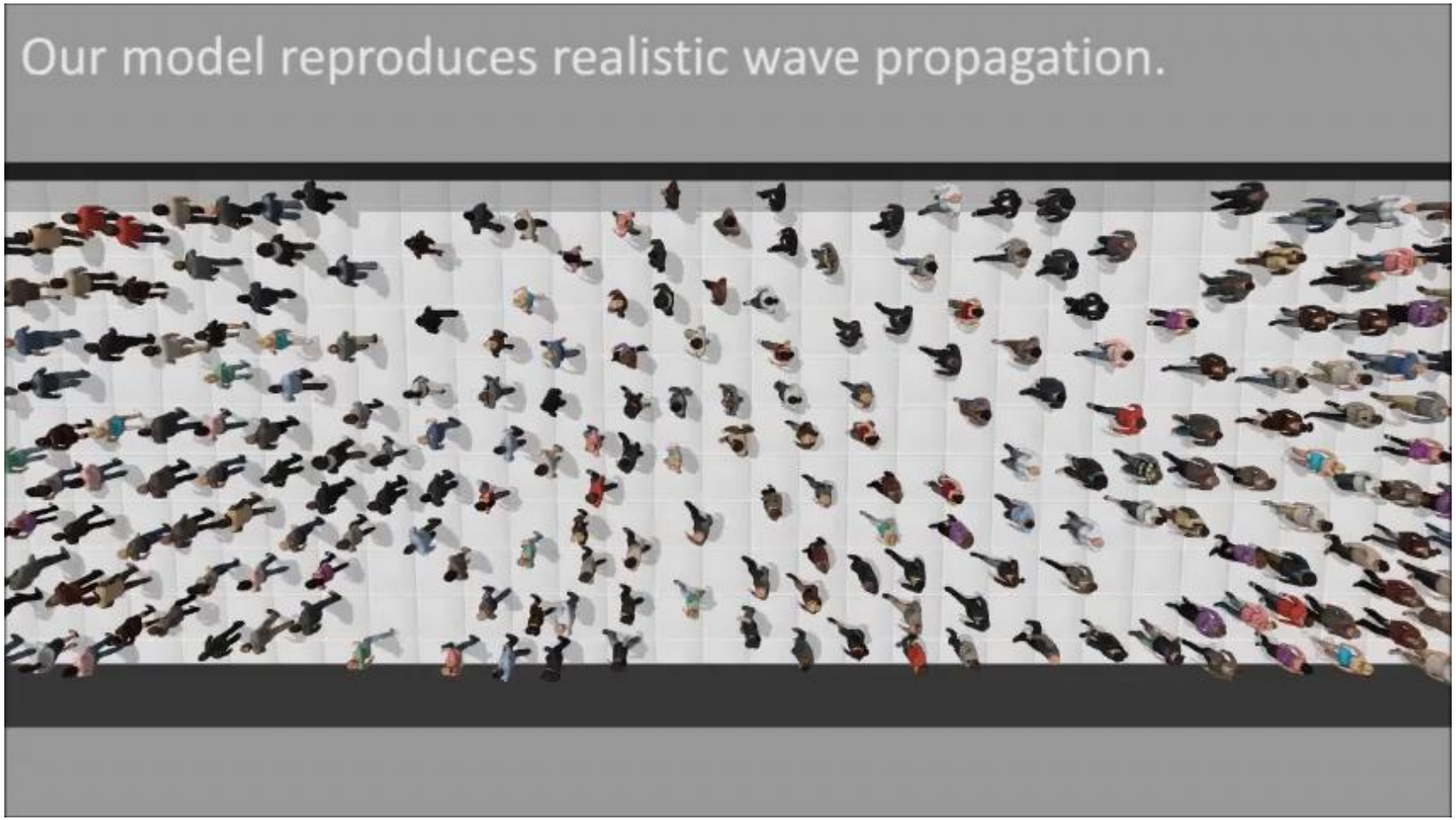

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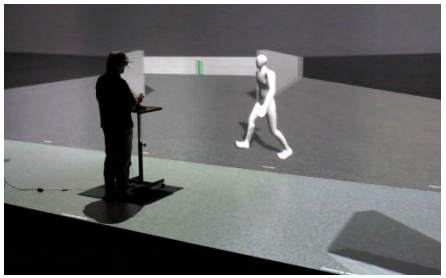
Just in case

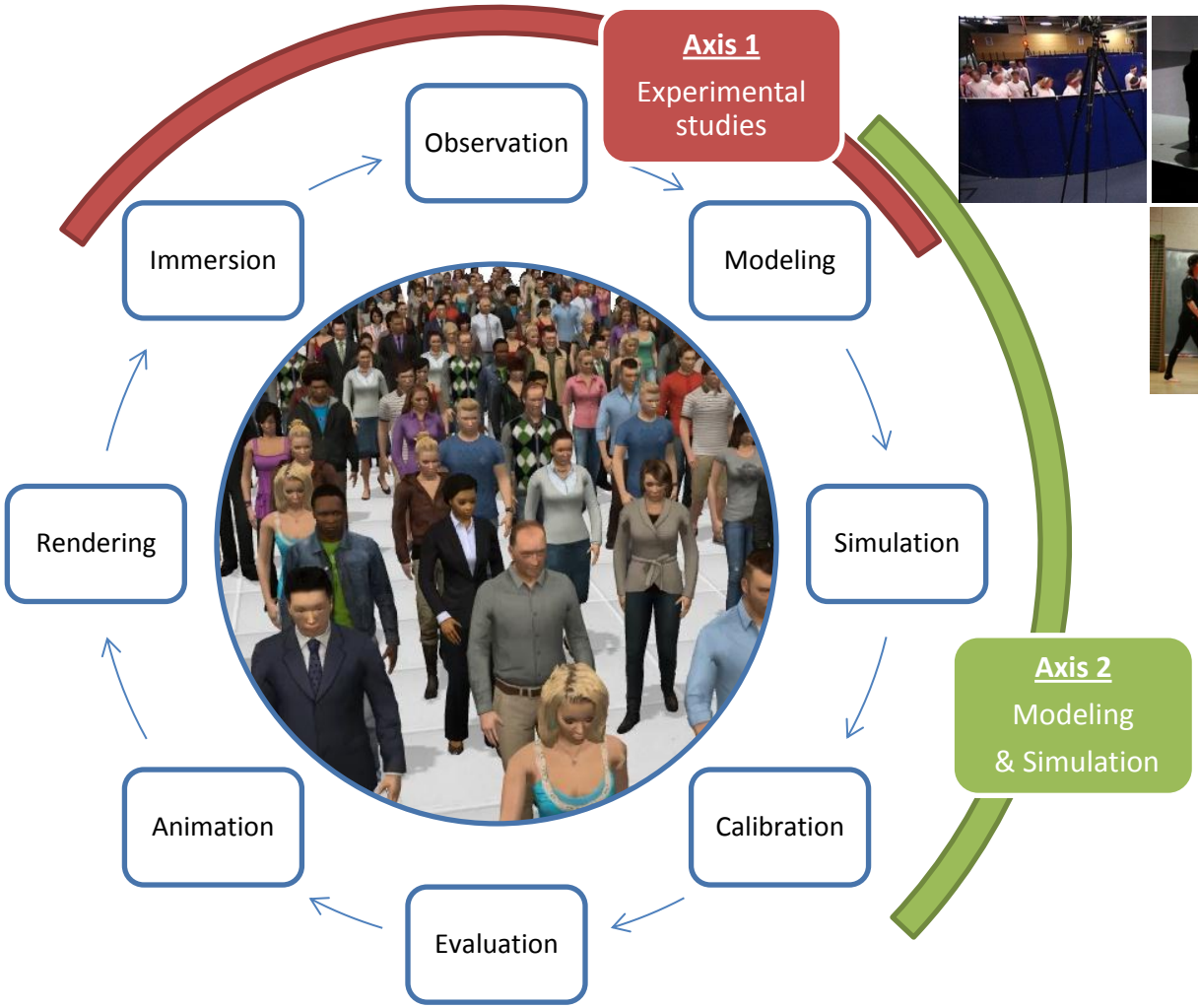
Conclusion

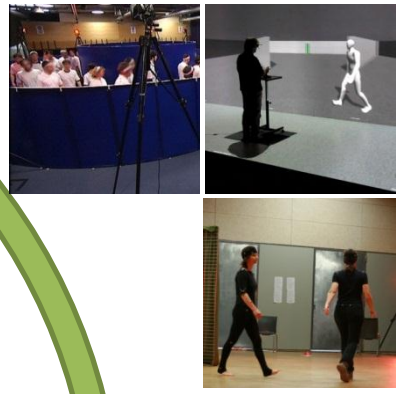
- Contributions:


- Future directions:

Virtual Crowds

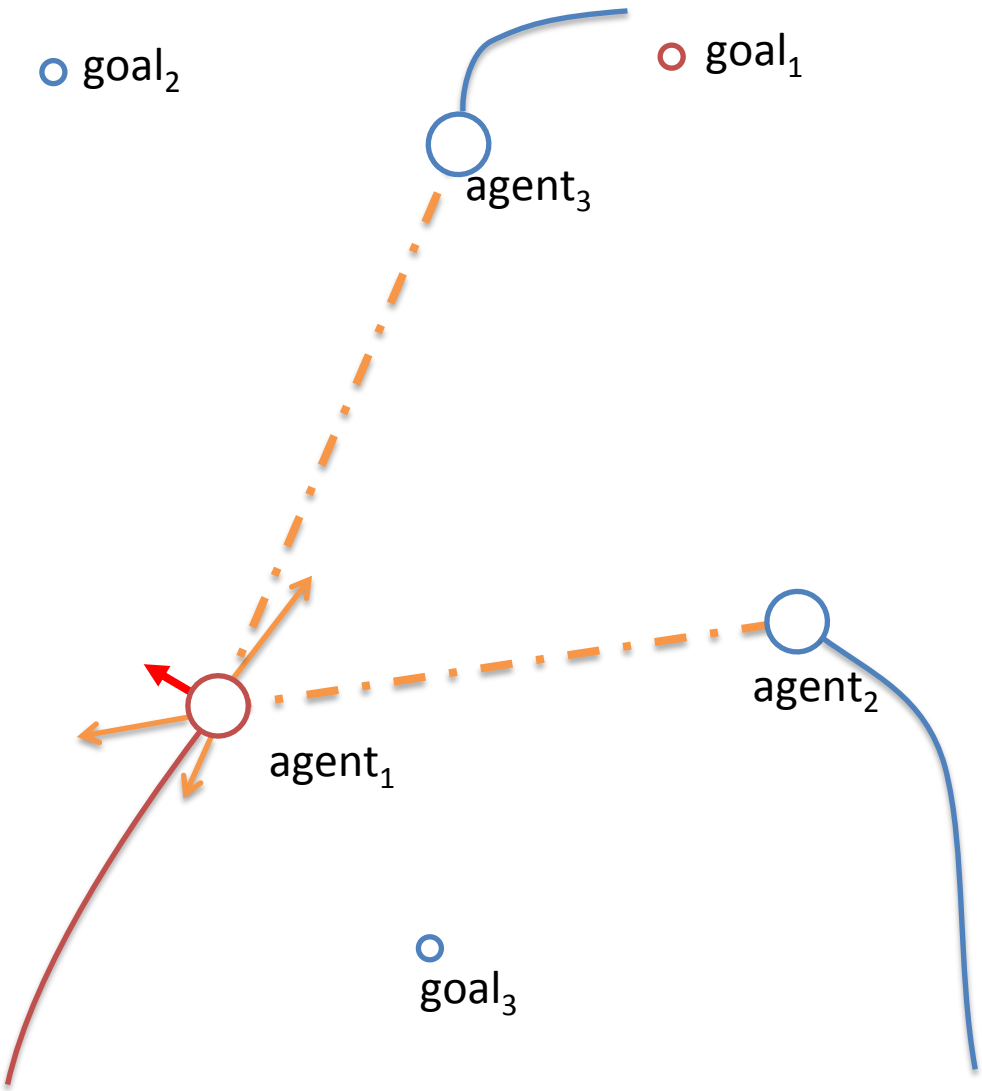




Introduction

To describe - mathematically, algorithmically - local interactions between agents

Local Interactions



Avoidance:

$$d > s$$

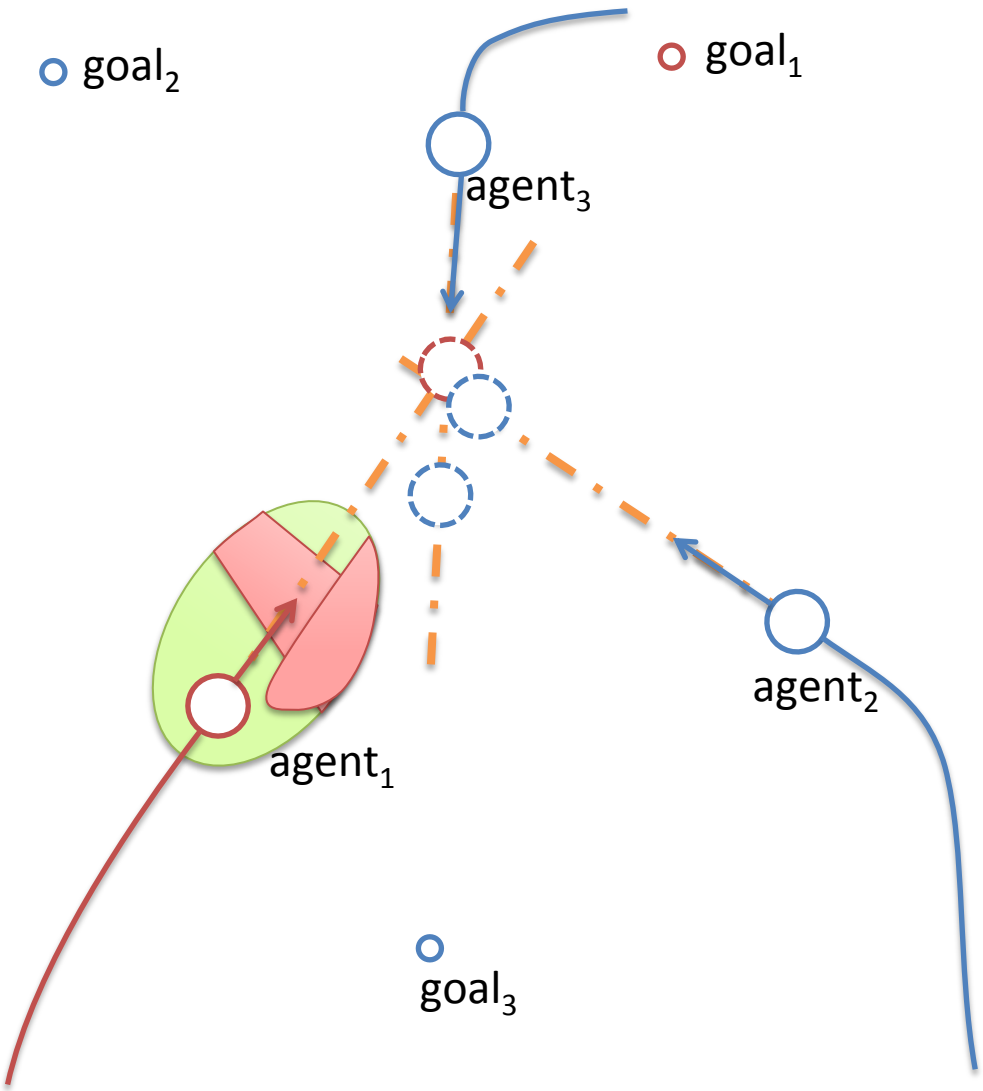
Repulsive forces:

$$\overrightarrow{F_{1,i}} = r(d).\frac{\overrightarrow{P_iP_1}}{\|P_iP_1\|}$$

Motion:

$$\overrightarrow{a_1} = \overrightarrow{F_{1,goal_1}} + \sum_i \overrightarrow{F_{1,i}}$$

Local Interactions



Avoidance:

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

Constant velocity hypothesis
$\Rightarrow$ future distance of closest approach

Admissible velocities:

$$VA_{1|2} = \{\overrightarrow{v_1} | \forall t \in [t_0, t_0 + \tau], d(t) > s\}$$

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- **2009**
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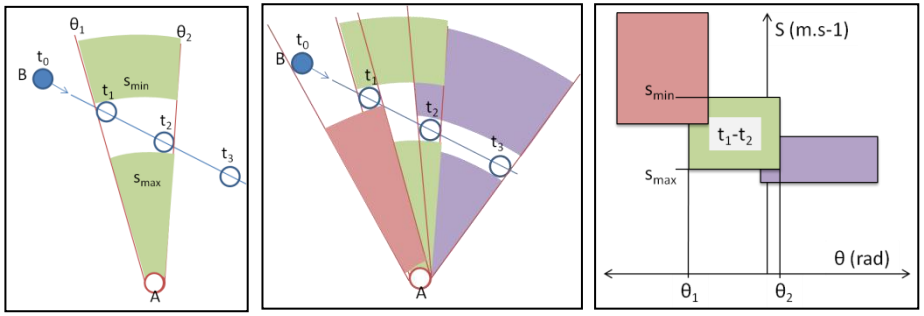
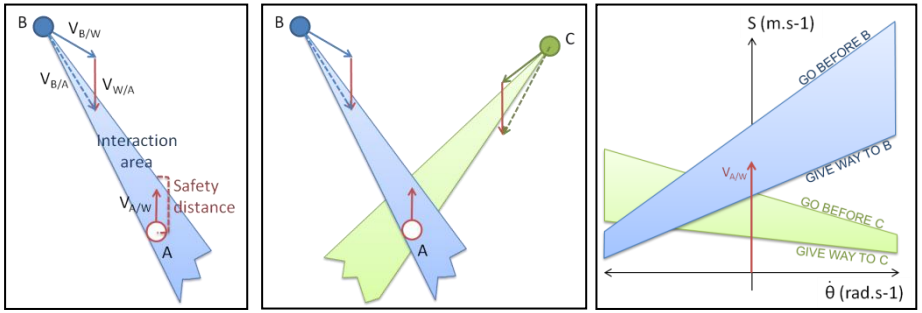
Collision avoidance: geometrical approaches



[Paris et al. *Eurographics* 2007]



[Pettré et al. *SCA* 2009]

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Following Behaviors

[Lemercier et al. *Eurographics* 2012]

[Bruneau et al. *MIG* 2014]

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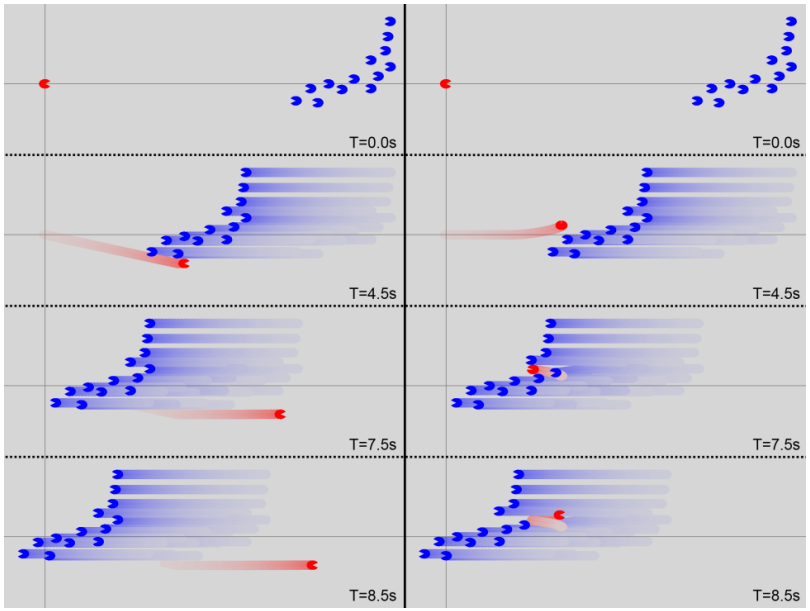
Mid-term strategies



[Bruneau et al. *SCA* 2015]

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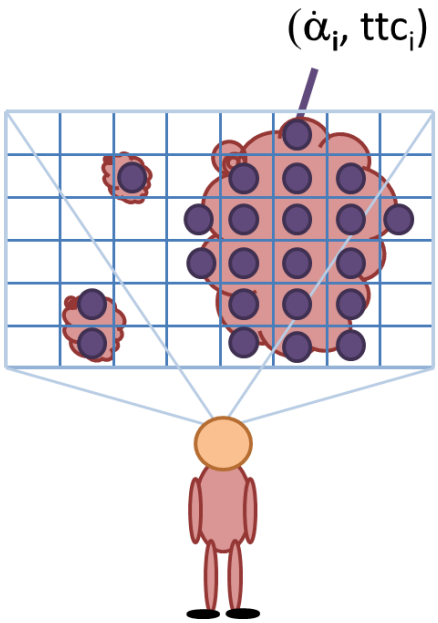
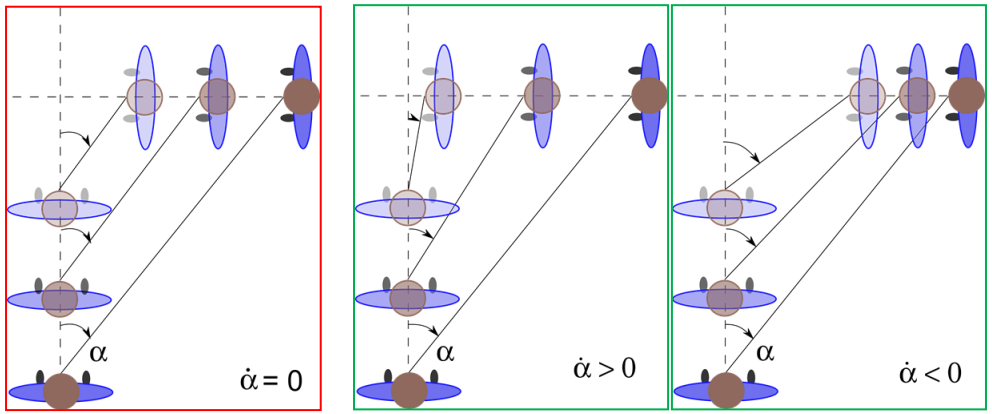
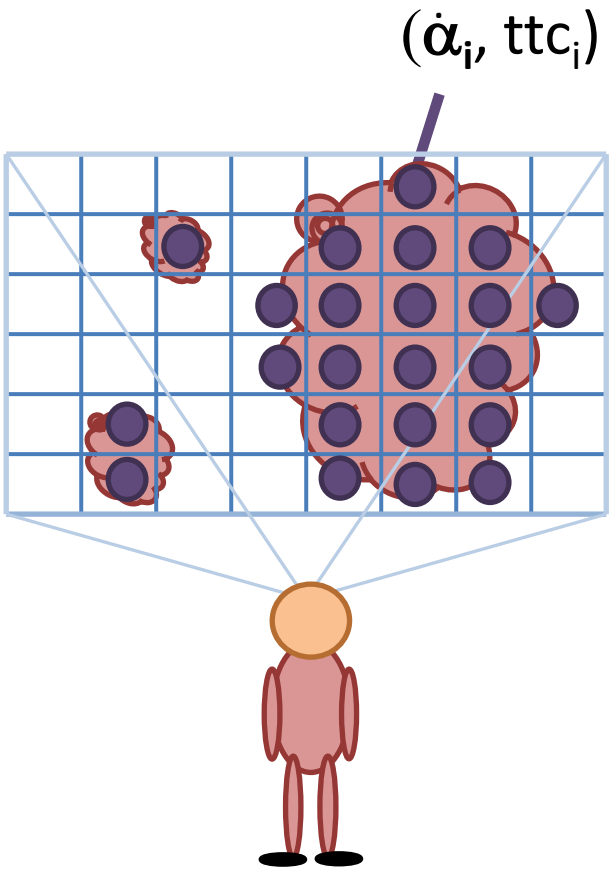
Realistic perception-action loop



Synthetic Vision





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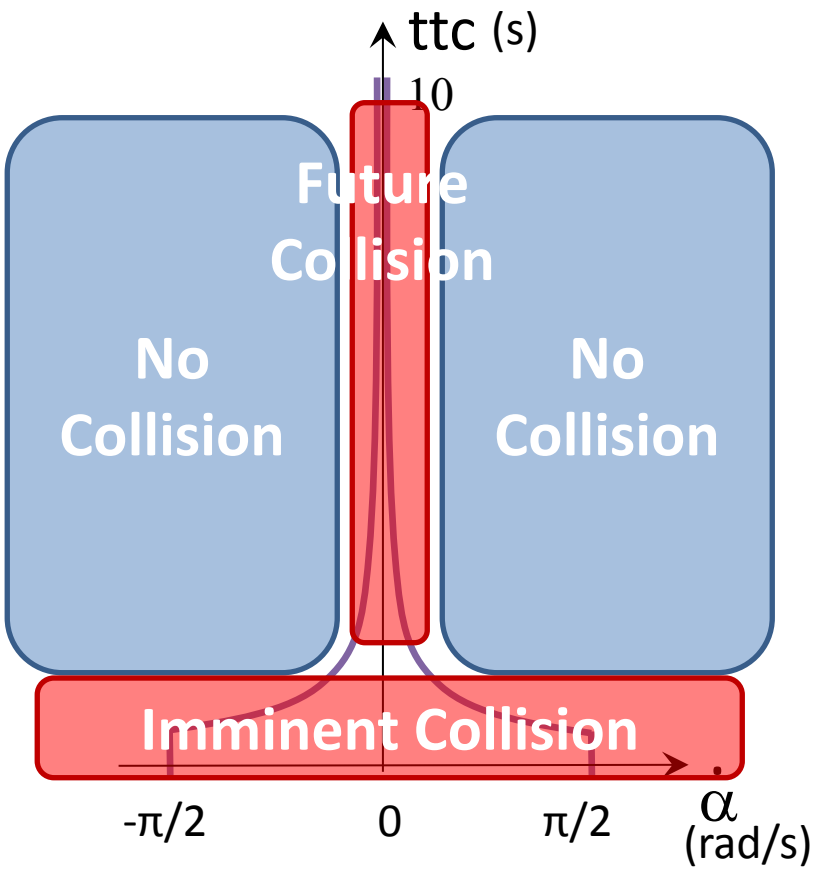

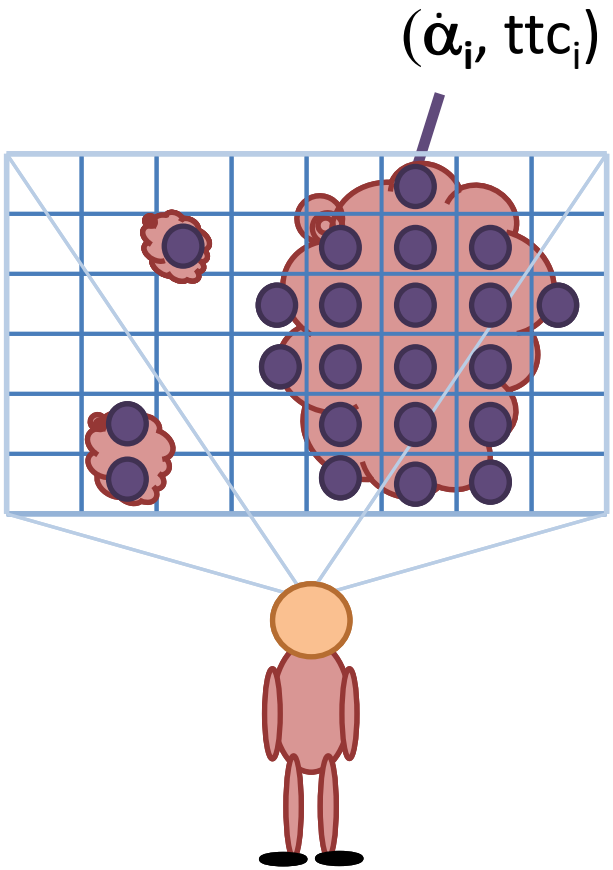

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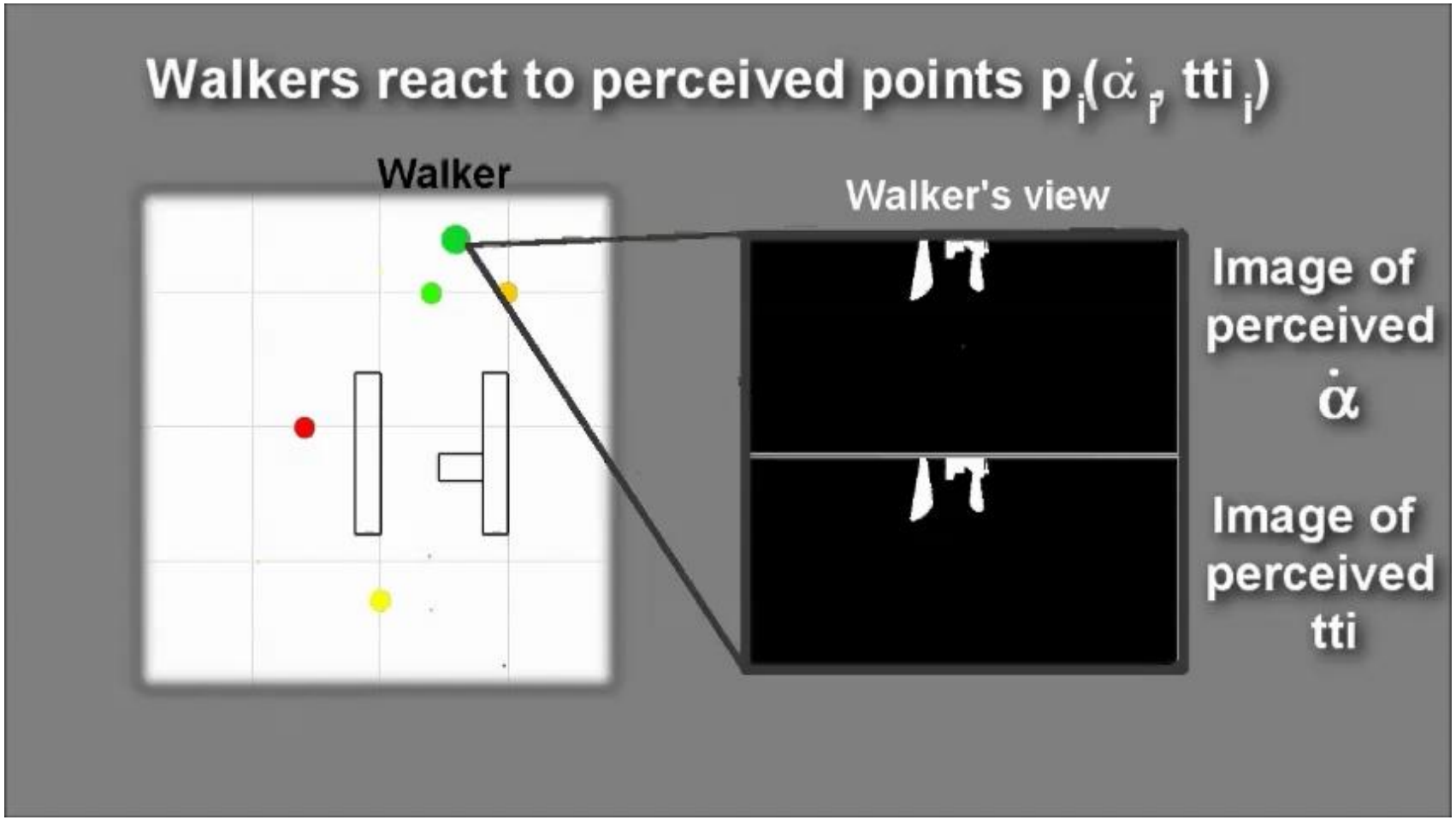
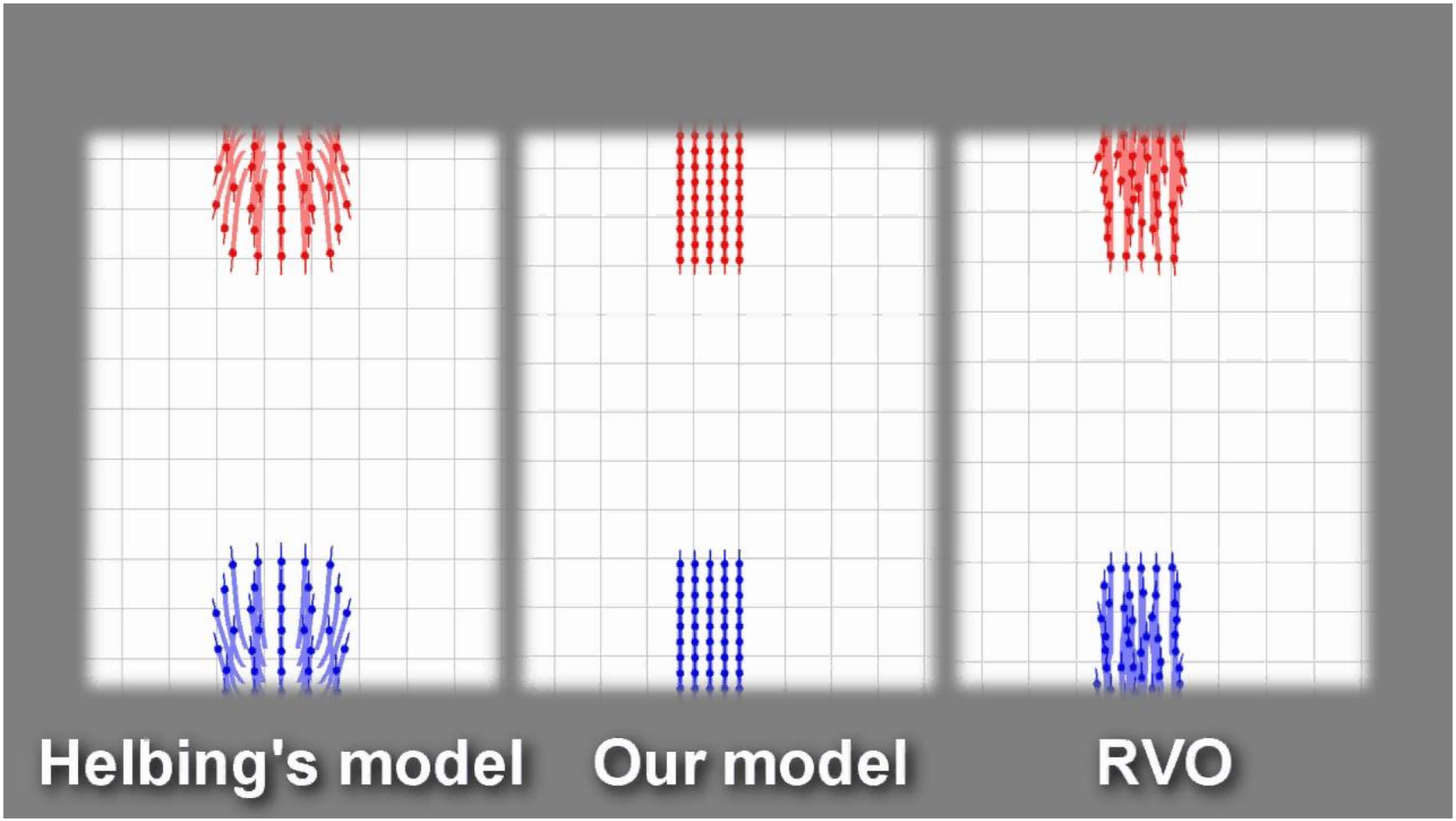


[Ondrej et al. *SIGGRAPH* 2010]

Just in case

Synthetic Vision

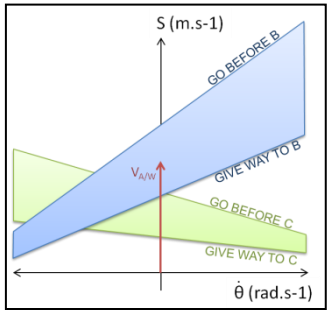


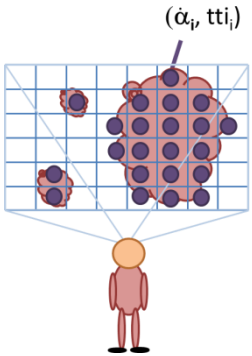
[Ondrej *SIGGRAPH* 2010]

Just in case

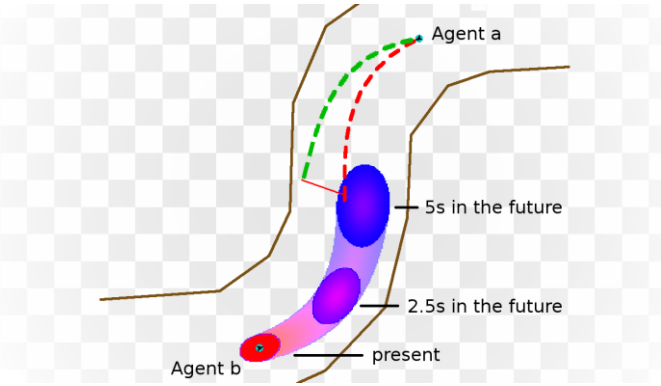
Conclusion

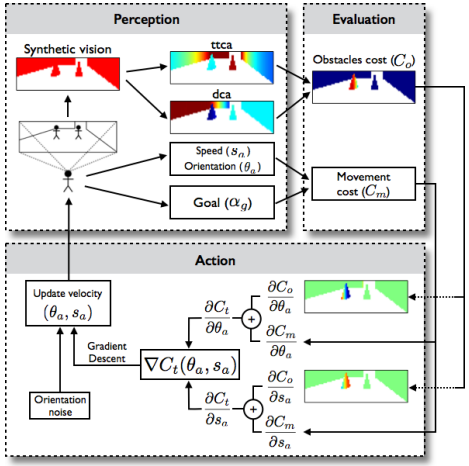
- Original simulation models and algorithms:

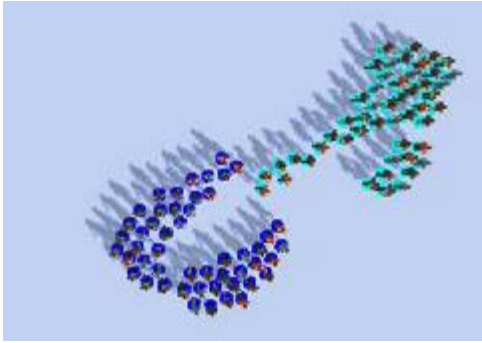




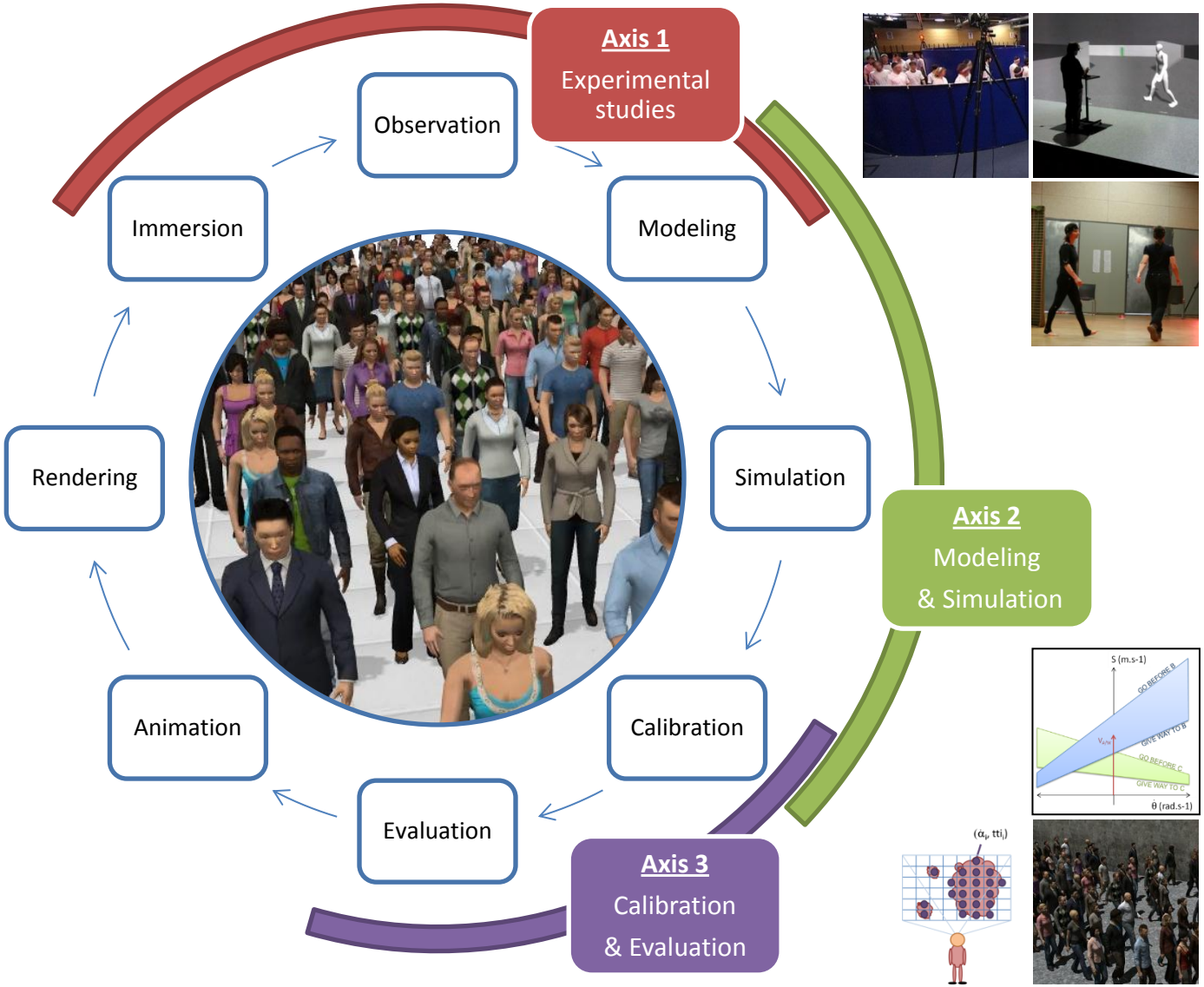
- Future directions:







Virtual Crowds



Introduction

To compare real and virtual crowds

Timeline

- **2007**
  - Paris et al., **Pedestrian reactive navigation for crowd simulation: a predictive approach**, *Eurographics*
- **2009**
  - Pettré et al., **Experiment-based modeling, simulation and validation of interactions between virtual walkers**, *Symposium on Computer Animation*
- **2010**
  - Ondrej et al., **A synthetic-vision based steering approach for crowd simulation**, *SIGGRAPH*
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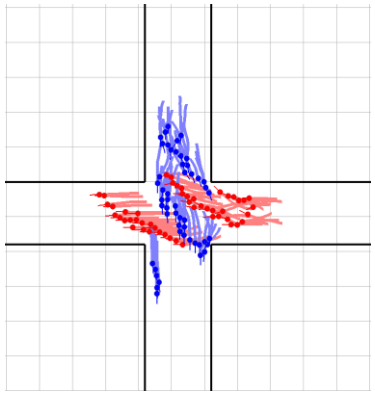
  - Lemercier et al., **Realistic following behaviors for crowd simulation**, *Eurographics*
- **2014**
  - Wolinski et al., **Parameter estimation and comparative evaluation of crowd simulations,** *Eurographics*
- **2015**
  - Bruneau et al., '**Going through, going around: A study on individual avoidance of groups**', *IEEE VR*

Visual comparisons



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- **2015**
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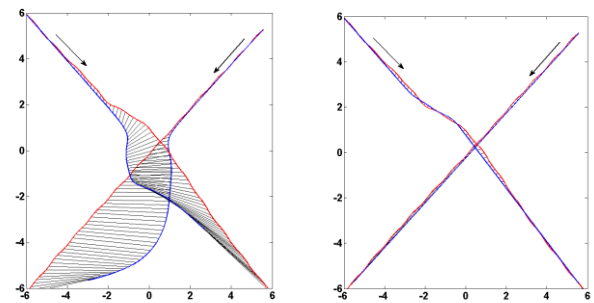
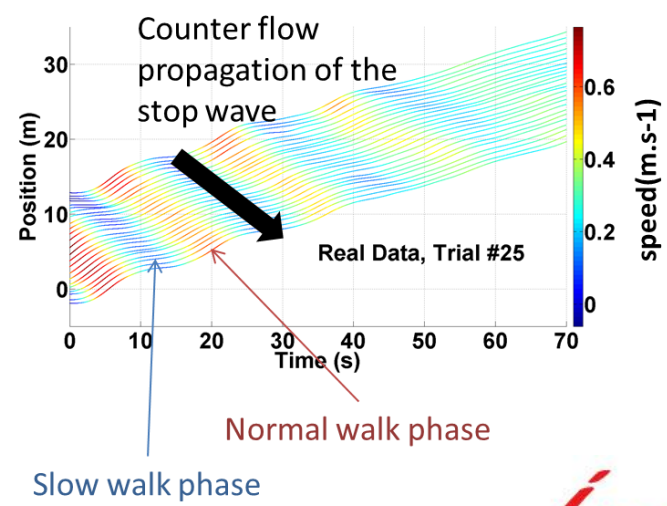
Quantitative comparisons



Force-based Velocity-based



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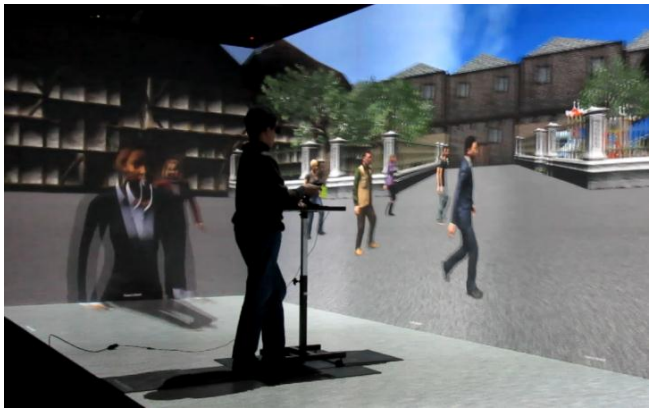
- **2015**
  - Bruneau et al., '**Going through, going around: A study on individual avoidance of groups**', *IEEE VR*

Using Virtual Reality



[Bruneau et al. *IEEE VR* 2015]

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- **2007**
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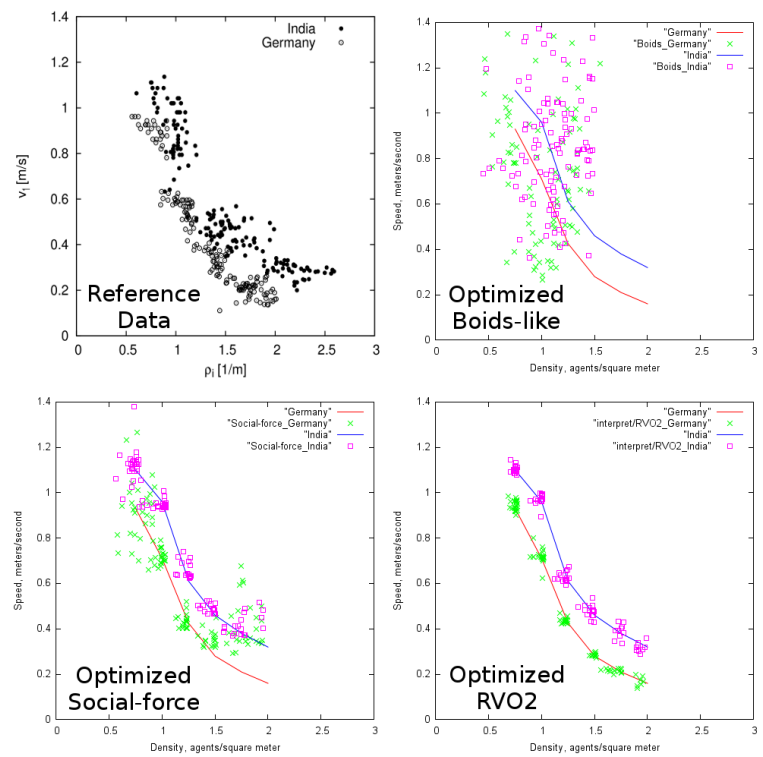
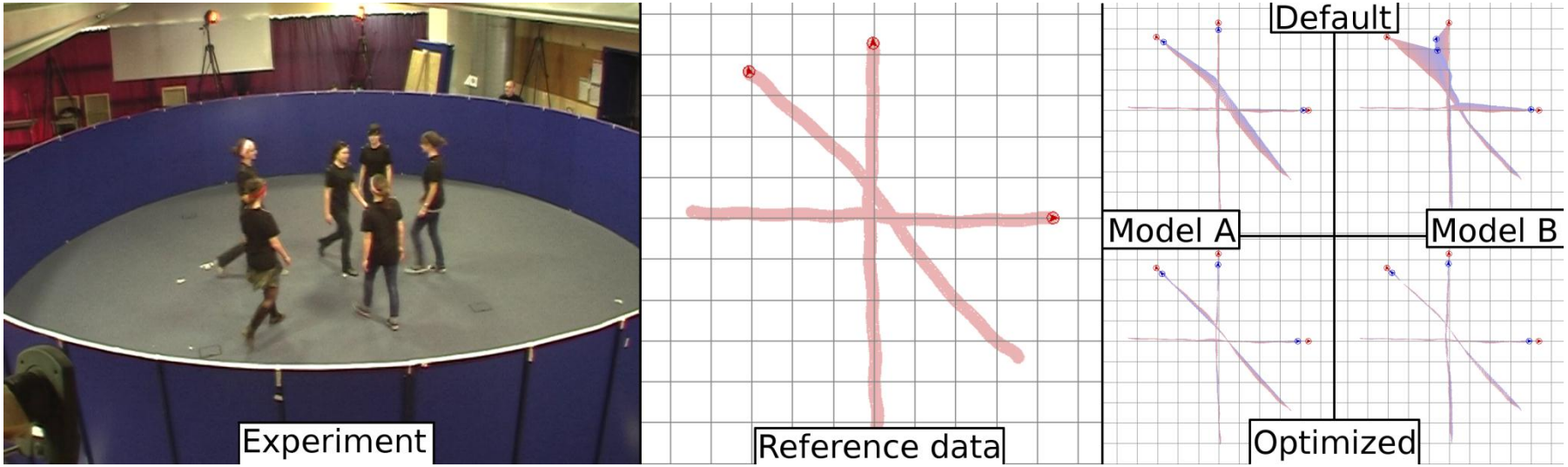
- **2014**
  - Wolinski et al., **Parameter estimation and comparative evaluation of crowd simulations,** *Eurographics*
- **2015**
  - Bruneau et al., '**Going through, going around: A study on individual avoidance of groups**', *IEEE VR*

Calibration



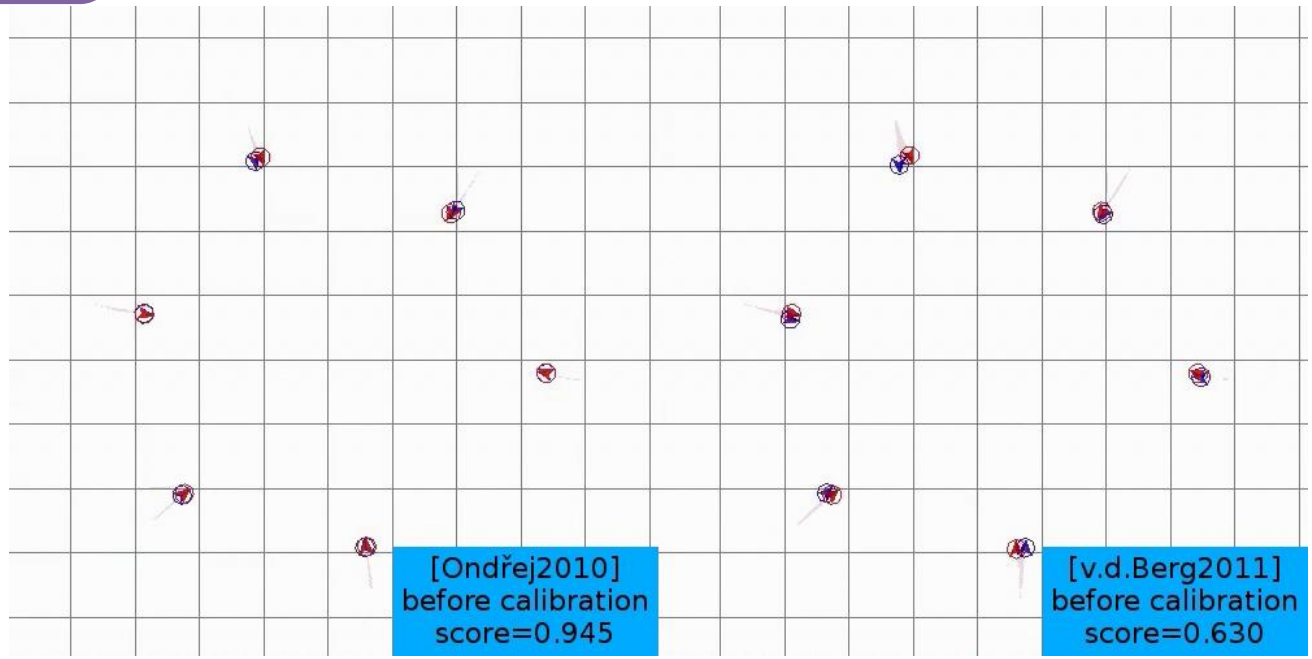
[Wolinski et al. *Eurographics* 2014]

Parameter estimation



[Wolinski et al. *Eurographics* 2014]

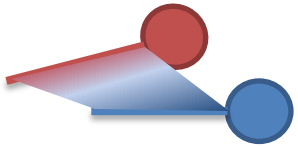
Parameter estimation



[Wolinski et al. *Eurographics* 2014]

Real Trajectories

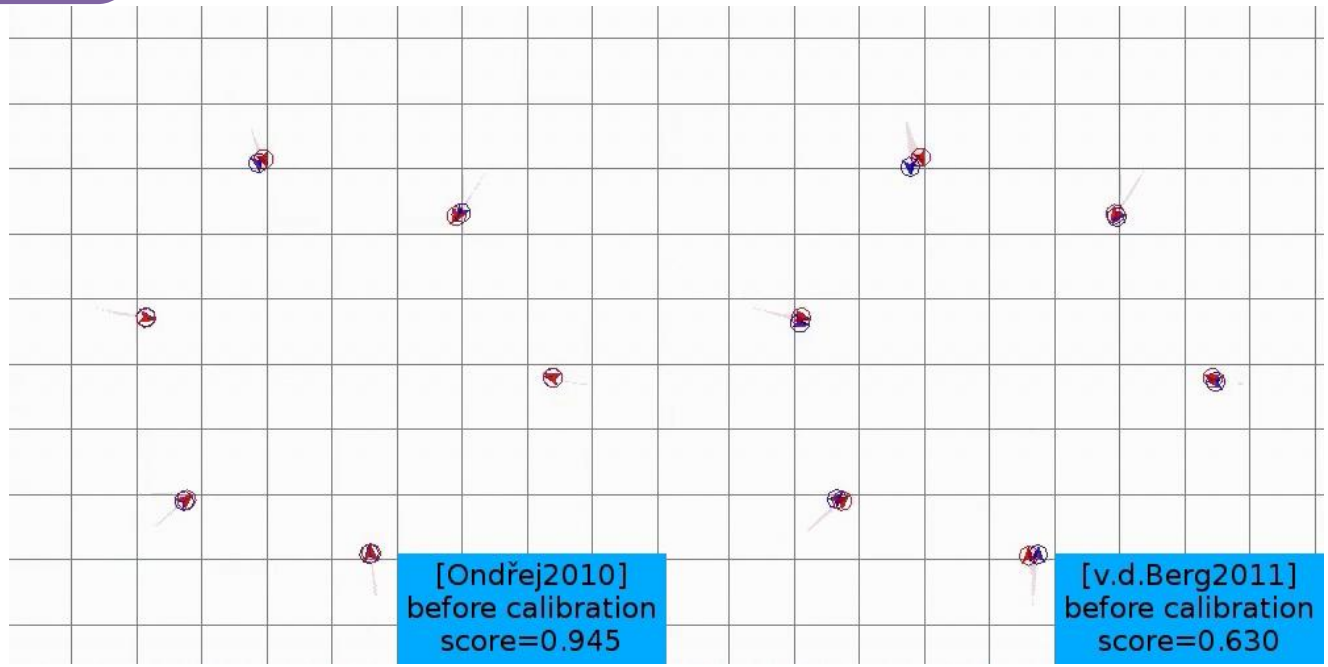
Simulated Trajectories



Difference

Just in case

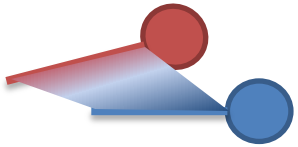
Parameter estimation



[Wolinski et al. *Eurographics* 2014]

Real Trajectories

Simulated Trajectories

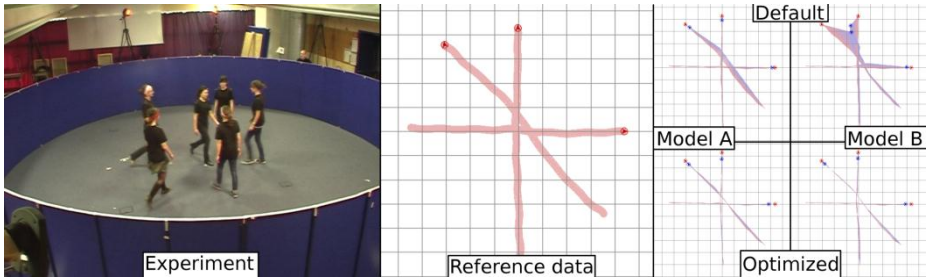


Difference

Just in case

Conclusion

- Contributions:



- Future directions:

?
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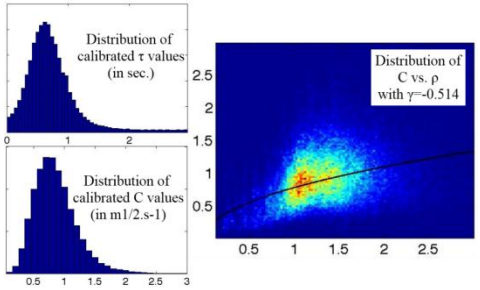
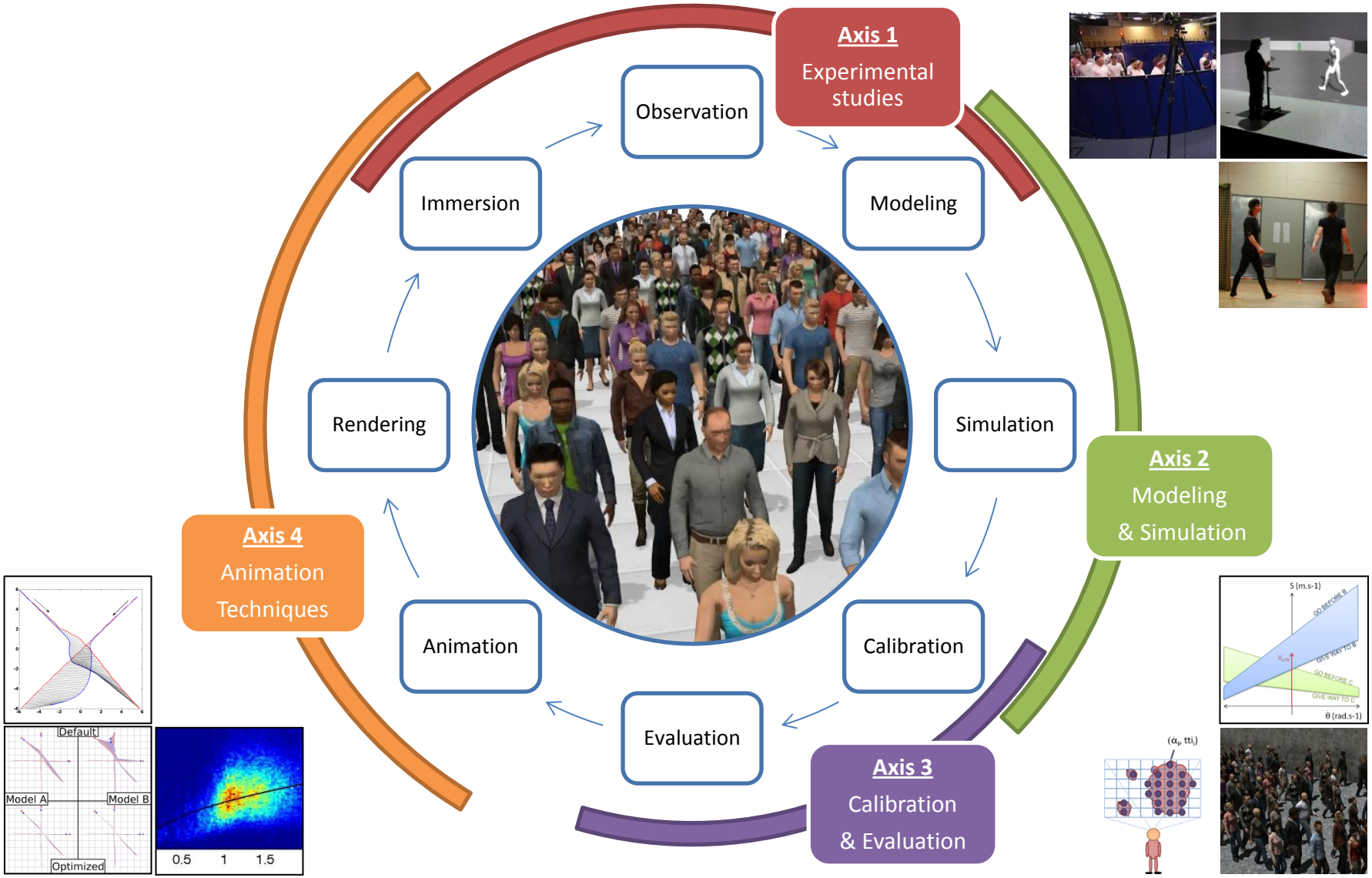


Virtual Crowds



Introduction

To implement virtual crowds

Timeline

- **2006**
  - Pettré et al., **Real-time navigating crowds: scalable simulation and rendering**, *Computer Animation and Social Agents*
- **2009**
  - Yersin et al., **Crowd patches: populating large-scale virtual environments for real-time applications**, *Interactive 3D Graphics*
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- **2014**
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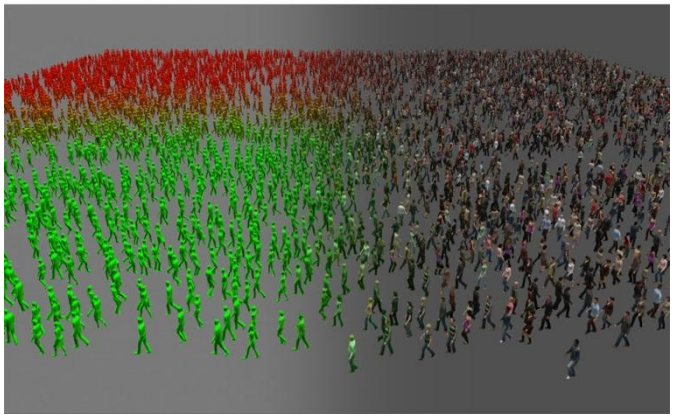
  - Jordao et al., **Sculpting crowd motion**, *Eurographics*

Level of detail strategies

[Pettré et al. *CASA* 2006]



[Kulpa et al. *SIGGRAPH Asia* 2014]

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Augmented Reality

[Ren et al. *The visual Computer* 2013]

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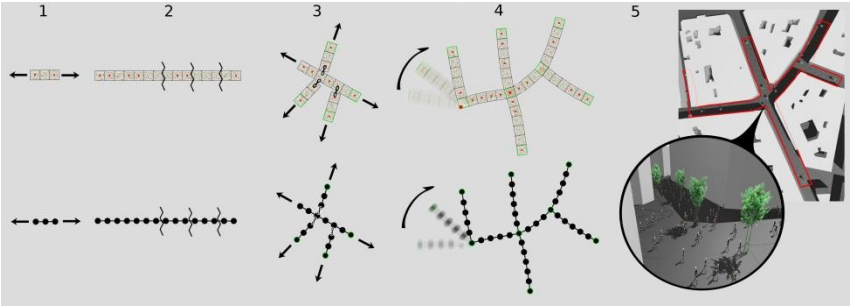
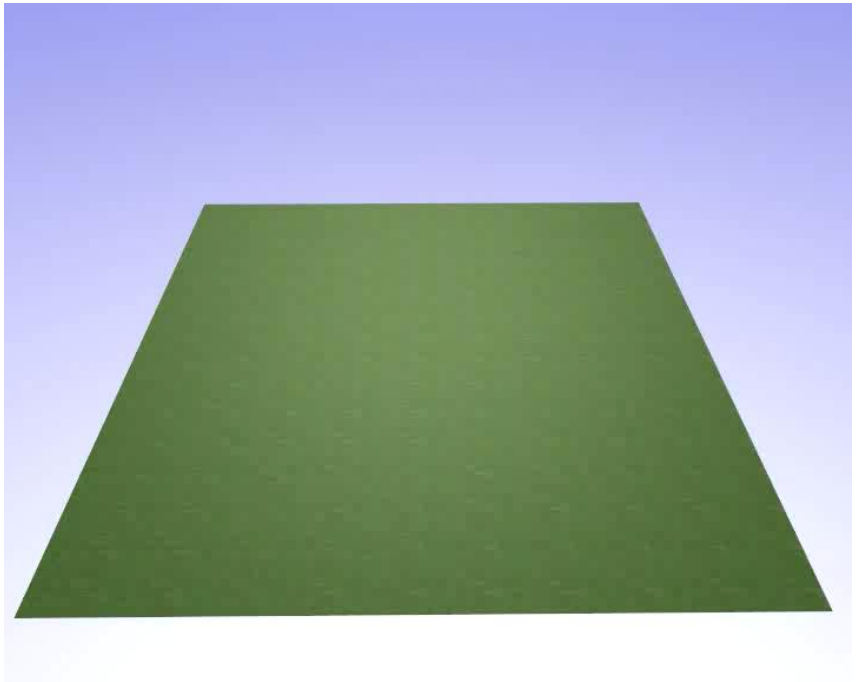
Crowd Patches

[Yersin et al. *I3D* 2009]



[Jordao et al. *Eurographics* 2014]

Crowd patches



[Yersin et al. *I3D* 2009]

Just in case

Sculpting crowds

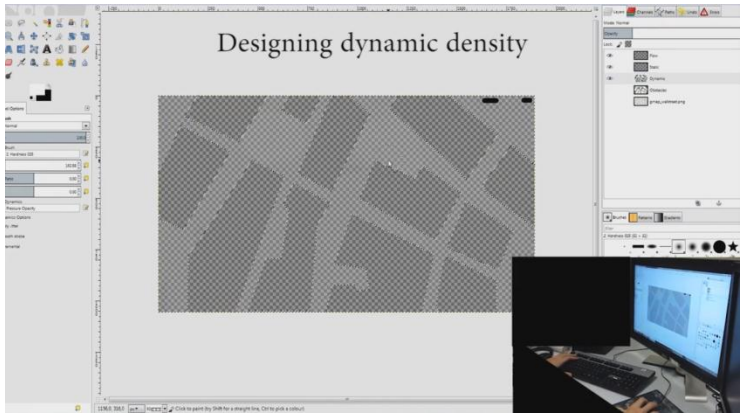
[Jordao et al. *Eurographics* 2014]

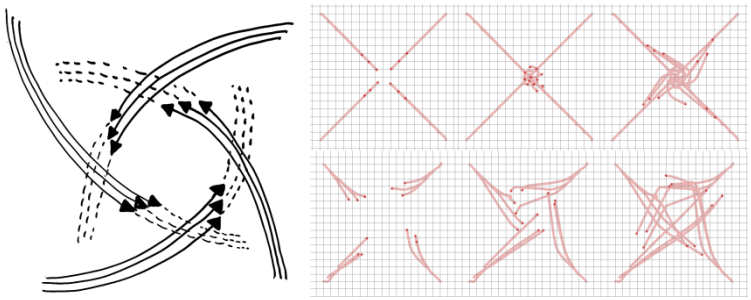
Just in case

Conclusion

- Contributions:

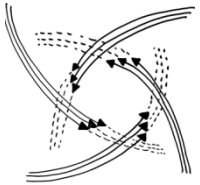
- Future directions:

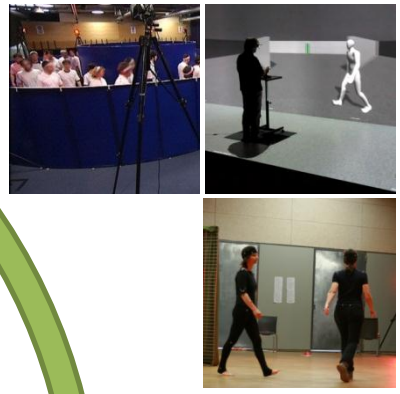


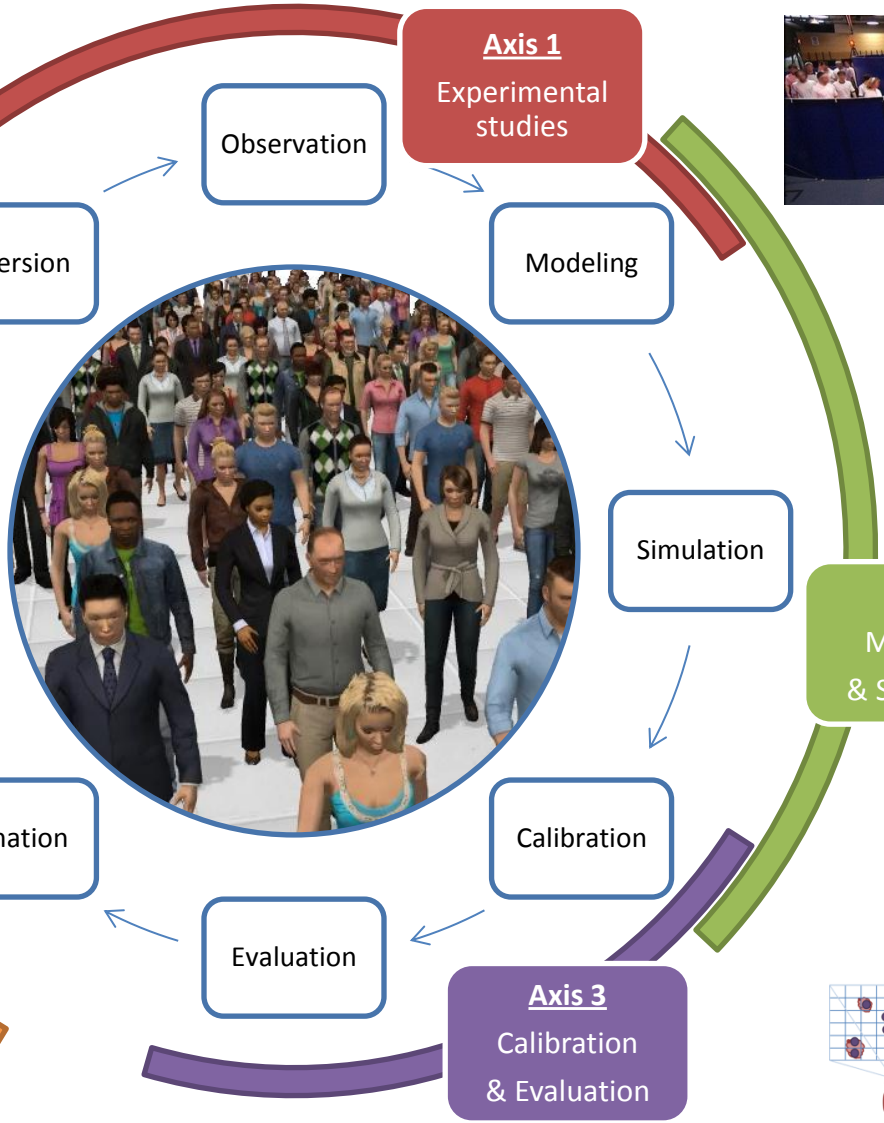


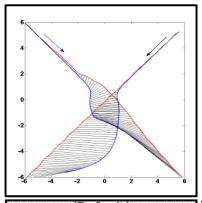
[Wolinski et al. *Eurographics* 2014]

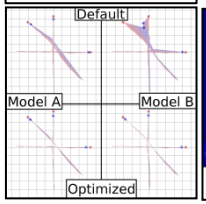
Virtual Crowds

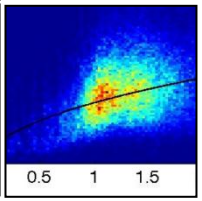


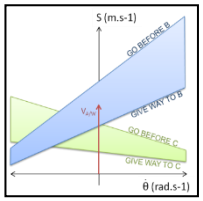


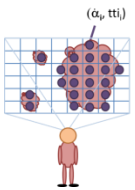






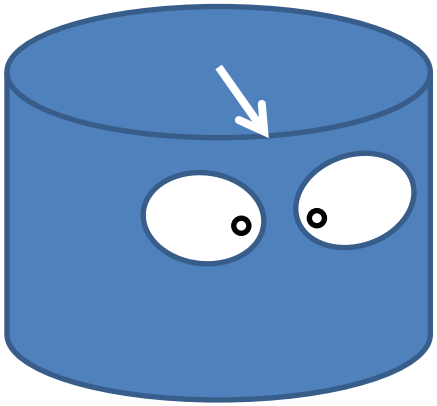


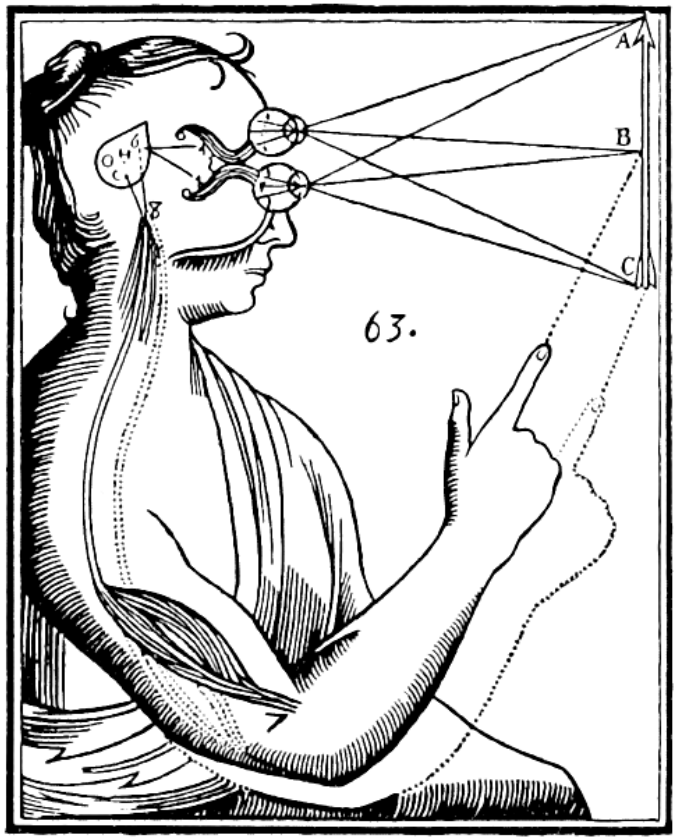




Perspectives

Sensorimotor simulation agents

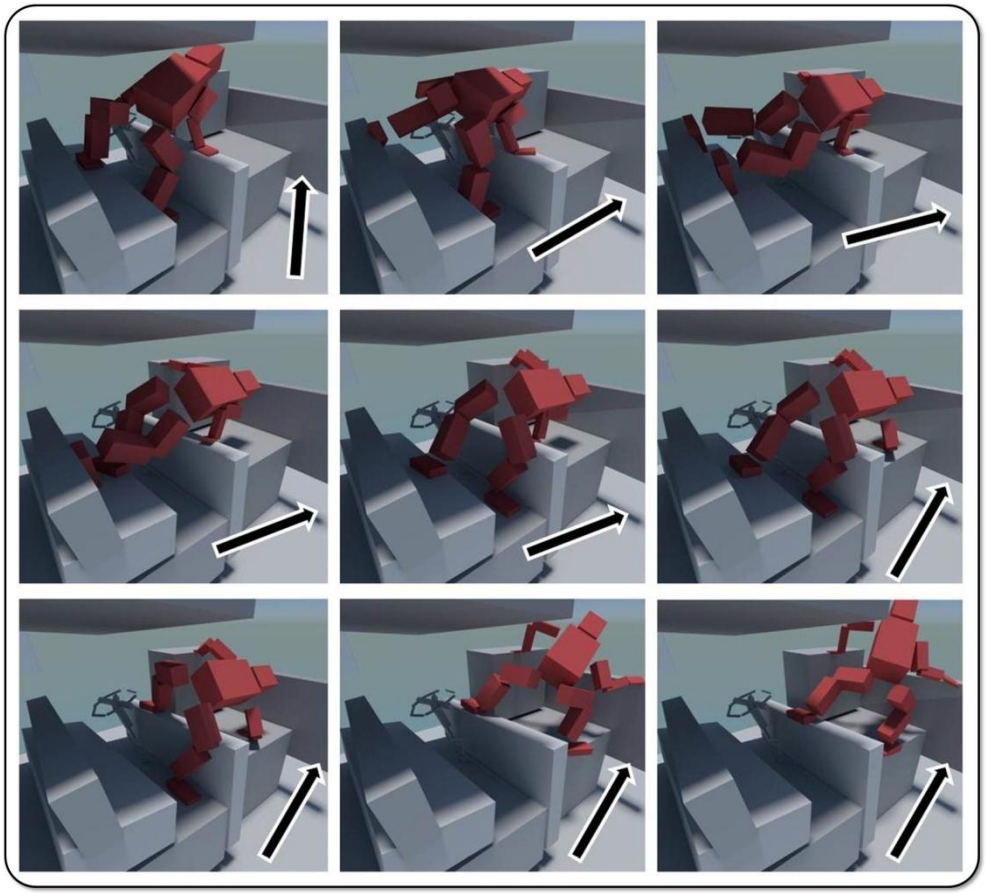




Descartes

Perspectives

Sensorimotor simulation agents



[Tonneau et al. *Computer & Graphics* 2014]

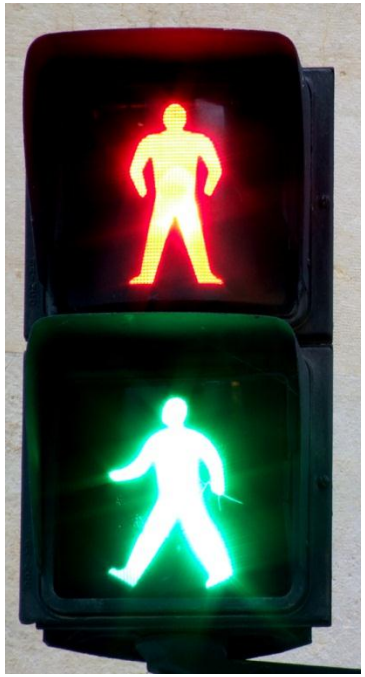
Perspectives

Immersive populated spaces

[Bruneau et al. *IEEE VR* 2015]

Perspectives

Pedestrian traffic forecast



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- PhD students and postdocs:
  - Julien Bruneau
  - Panayiotis Charalambous
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  - Samuel Lemercier
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  - Jonathan Perrinet
  - 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
  - Jean-Paul Laumond
  - Franck Multon
  - Anne-Hélène Olivier
  - Daniel Thalmann
  - …

A more special thank

To colleagues for all the ~~fun~~ hard work

To family for accepting bad deadlines during christmas holidays (e.g., SIGGRAPH) and conferences during summer holidays (e.g., SIGGRAPH)