Tutorial T2
« Modeling Individualities in Groups and Crowds »
Part
« Individualized versus collective behaviours »

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Summary

What is Bunraku ?

A research team funded by five research organisms

A joint scientific objective

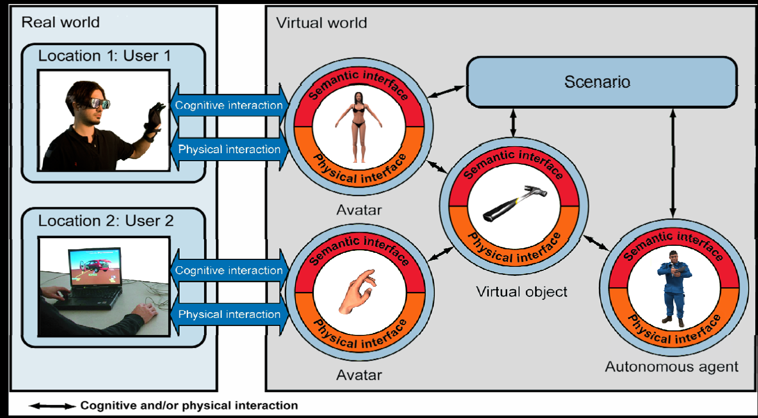
Perception, decision and action of real and virtual humans in virtual environments and impact on real environments

Team Composition in october 2008

- 3 Professors: B. Arnaldi, K. Bouatouch, Y. Beckers
- 3 Researchers: S. Donikian, A. Lécuyer, J. Pettré
- 6 Assistant Professors: R. Cozot, T. Duval, G. Dumont, V. Gouranton, F. Lamarche, M. Marchal
- 2 Visiting Researchers: S. Gibet, M. Christie
- 2 Collaborators: F. Multon, R. Kulpa
- 2 Research Engineers: A. Chauffaut, C. Bouville
- 3 Post-doc: N. Ouarti, Z. Gao, T. Regia Corte
- 18 PhD students
- 6 Technical staff

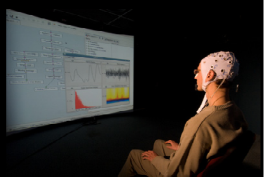
- Total : 45

Overall Objective of our Research Team



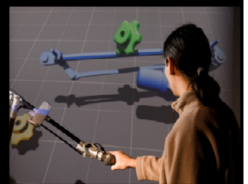
Our challenges

- Increase cross fertilization between two complementary research thematics
  - Virtual Reality and Virtual Humans
- Allow Real and Virtual Humans to naturally interact in a shared virtual world
- Combine two kinds of interaction of different nature: cognitive and physical



Complementary Research Thematics

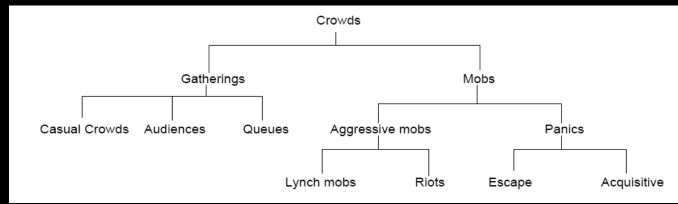
- Multimodal Interaction with objects within the world
  - A generic multilevel model of an object
  - Multimodal rendering
    - visual, haptic, audio, cognitive
  - Acting on the objects of the world
    - language, gesture, mind
- Expressive Autonomous Characters
  - Complex and believable movements for human-like characters
  - Unified architecture to model individual and collective human behaviors
- Interactive scenario languages



A quick Introduction to crowd simulation

Crowd definition

- Group: any gathering of two or more persons
- Mass: a large group
- Crowds: large groups that occupy a single location and share a common focus [Forsyth99]



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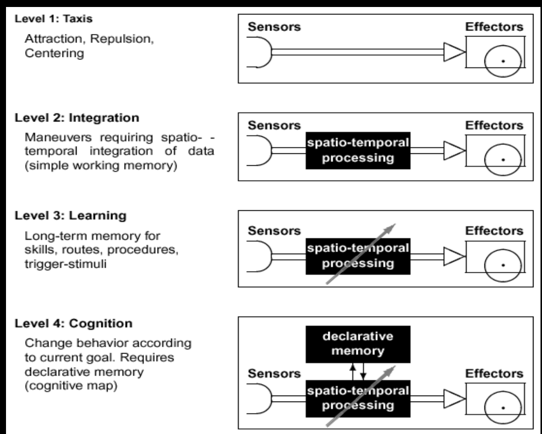
Behavioral model classification [Mallot99]



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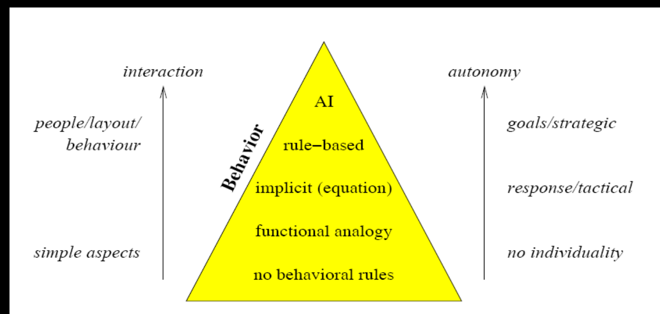
Behavioral model classification [Klüpfel03]



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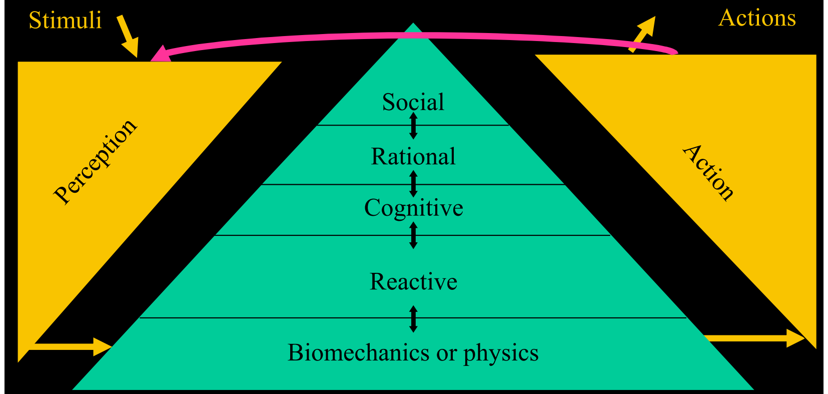
Behavioral model classification
[Donikian04]



Models for Crowd Simulation

- Specific ←→ General
- Discrete ←→ Continuous
- Stochastic ←→ Deterministic
- Quantitative ←→ Qualitative
- Macroscopic ←→ Microscopic (Hybrid in between)

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Macroscopic Models

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Macroscopic Models

- In this approach the pedestrian is not treated on its own but as a component of a more macroscopic element.
  - Statistical approach
  - Dynamics models (gas, fluid)

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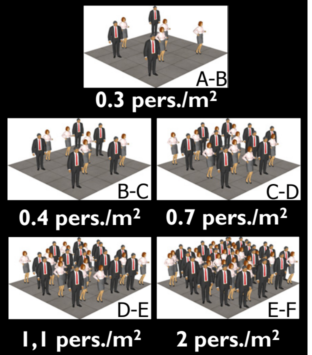
Levels of service (LOS) [Fruin71]

- Based on real data collect
  - flow rate = f(density)

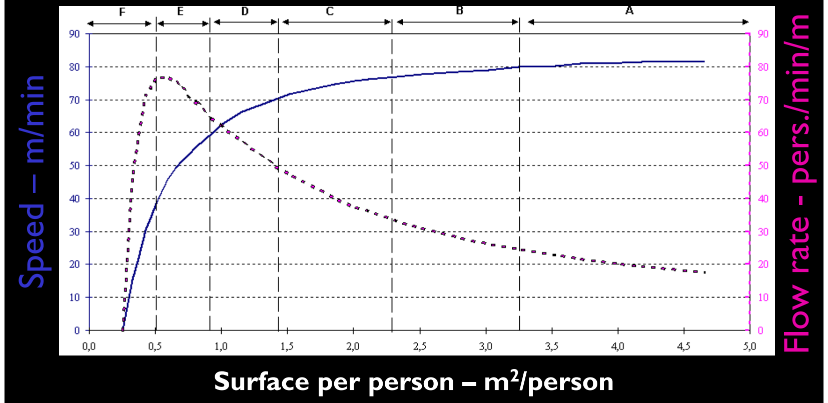
Level of service	Density		Flow rate
	pers./m²	m²/pers.	pers./min/m
A	< 0.3	> 3.2	< 23
B	[0.3, 0.4[	]2.3, 3.2]	[23, 33[
C	[0.4, 0.7[	]1.4, 2.3]	[33, 49[
D	[0.7, 1.1[	]0.9, 1.4]	[49, 66[
E	[1.1, 2[	]0.5, 0.9]	[66, 82[
F	≥ 2	≤ 0.5	variable



Levels of service of J.J. Fruin

- Many variants [Puskarev77, Polus83, Tana89, Brilon94, Milazzo99]
  - Sociocultural Influence

Relation between density, possible speed and flow rate



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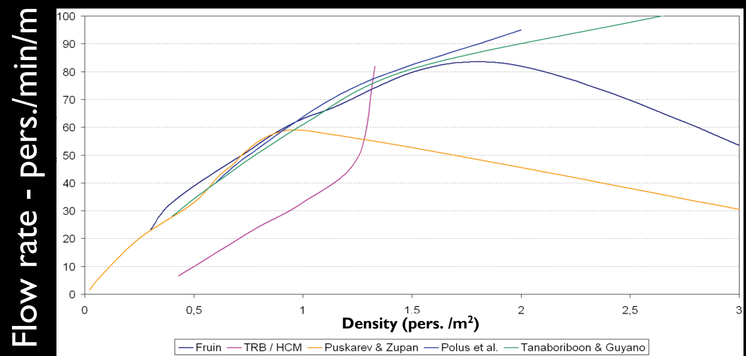
Big disparity between models

- Model completely related to the observed situation, different for each model => a need for standardization



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Macroscopic Simulation of crowds

- Gazeous Model for low density [Henderson71]
  - Use of the Maxwell-Boltzmann Theory
  - Three possible states (stop, walk, run)
  - Distribution of velocities is Gaussian
- Hydraulic Model for high density [Archea79, Predtechenskii78]
  - The motion of persons in corridors, stairways and doors is assimilated to the one of water inside pipes ans sluice-gates
  - Uniform distribution of persons inside pipes
  - Uniform flow rates and unidirectional flows
- Partial differential Equations are used in both cases to explain how crowd densitiy and velocity are evolving.

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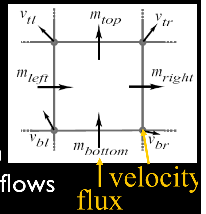
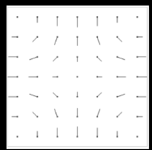
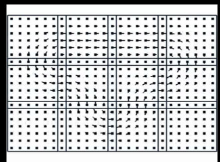
Macroscopic Simulation of crowds [Chenney04]



- Flow tiles provide a set of flow fields that can be combined together to form large tilings.
- A tiling selection algorithm works on any mesh of edges, allowing to generate divergence-free flows
- Flow tiles drive the crowd using the velocity to define the direction of travel for each member.





Statistical Models

- Statistical Models to determine the evacuation time of an aera by separating horizontal and vertical circulation spaces
- The Togawa Model [Togawa55]

$$V = V_0.\rho^{-0.8}$$

Speed of the crowd function of the density

- With V_0=1.3 m.s^{-1}, and ρ = density (person / m^2)

$$N = \rho.V = V_0.\rho^{0.2}$$

- With N = flow rate (person / s / m), 1.3 < N < 1.7

$$T = \frac{P}{C_c.\sum L_e} + \frac{L_h}{v}$$

- With T the evacuation time, P the number of persons in the building, L_e the width of circulation areas, C_e a flow rate (fixed at 1.3 pers./m/s), L_h the total length of evacuation path and v the evacuation speed (usually 0.6 m/s)

Statistical Models

- The Pauls Evacuation Model [Pauls75, Pauls84a, Pauls84b]

$$Q = 0.206.(L - 0.3).(\frac{P}{L - 0.3})^{0.27}$$

- with
  - Q the flow rate
  - P the number of people to evacuate
  - L the width of the stairway (- 0.3 m as people are not using the full width)
- The evacuation time T is driven by the following equation

$$\frac{L}{P} = 8040.T^{-1.37}$$

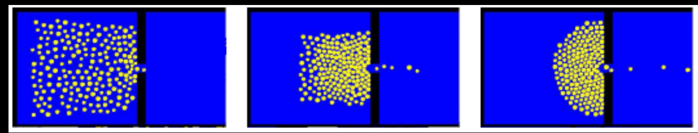
Microscopic Models

Microscopic Model

- Microscopic models consider persons as the elementary units of the model, and manage their interaction inside the environment.
- Different kinds of model
  - Particle systems
  - Cellular Automata
  - Predictive geometric models
  - Steering methods
  - Agent based approach

Particle System

- Introduced by I. Peschl in 1971 [Peschl71]
- Analogy between the displacement of persons in very dense area with the outflow of particles in a compartment
- Allow to model the agglutination phenomenon



- The probability of an arch appearance increases with the density
- The flow is linearly dependent of the exit width

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Social Forces [Helbing95]

- Introduced by Dirk Helbing and Peter Molnar in 1995
- A social force is not a real force exerted by its surrounding on a pedestrian but rather a quantity that describes its motion to act

$$\vec{F}_\alpha(t) := \vec{F}^0_\alpha(\vec{v}_\alpha, v^0_\alpha \vec{e}_\alpha) + \sum_\beta \vec{F}_{\alpha\beta}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_\beta) + \sum_B \vec{F}_{\alpha B}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}^\alpha_B) + \sum_i \vec{F}_{\alpha i}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_i, t).$$

Desired Motion Social Force Obstacle Avoidance Attractive Forces

- This model has evolved over the last decade with later contributions from Illes Farkas and Tamas Vicsek.

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The Helbing-Molnar-Farkas-Vicsek Social Force Model [Helbing00]

- Each pedestrian feels and exerts on others two kinds of forces, social and physical.
  - Social forces (repulsion/attraction) reflect the intention of a pedestrian not to collide with others
  - Physical forces (pushing and friction) are used when pedestrian are forced to collide at very high density

$$\vec{f}_{ij} = \vec{f}_{\text{social repulsion}} + \vec{f}_{\text{pushing}} + \vec{f}_{\text{friction}}$$

$$\vec{f}_{\text{social repulsion}} = A\, e^{(R_{ij}-d_{ij})/B}\, \vec{n}_{ij}\,,$$
$$\vec{f}_{\text{pushing}} = k\, \eta(R_{ij}-d_{ij})\, \vec{n}_{ij}\,,$$
$$\vec{f}_{\text{friction}} = \kappa\, |\vec{f}_{\text{pushing}}|\, \vec{t}_{ij}\,,$$

A, B, k, constants
n_{ij}: vector $\vec{ij}$
t_{ij}: tangential direction
R_{ij}: sum of radii of i & j
d_{ij}: distance between i & j

$$\eta(x) = \begin{cases} x, & x \geq 0; \\ 0, & x < 0. \end{cases}$$

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The Helbing-Molnar-Farkas-Vicsek Social Force Model [Helbing00]

Force between a pedestrian I and an obstacle

$$\vec{f}_{io} = A\, e^{(r_i - d_{io})/B}\, \vec{n}_{io} + k\,\eta(r_i - d_{io})\,\vec{n}_{io} + \kappa\, k\,\eta(r_i - d_{io})\,\vec{t}_{io}$$

Force corresponding to preferred velocity of a pedestrian

$$\vec{f}_{\text{preferred}} = -m\frac{\vec{v} - \vec{v}_0}{\tau}, \qquad \vec{v}_0 = (1-p)V_0\vec{e}_i + p\langle \vec{v}_j \rangle_i$$

It is a weighed average between his "own" velocity and a "collective" velocity that he perceives around himself

$$\frac{d\vec{x}_i(t)}{dt} = \vec{v}_i(t)$$

$$m_i\frac{d\vec{v}_i}{dt} = \vec{f}_i(t) + \vec{\xi}_i(t)$$

$\vec{x}_i$ $\vec{v}_i$ m_i **Position, velocity and mass of pedestrian i**

$\vec{\xi}_i(t)$ **Fluctuation in panic situation**

$\vec{f}_i(t)$ **Sum of the preceding forces**

Illustration of the HMFV Model in Normal and Evacuation Situations

- Simulation of pedestrians moving with identical desired velocity
- 1m wide exit
- Room size 15m x15m
- [Helbing01]

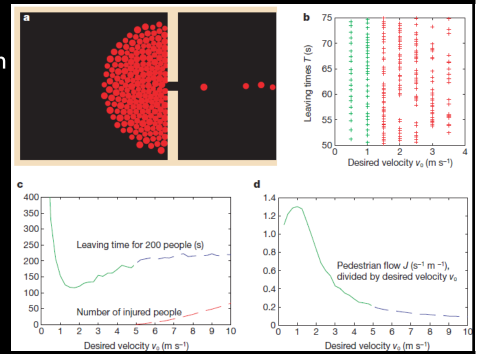


Illustration of the HMFV Model in Normal and Evacuation Situations

- Typical usage (validated):
  - high densities of people, evacuation scenarios
- Major problem:
  - lack of anticipation

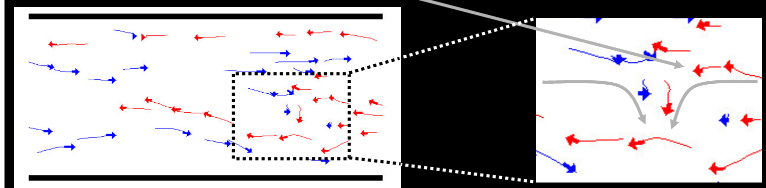
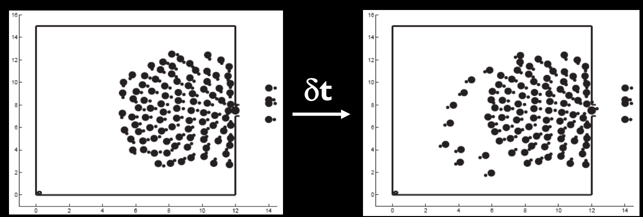


Illustration of the HMFV Model in Normal and Evacuation Situations

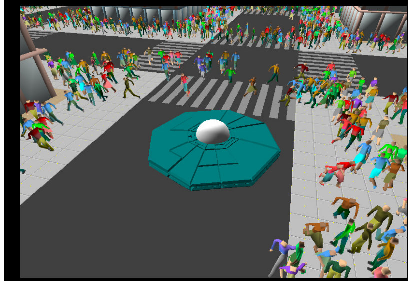
- The validity domain is limited to very high densities
- Trajectories are not correct for individual pedestrians in sparse conditions.
- Problems may also arise at the boundary of the crowd



The Lakoba-Kaup-Finkelstein Model [Lakoba05]

- Modification of the Helbing-Molnar-Farkas-Vicsek Social Force Model
  - To increase its domain of validity for lower densities
  - To eliminate overlapping between pedestrians
    - Stable solutions using the explicit 1st-order Euler Method
  - To add a memory providing to a pedestrian the knowledge about the location of exit(s)
    - Determines the vector of its preferred velocity

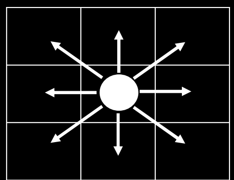
Potential fields [Treuille06]



- Based on global attraction / repulsion forces
  - High performances
- Major problems:
  - unrealistic speeds
  - lack of control over individual destinations

Cellular Automaton [Schadschneider01]

- Discrete approach
  - use of a regular lattice, each cell approximately 40 x 40 cm²)
  - Each cell is either empty or occupied by exactly one person



$P_{-1,1}$	$P_{0,1}$	$P_{1,1}$
$P_{-1,0}$	$P_{0,0}$	$P_{1,0}$
$P_{-1,-1}$	$P_{0,-1}$	$P_{1,-1}$

- $P_{i,j}$: probability to go in the cell $(x+i, y+j)$: preferred walking direction
  - $\Sigma P_{i,j} = 1$
- In case of conflict (two particles share the same target cell), one is chosen according to their relative probabilities to choose the target

Cellular Automaton [Klüpfel03]

- A pedestrian can move more than one cell in a time-step Δt
- Use of a time-step-slice Δt_s
  - $\Delta t_s = \Delta t / v_{max}$ (v_{max} the maximum speed)
- For each time-step-slice:
  1. Try to access the desired cell
  2. If this is not possible, try to go to one of the two 45° neighbors
  3. If this is not possible, try to go to one of the two 90° neighbors
  4. If none of those five cells are accessible, then stop.
- The fact that diagonal movement corresponds to a longer distance is taken into account by a factor $\sqrt{2}$

Floor Field [Schadschneider01]

- The floor field modifies the transition probabilities to increase the probability to move into the direction of larger fields.
- Dynamic floor field (Matrix D_{ij}):
  - Used to model long-ranged attractive interaction between persons
  - Virtual trace are left by pedestrians, but they are subject to diffusion and decay
    - dilution until the vanishing of the trace after some time
- Static floor field (Matrix S_{ij}):
  - Used to specify regions of space that are more attractive

Floor Field [Schadschneider01]

- The transition probability p_{ij} in direction (i, j) depends on four contributions:

$$p_{ij} = N\, P_{ij}\, D_{ij}\, S_{ij}\, (1 - n_{ij})$$

- With:
  - N: normalization factor to ensure $\Sigma_{(i,j)}\, p_{i,j} = 1$
  - n_{ij}: occupation number of the target cell (1 occupied, 0 free)
- Advantage:
  - simple, and can be used for large scale simulations

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Example

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CA + Social Distance [Was06]

- Four sort of distances:
  - Intimate distance: below 40-50 cm
    - Can appear between couples, parents and children
  - Personal distance: from 40-50 cm to 150 cm
    - Close phase below 90 cm for people who know each other very well
  - Social distance: from 150 cm to 300 cm
    - Casual interaction-distance between acquaintances and strangers
  - Public distance: above 300 cm

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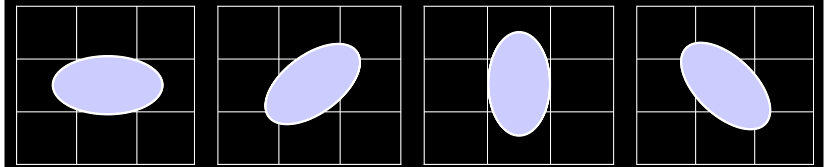
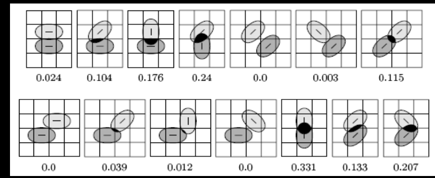
CA + Social Distance [Was06]

- Use of an elliptic body shape
  - a = 0.225 cm (semimajor axis) and b = 0.135 cm (semiminor axis)
  - It is assumed the average size of a person (*WHO* data)
- Four allowed orientations in a cell

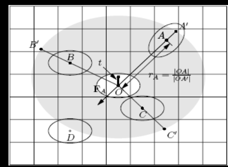


CA + Social Distance [Was06]

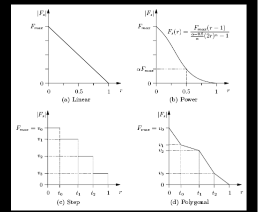
- A limited number of combinations



- Use of the social area ellipse (4a, 5b) and of social distance forces



in the example:
Fs = FA+FB+FC



Different social distance force models

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Predictive methods

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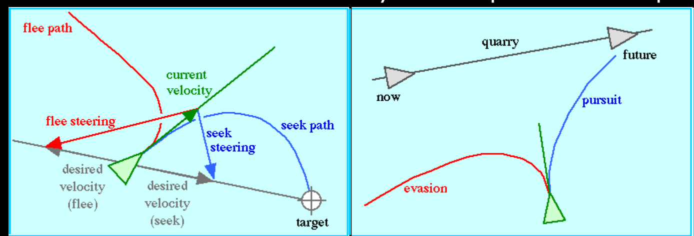
Steering Behaviors [Reynolds99]

- Use of several different behaviors
  - Seek: steer the character towards a specified position
  - Flee: inverse of seek
  - Pursuit: identical to seek but with a moving target
  - Evasion: used to steer away from the predicted future position



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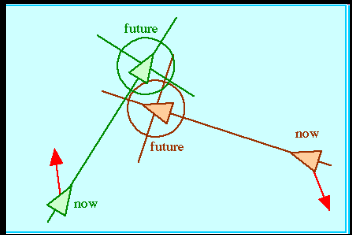
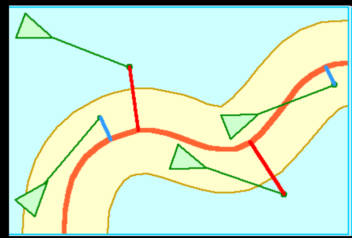
Steering Behaviors [Reynolds99]

- Obstacle avoidance
- The obstacle which intersects the forward axis nearest the character is selected as the "most threatening."
- Steering to avoid this obstacle is computed by negating the (lateral) side-up projection of the obstacle's center.

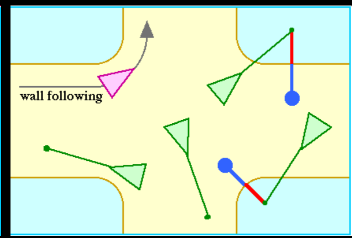


Steering Behaviors [Reynolds99]

- Other behaviors

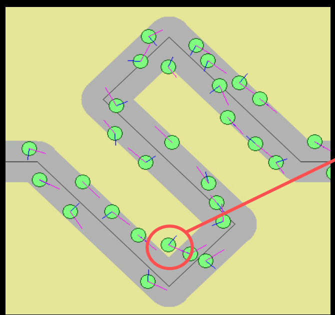


Path following



Wall following and containment

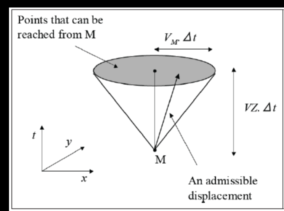
Steering Behaviors [Reynolds99]



- Artifacts
- Major problem:
  - all the interactions must be described

Predictive Geometric Model [Feurtey00]

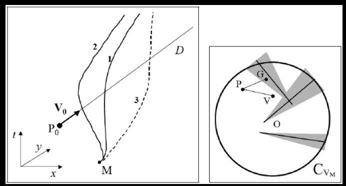
- Predictive approach to manage collision avoidance.
- Navigation of persons represented in a (x,y,t) reference system



- At each time t, all possible positions that can be reached by a pedestrian are included in a circle of radius $(V_M.\Delta t)$ with V_M its maximal velocity.

Predictive Geometric Model
[Feurtey00]

- A possible collision is represented in the cone by a segment in the case of an intersection with the trajectory of a surrounding entity.



- To manage the vagueness of the trajectory prediction, the potential collision area is extended to become a triangle.

Predictive Geometric Model
[Feurtey00]

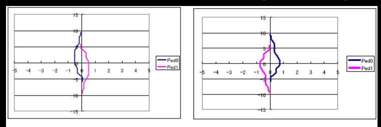
- Feurtey postulates that a person apply three rules with different priorities
  - Preserve its direction
  - Preserve its velocity
  - Preserve the time necessary for the displacement
- Those rules are synthesized in a cost function for each point P included in the circle of possible displacements of radius r_M

$$C_P = K_1 \frac{GP}{2.r_M} + K_2 \frac{\text{angle}(OV,OP)}{180} + K_i \frac{|OP - OV|}{2.r_M}$$

- With:
  - $i = 3$ if $OP \geq OV$ and $i = 4$ otherwise
  - G the target location, K_1 the cost of moving away from the goal, K_2 the cost of changing direction, K_3 the cost of acceleration, K_4 the cost of deceleration

Predictive Geometric Model
[Feurtey00]

- This approach has been tested only on tiny examples

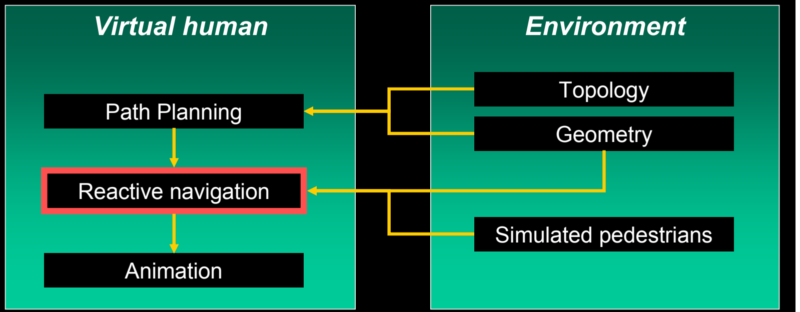


$d_{min}=0.85\ m$ $d_{min}=1.25\ m$

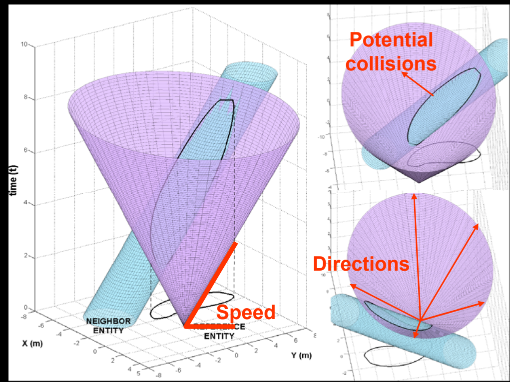
- When many pedestrians need to be avoided, the disk may be saturated.
  - It is necessary to limit the number of pedestrians to take into account
- Oscillations may occur when two pedestrians are face to face

A new predictive reactive navigation algorithm [Paris07]

Part of a more complex virtual human presented hereafter



A predictive approach

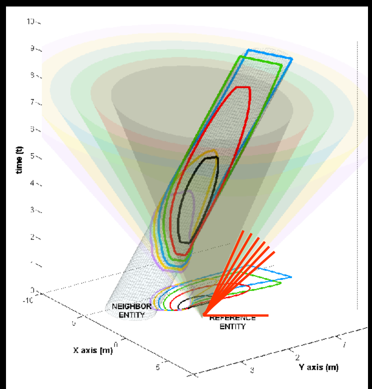


- Reference entity
- Neighbor entity (position, speed)

Problem

How to choose a speed and direction to avoid all collisions in the near future?

A predictive approach



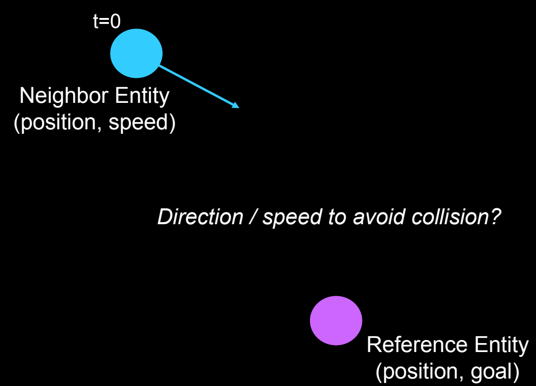
Problem

Compute a cone/cylinder intersection.

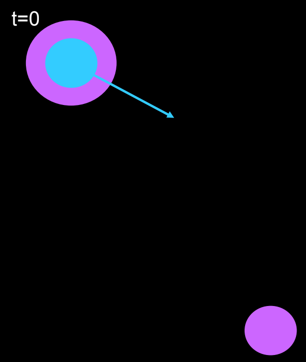
Solution

We choose a discrete model.

A discrete model
Initial conditions



A discrete model
Initial conditions



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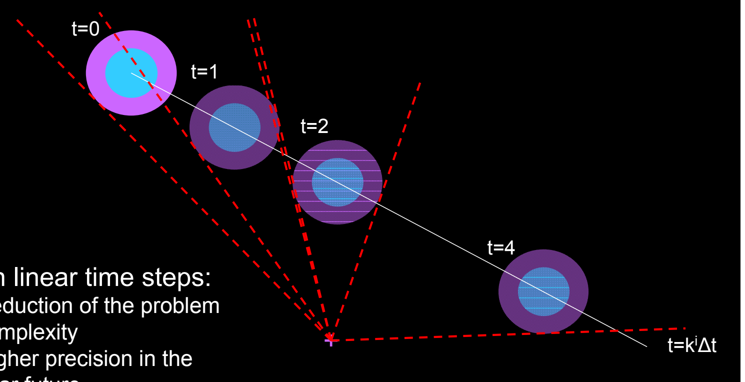
A discrete model
Prediction



Non linear time steps:

- Reduction of the problem complexity
- Higher precision in the near future

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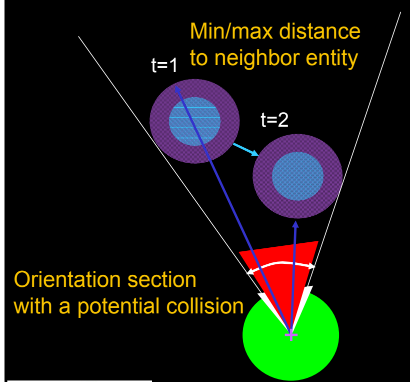
Computation for each time interval



We deduce for each interval the critical speeds:

- The required fast velocity to get ahead of the neighbor
- The allowed slow velocity to move after the neighbor
- An analytic calculation is possible:

$$V_{slow} = \min_{t=t_1}^{t_2}\left(\left(\left\|\overrightarrow{P_r P_n(t)}\right\| - R\right)/t\right)$$

$$V_{fast} = \max_{t=t_1}^{t_2}\left(\left(\left\|\overrightarrow{P_r P_n(t)}\right\| + R\right)/t\right)$$

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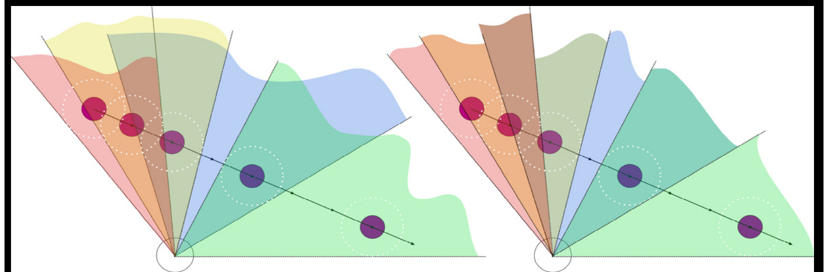
Merging the data of each overlapping section



- Merging done for the intervals provided by:
  - One given neighbor entity
  - All entities taken into account

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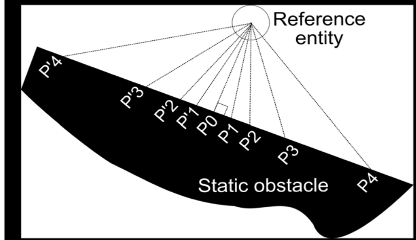
Taking into account the static obstacles



The same discrete approach as before is used:

- V_{fast} is a nonsense
- The intervals are computed from the nearest point of the obstacle P0 to both of its edges

Selection of the best orientation and speed

- Computation of a weight for each section:
  - Reference entity: *goal, current state*
  - Section: V_{slow}, V_{fast}, *orientations*
- The lower weight gives the best move.
- The cost function:
  - defines the realism level
  - requires a calibration phase: *experimental data are needed*

Simulation Results of the model

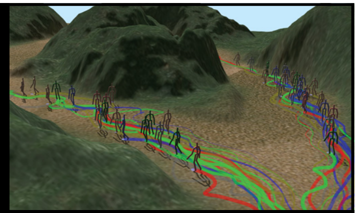
Nead of social and group behaviours

Raccourci vers compo-groupes.avi.lnk

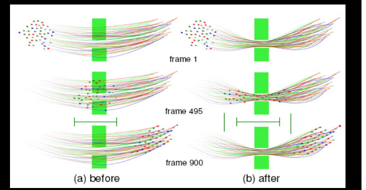
Group based crowd simulation [Musse99]

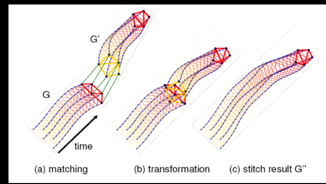
- Individual trajectories of virtual humans determined by the behaviour of the group they belong to.

Group Motion Editing [Kwon et al. 08]



- Provide an easy to use manner to control the trajectory of groups of people in a virtual environment.
  - Edit
  - Combine several spatial elements





Raccourci vers 0370.avi.lnk

Multi-layered Models

Multi-layer Approach

Dynamic approach in three layers [Goldenstein01]

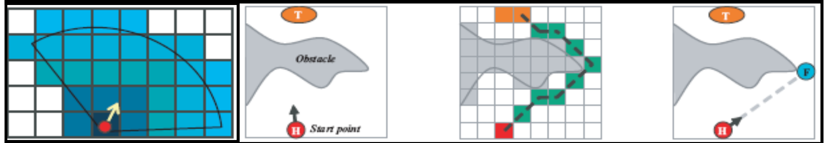
1. Particle based dynamic system
2. Management of the relations between moving objects and the environment (based on Delaunay triangulation)
3. Path planning and calculation of the desired orientation to reach a destination.

Autonomous pedestrians in a train station [Shao07]

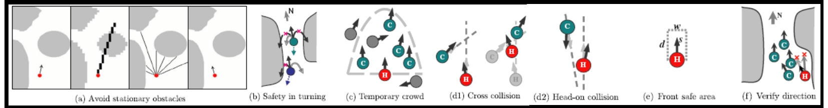
Raccourci vers Shao-terzopoulos1.avi.lnk

Raccourci vers Shao-terzopoulos2.avi.lnk

- Modelling of individual behaviours
- Use of a regular grid for reactive navigation and perception

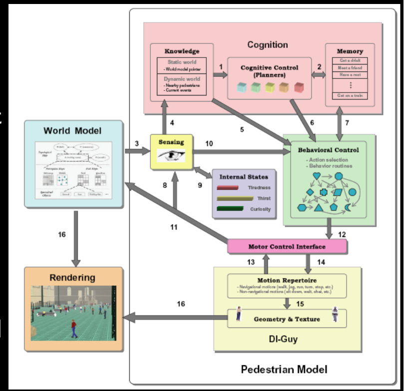


- Use of six basic reactive behavior routines



Autonomous pedestrians in a train station [Shao07]

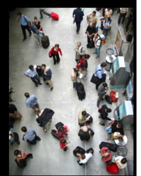
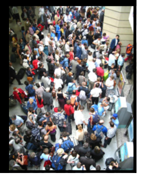
- Motivational behaviors are used to supplement basic reactive routines, such as:
  - Meet with friends and chat
  - Queue at a ticketing area
- An action selection mechanism chooses the appropriate behavior to fulfill needs.
- A cognitive model is responsible for creating and executing plans suitable.



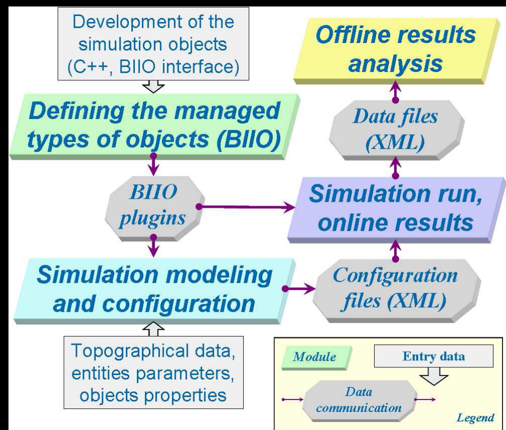
Simulem A Goal Oriented Multi-layered Behavioral Simulator dedicated to Mobility Areas [Paris08]

- Objective
  - Develop the first goal oriented simulation tool
    - dedicated to train station and more generally to transportation terminals
    - including all the human activity inside this restricted area

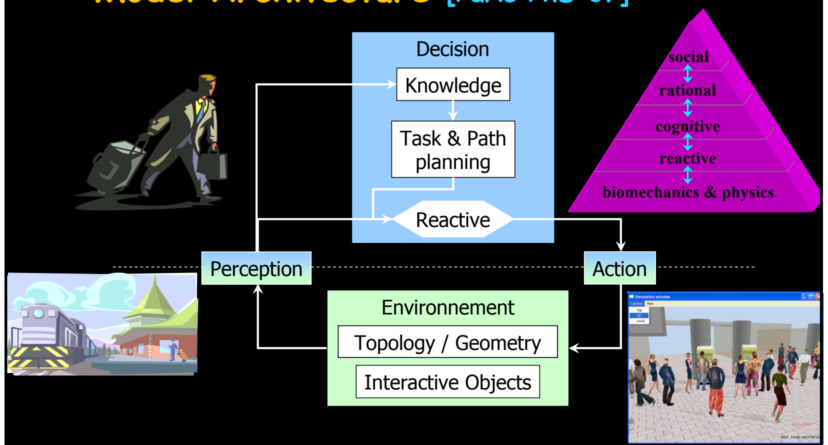


Simulator Architecture

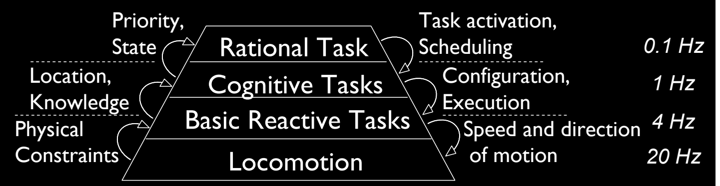


Model Architecture [Paris PhD 07]

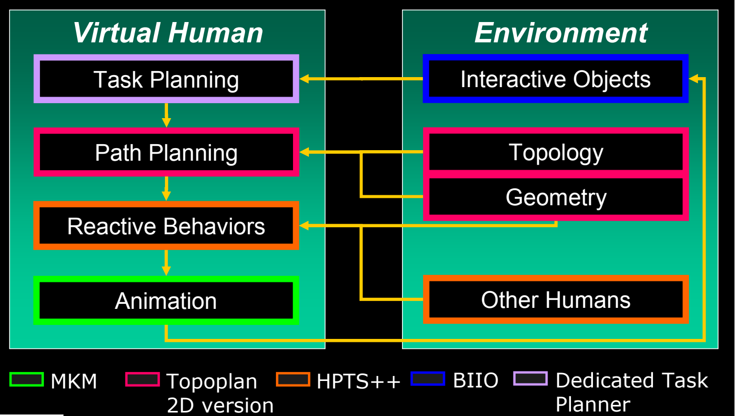


An Embodied and Situated Virtual Human

- Based on the Behavioral Pyramid
  - All processes are independant and only connected to the connex layers

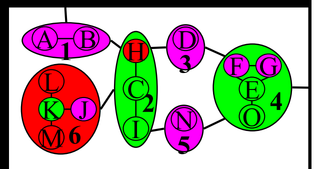


Global crowd simulation architecture



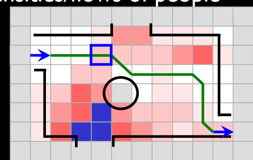
Environment Representation [Paris06]

- Based on the exact geometry of the digital mockup (AutoCAD)
- Computation of a 3 layers hierarchical graph
- Pre computed data / computation procedures
  - PVS, shortest paths, paths widths, densities/flows of people



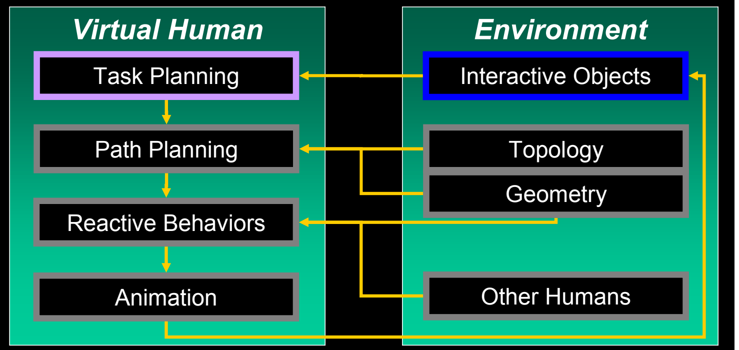
Hierarchical graph example

Potential Visibility Sets



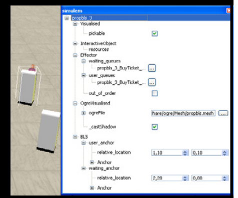
Fine density computation on oriented grids

Global crowd simulation architecture

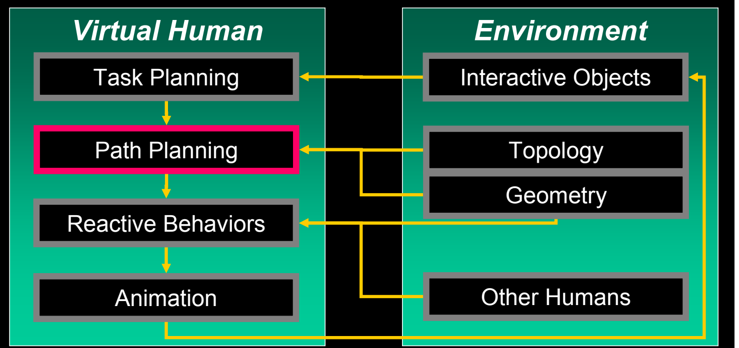


Cognitive and Rational Tasks

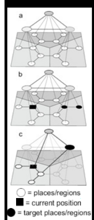
- Cognitive Tasks
  - Concurrent Atomic Processes (priorities)
    - Interact: complete management of an affordance
    - Move: management of default displacement
    - Observe: mangement of visual attention
- Goal Oriented Rational Model
  - manage all affordances
    - Rational Process classifying all interactions
    - Hierarchical Organization of affordances



Global crowd simulation architecture

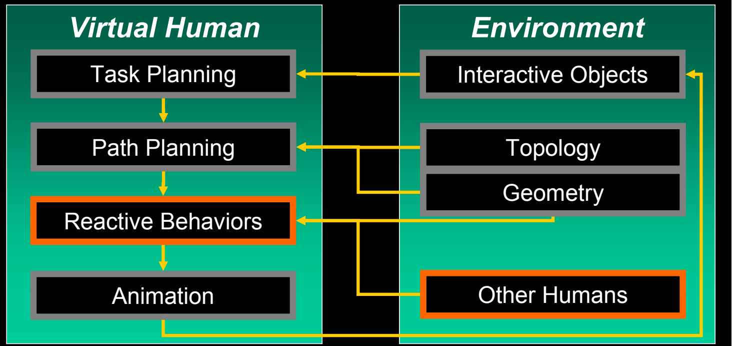


Path Planning: a Hierarchical Technique [Paris06]



- Full path calculation in the more abstracted graph
  - To find an approximate path from current to destination zone
- By part calculation in the contained sub-graphs
  - Locally refine the path as the entity moves inside the environment
- 3 specializations for the full path calculation
  - Reach a unique identified target
  - Choose the best target between a set of identified ones
  - Explore: Reach a target which may improve the entity's knowledge of the environment
- Multicriteria Heuristic based on static data (path width & length, deviation angles, discovering potential) and dynamic data (densities and flows of people)

Global crowd simulation architecture



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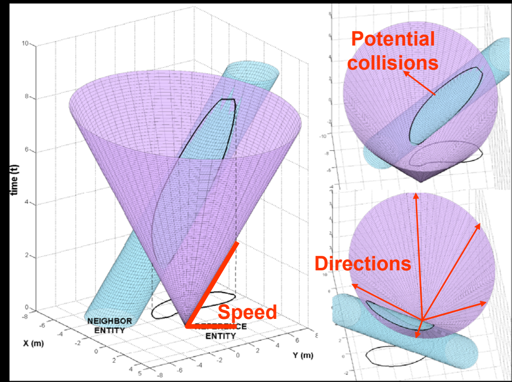
A predictive approach
[Paris07]



- Reference entity
- Neighbor entity (position, speed)

Problem

How to choose a speed and direction to avoid all collisions in the near future?

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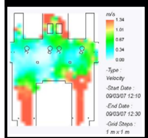
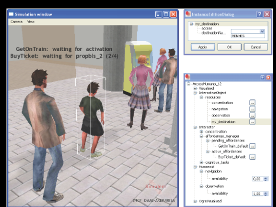
Simulation Characteristics

- Population generation based on exploitation data, distribution of delay before departure, Origin Destination Graph, …



Mean Speed Spatial Distribution



Queuing up to buy a ticket

Each virtual human interacts with others but behaves depending on its own goals

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Configuration of a simulation

- Population generation based on exploitation data, distribution of delay before departure, Origin Destination Graph, …

Parameters

General | Populations | Trains | Exploitation | Equipments

	Number	Departure Time	Arrival Time	From	To	Quality	Material	Population	Platform	engers in	engers out
1	5360	10:56	10:54	MARSEILLE ST CHARLES	RENNES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_1	100	100
2	5214	11:18	11:15	LILLE EUROPE	RENNES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_2	100	100
3	5326	10:56	10:51	PARIS	RENNES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_1	100	100
4	5128	10:57	10:52	BREST	PARIS	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_2	100	100
5	5264	10:58	10:53	TOULOUSE MATABIAU	LILLE EUROPE	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_1	100	100
6	5213	11:18	10:56	LILLE EUROPE	NANTES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_2	100	100
7	5318	12:00	11:27	RENNES	MARSEILLE ST CHARLES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_1	100	100
8	5224	12:21	12:18	LILLE EUROPE	RENNES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_2	100	100
9	5227	12:21	12:18	LILLE EUROPE	NANTES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_1	100	100
10	5218	12:30	12:28	LILLE EUROPE	TOULOUSE MATABIAU	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_2	100	100
11	5368	12:48	12:45	MARSEILLE ST CHARLES	NANTES	QualiteTGV_1	TGV_type1	Population_TGV1	Voie_1	100	100

Build Simulation

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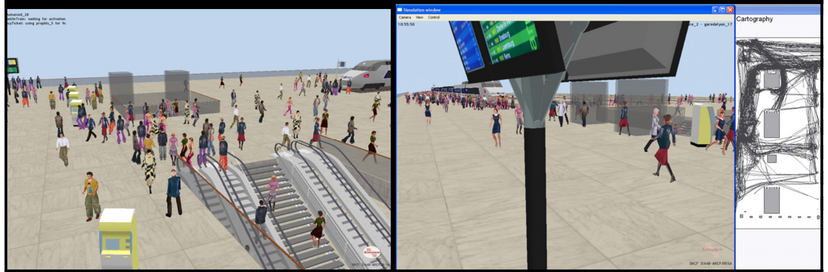
Running a simulation



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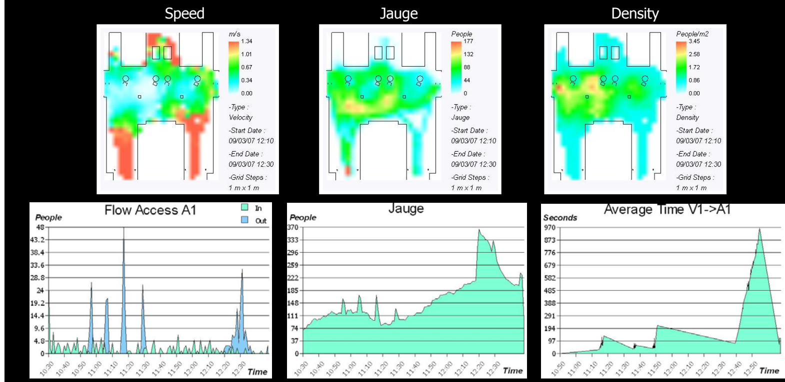
Exploitation of simulation results



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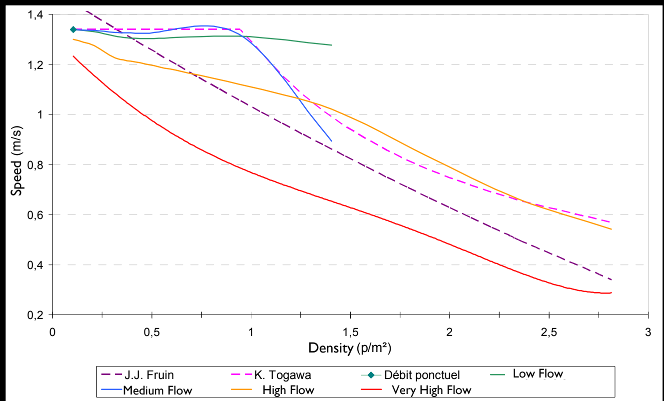
Comparison with statistical models



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Experimental studies

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The Experimental Validation Problem

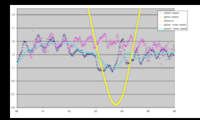
- Validate the proposed models
- Problem:
  - impossible to compare a virtual behavior with a real one on complex examples
- Solution:
  - Statistical validation based on macroscopic data or mean data
  - Use real data to calibrate the model

[Lee07]

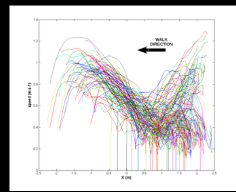
[Lerner07]

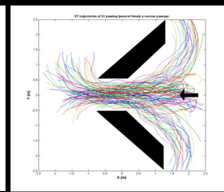
Experimental Studies

- Study interactions between two persons under different configurations



- Observation of micro-phenomena in micro-crowds





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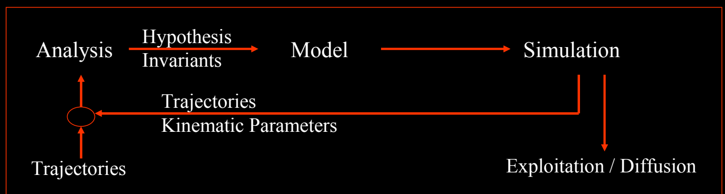
Analysis and Synthesis Approach for Virtual Humans

- Use an Analysis/Synthesis approach to model human characteristics:
  - Locomotion, reactive navigation, path planning, …



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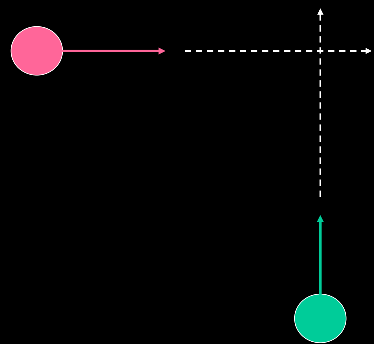
Experiments for Model Calibration
Interaction with 2 subjects



- Constrain trajectories to produce an interaction:
  - Geometrical
  - Temporal
- Goal:
  - Interaction condition ?
  - Avoidance strategy ?
- Technical method:
  - Motion capture

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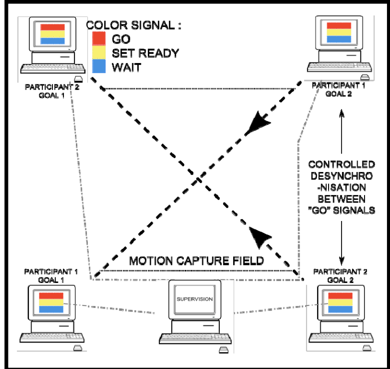
Experiments for Model Calibration
Interaction with 2 subjects



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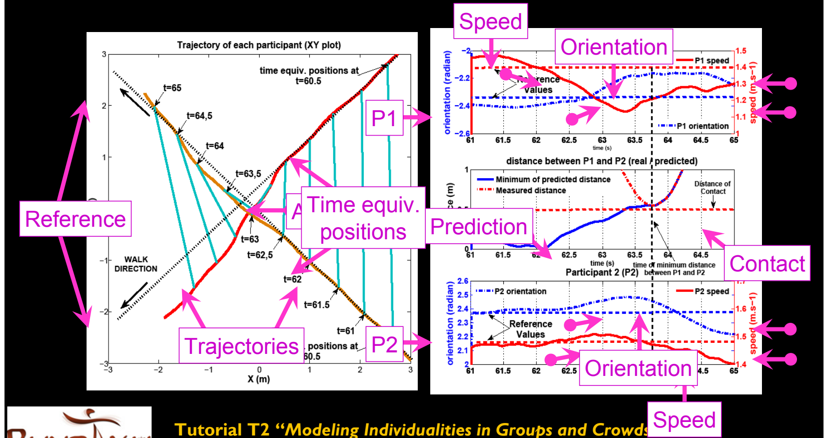
Experiments for Model Calibration
Interaction with 2 subjects



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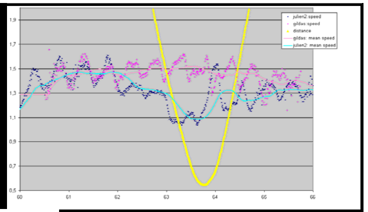
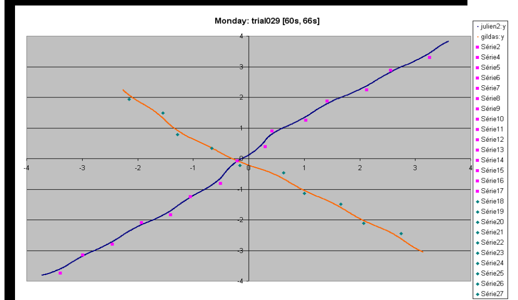
More details





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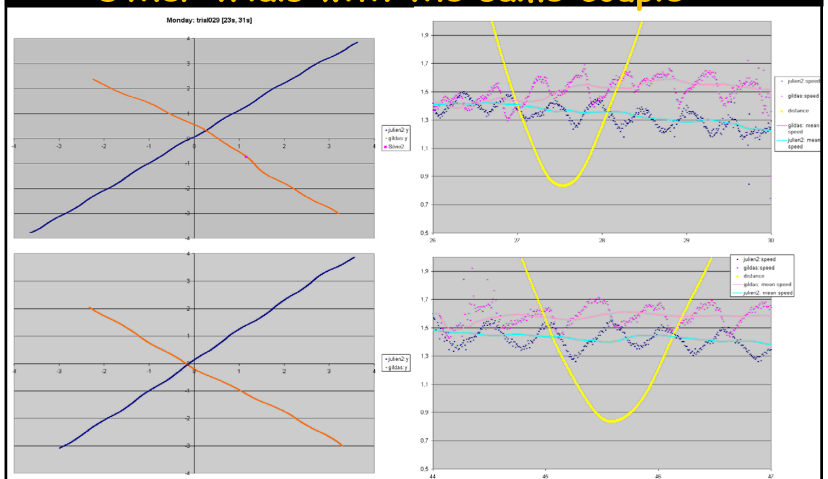
Other trials with the same couple



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Experiments for Model Validation
Micro-crowd

Problem

Do the rules which are observed for 2 subjects remain valid for more complex interactions?

Solution

Observation of crowds micro-phenomena in « classical situations » :

- Door crossing,
- Corridor,
- Crossroad,
- Etc.

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Experiments for Model Validation
Micro-crowd

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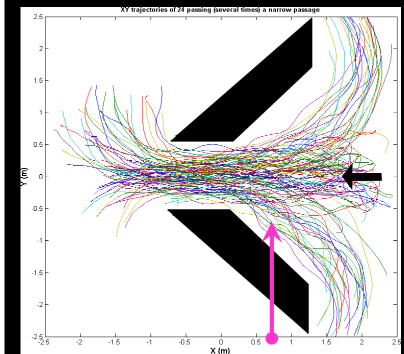
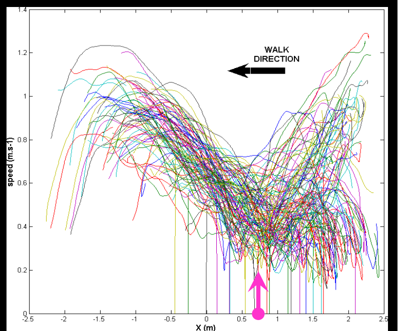
Experiments for Model Validation
Micro-crowd





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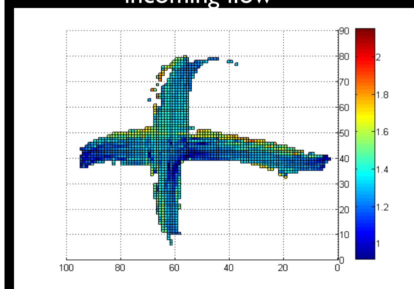
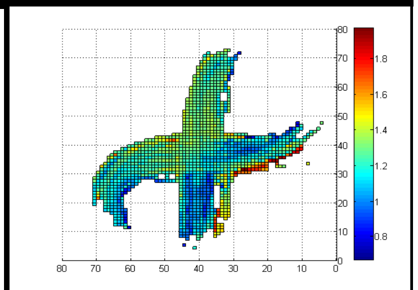
Experiments for Model Validation
Micro-crowd

- Navigation in an area with obstacles
- Two scenarios: with or without visibility of the other incoming flow





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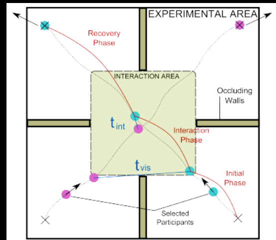
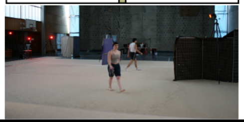
Comparison of crowd simulation models with real data

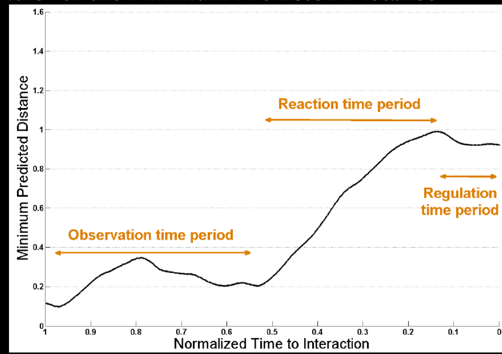
- Experimental square is 15m long, interaction area is 10m long.
- We randomize participants selection so that they cannot anticipate the direction from which one will appear.
- 429 experimental samples and 62 reference trajectories have been recorded.





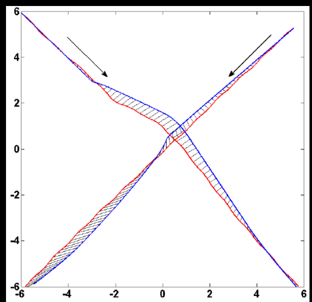
An interaction in three steps

- Control of the Minimum Predicted Distance



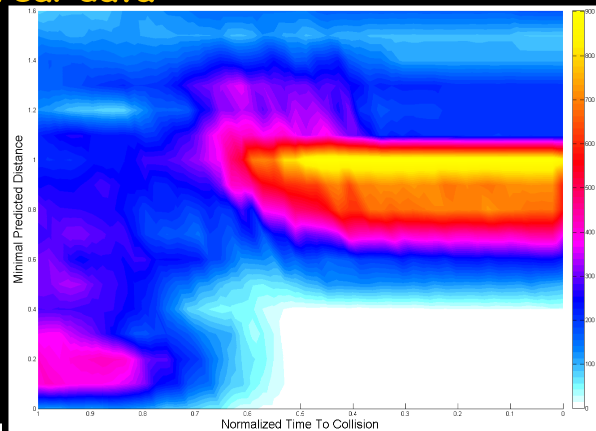
Reynolds Steering Behavior [Reynolds99] vs real data

- The Reynolds' method converges toward a correct final distance between walkers.
- Reaction is too abrupt, as mpd is suddenly increased.
- Walkers adapt their motion simultaneously in this approach while in reality, adaptations are not synchronized,



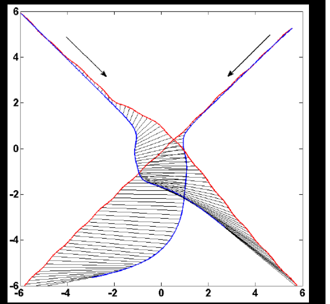
Real trajectory
Reynolds Steering Behavior

Reynolds Steering Behavior [Reynolds99] vs real data



Helbing Molnar Model [Helbing95] vs real data

- The lack of anticipation is clearly observable.
- The minimal distance between walkers is maintained over realistic values.



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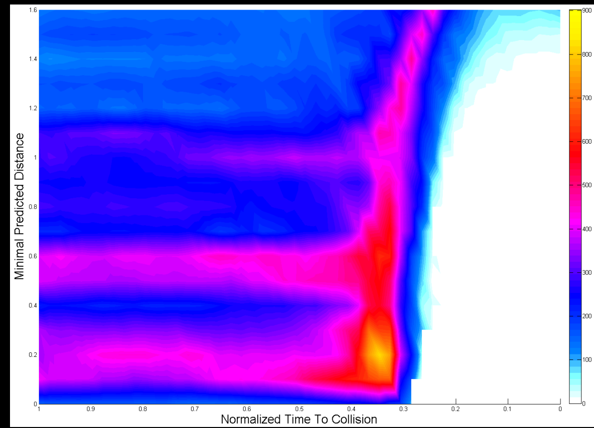
Helbing Molnar Model [Helbing95] vs real data



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Conclusion

- Models of reactive navigation are usually reactive which is not sufficient at low density
- Models do not take into account several steps in the interaction
  - They are usually reacting too late and overmuch
- There is a need for a realistic predictive navigation model
- Recently, multi-layered models have been proposed allowing to combine reactive and cognitive behaviors increasing the realism of resulting simulations by providing goals and motivations to the virtual populace.

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Open questions

- What is the model used by a pedestrian to adapt its trajectory to potential interactions with others ?
- Combination of speed and orientation adaptation due to the interaction with a subset of its neighbors
  - How is this combination ?
  - How are filtered the neighbors ? How many are they ?
- We are working in a pluridisciplinary project (Locanthrope) to answer these questions in a near future.

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The End!

Thank you for your attention

Questions ?

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