SOME EFFECT OF INTERPERSONAL DISTANCE CONSTRAINTS IN MODELING WAYOUT FINDING FROM AN EXHIBITION HALL

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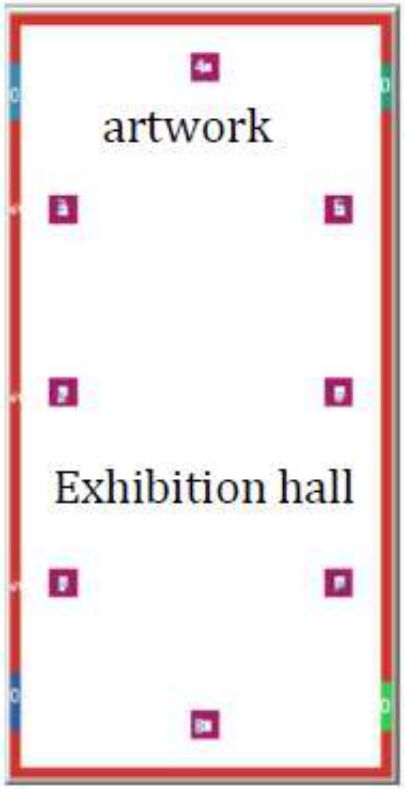
Outline

1. **Case study: model of exhibition hall where people move trying to maintain interpersonal distancing**
2. **Overview, Design concepts, Details of a NetLogo model**
3. **PathFinder MonteCarlo simulation results**
4. **Conclusion and future research topics**

The case study



Exit door #2

Exit door #1

I) Pre-evacuation phase (normal state)

People move inside visit the exhibition hall and try to maintain some interpersonal distance while enjoying the event.

II) Egress phase (emergency state)

An alarm is suddenly triggered and people are supposed to immediately understand the necessity of moving out through two exit doors.

1 The People and the distancing constraint

a) Group: 1 Leader and 7 visitors → *NetLogo*

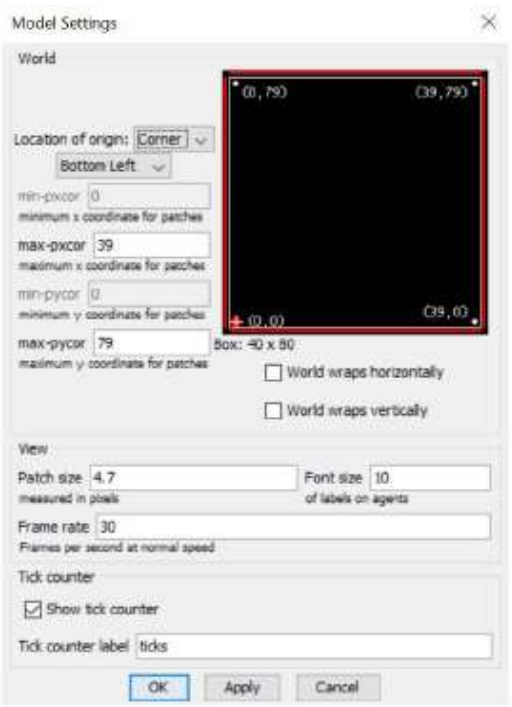
The focus is here on the leader with its group of visitors during the visiting time (pre-evacuation phase) and the capabilities of the model to capture the interactions in the group moving under an interpersonal distance constraint.

b) Group: 1 Leader and 7 visitors + 7 autonomous visitors → *PathFinder*

NetLogo

NetLogo is an open source environment that uses specific entities: the very basic are the *patches*, the *turtles* and the *link*.

- The *patches* are used in this study to describe the environmental space while the *turtles* model the occupants. Each *patch* is a square (rectangular) piece of "ground" over which *turtles* can move. Both *patches* and *agents* have coordinates, but *patch*'s coordinates are always integers, while *turtle*'s coordinates can have decimals allowing that a *turtle* can be positioned at any point within its *patch*.
- The *links* model some characteristic that is useful to be associated with the *turtles*.



The *patches* and the *turtles* represent the *world*.

Ticks mark the advancement of the simulation when all of the rules of all of the agents are executed in the current step.

NetLogo

The model is initialised by designing the environment and the agents

- The input data of the environment:
  - geometry (plan area, walls, doors, artworks)
  - effects (solid boundaries, unavailable doors, exits, alarms and signals)
- The input data of the agents:
  - position (number, spatial distribution)
  - characteristics (physical and cognitive)
  - actions of the occupants:
    - positioning (interpersonal distances)
    - movement (visit, wander, dodge, move out, stop)
    - decisions (reactive, adaptive)

NetLogo - Behavioral rules and constrains

The basic idea of this study is to use a relatively few rules internal to the agents, in such a way to let the system evolve to some state with not too strong a forcing from the outside.

The rules depend on the nature of the agents:

- the rules for the **patches** deal with the *properties of the environment* (walkable space or not, pre-alarm and post-alarm sounding, employing a color-based picturing for a quick visualization)
- the rules for the **turtles** deal with the *breed* (leader, visitor, wanderer) and the *actions* (leading or following while moving, moving independently, checking for sufficiently available room around oneself, checking for obstacles, pointing some target)
- the rules for the **links** deal with the characteristic (room around oneself)

NetLogo - Behavioral rules and constrains

Several constraints need to be implemented in the model for the agents:

- internal and external to their own state.
  - Internal constraints describe programmed or derived biases, such as: avoiding obstacles or pointing one target;
  - external constraints describe the effect of the world, such as: solid barriers or responding to the alarm.

While, in general, different sets of rules are assigned to each group of agents depending on their breed, same constraints are assigned to the agents as such.

NetLogo - Behavioral rules and constrains

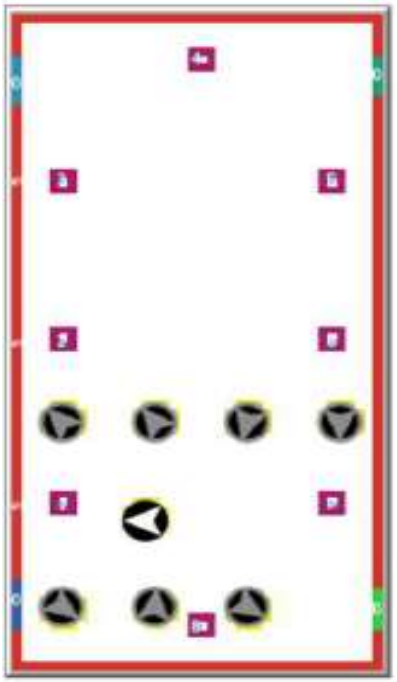
The *interpersonal distance* constraint, usually associated with the room freely available for each agent, *may span from* **contact** (practically in touch) to **proximity** (near vicinity).

With the use of the *links*, the room constraint around each turtle is visualised as a halo that moves together with the *turtle* itself.

The *distance of the leader with its nearest visitors*, dynamically variable during the movements, is adopted here as reference metric, but alternative metrics could refer to each occupant or to any other specific occupant

NetLogo

The initial position of the leader is set at random near one artwork while the initial position of the seven visitors is set in chosen points automatically placed taking into account the relative distance to be maintained between the agents; the initial heading of the leader is set to face west, the initial heading of the visitors is set at random.



The agents are instructed to direct towards their target only if it is in their vision cones, otherwise they start a random walk till the target is detected.

NetLogo

Two social distancing schemes are applied.

In the first set of simulations - **visit type** - the basic behavioral rules assigned to the leader and the visitors of the group are (as seen by the agent):

- "*If I am the leader*, if I see in my cone of vision an artwork I'll move toward it, but If I don't see any artwork I'll move at random until I see one artwork; I'll keep trace of the distance from me to the near visitors".
- "*If I am the visitor*, if I see the leader in my cone of vision, if there is no other agent inside my interpersonal distance constraint I'll follow the leader, otherwise I'll move at random a little; if I don't see the leader in my cone of vision, I'll move at random until I catch sight of the leader".

NetLogo

Two social distancing schemes are applied.

In the second set of simulations - **maneuver type** - the basic behavioral rules assigned to the leader and the visitors of the group are (as seen by the agent):

- "*If I am the leader*, if I see in my cone of vision an artwork I'll move toward it, but If I don't see any artwork I'll move at random until I see one artwork; I'll try to maintain the interpersonal distance constraint; I'll keep trace of the distance from me to the near visitors".
- "*If I am the visitor*, if there is no other agent inside my interpersonal distance constraint, if I see the leader in my cone of vision I'll follow the leader, otherwise I'll manage to know where the leader is and move a little toward his direction".

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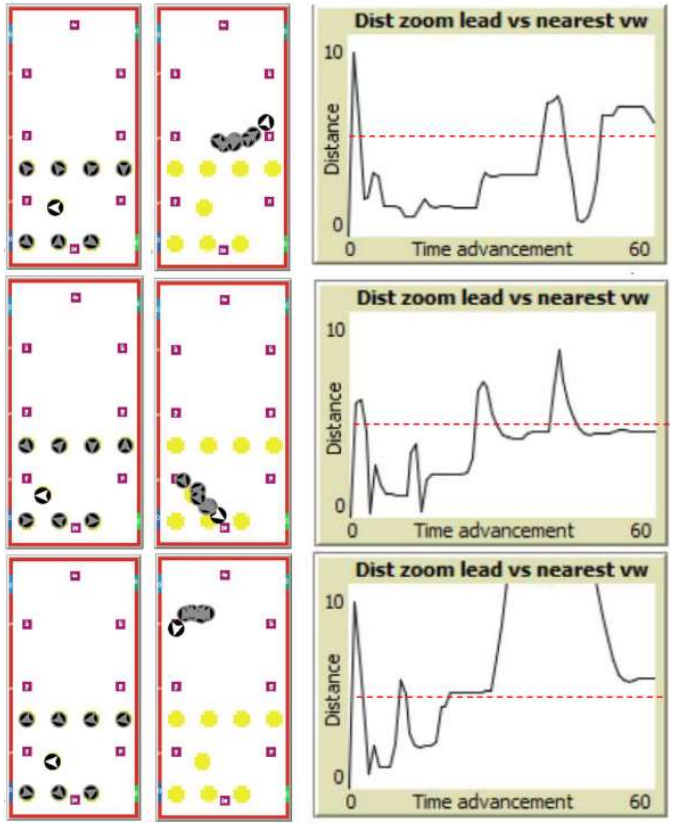
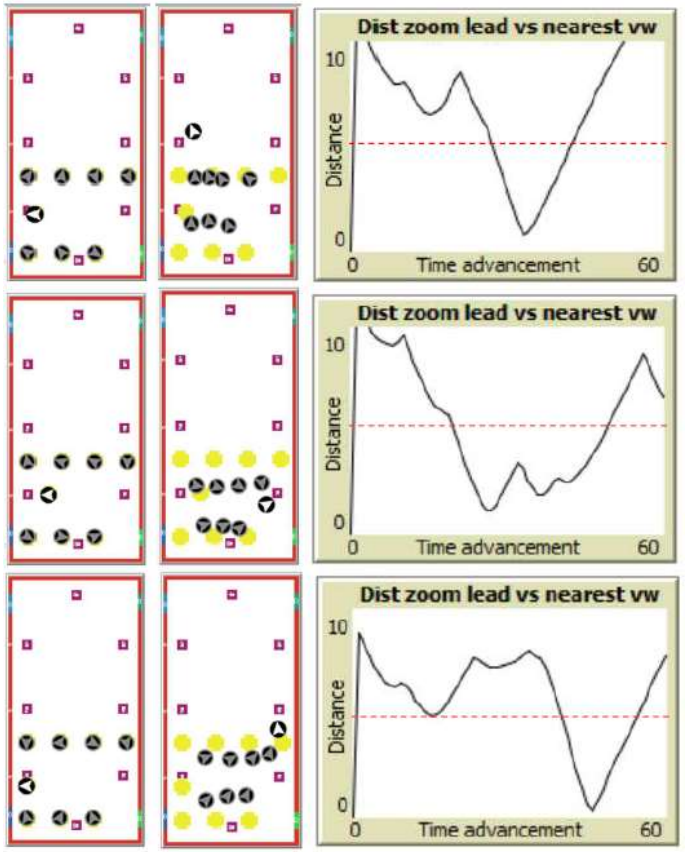
2 NetLogo



Visit type scheme. Initial setup (tick 0) and final state (tick 60) with distancing metrics of the leader vs nearest visitor obtained in three runs. Social distancing set to 1 m. (distance in patch units, 1 patch = 0.20 m; time advancement in ticks).
Population of 8 occupants formed by a group of 7 visitors and a guide.

2 NetLogo



Maneuver type scheme. Initial setup (tick 0) and final state (tick 60) with distancing metrics of the leader vs nearest visitor obtained in three runs. Social distancing set to 1 m. (distance in patch units, 1 patch = 0.20 m; time advancement in ticks).
Population of 8 occupants formed by a group of 7 visitors and a guide.

PathFinder

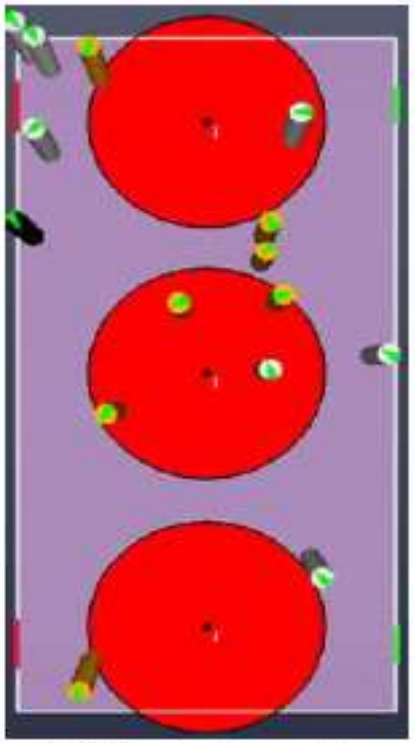
Population of 15 occupants formed by a group of 7 visitors and a guide and 7 autonomous visitors

Pre-evacuation phase: 10 s
Evacuation phase: Less distant exit at the alarm onset (scheduled @ 10 s)
Three primary movement scheme depending on social distancing rules

Table 1: Statistics of the exit times in PathFinder simulations

Exit times (s)	1. Free Flow		2.Social distancing partially constrained flow		3. Social distancing constrained flow	
	First out	Last out	First out	Last out	First out	Last out
Dev. std	0.99	2.03	1.07	1.95	1.04	1.83
Min	11.0	20.0	11.1	21.3	11.1	22.4
Max	14.7	30.6	14.8	31.6	15.1	32.1
Average	12.5	25.0	12.6	25.9	12.7	27.2

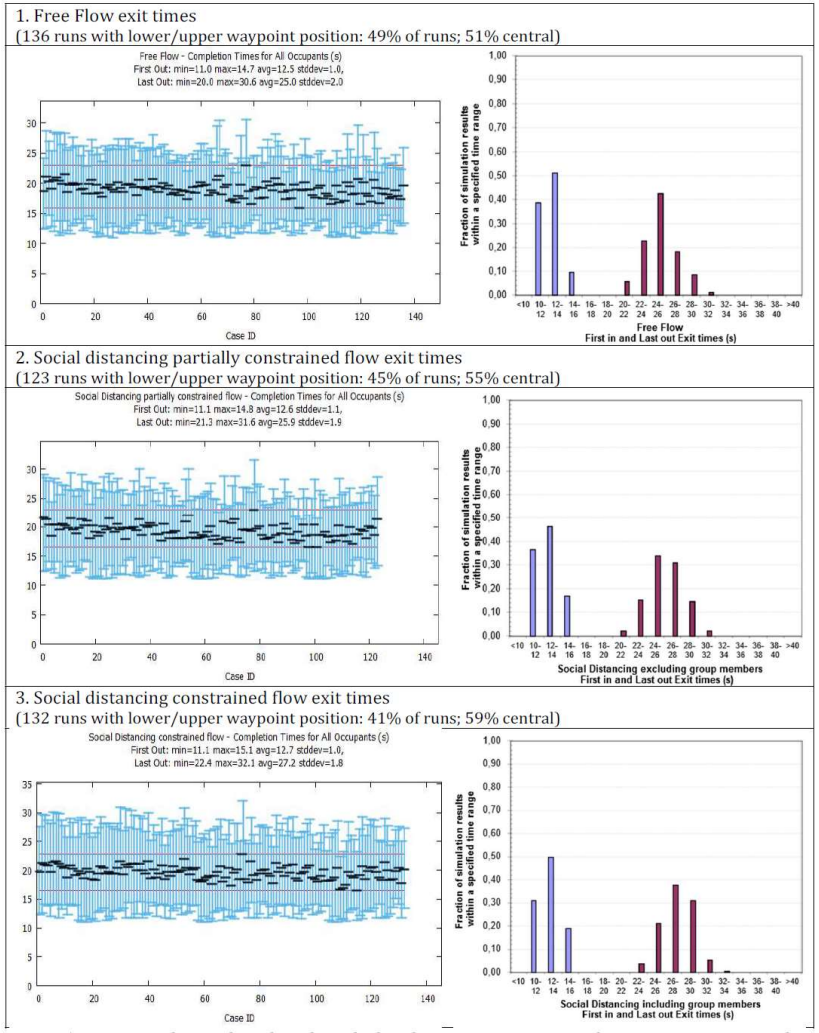
Randomize occupant positions; social distancing when applied = 1 m



PathFinder model with the initial agents positions and the location of the group waypoint

3 PathFinder

Exit Times



Summary plots with PathFinder calculated minimum, average and maximum exit time and First out and Last occupant exit times histograms
Population of 15 occupants formed by a group of 7 visitors and a guide and 7 autonomous visitors

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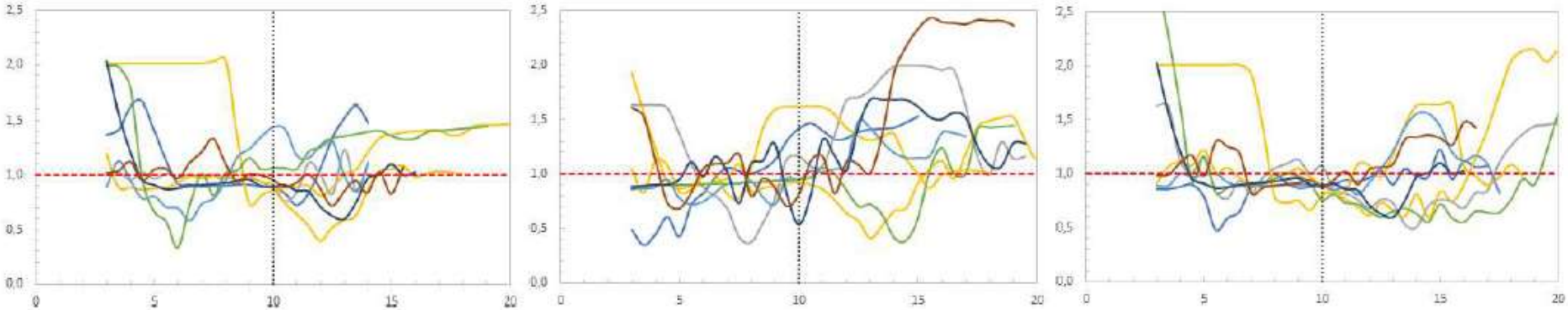
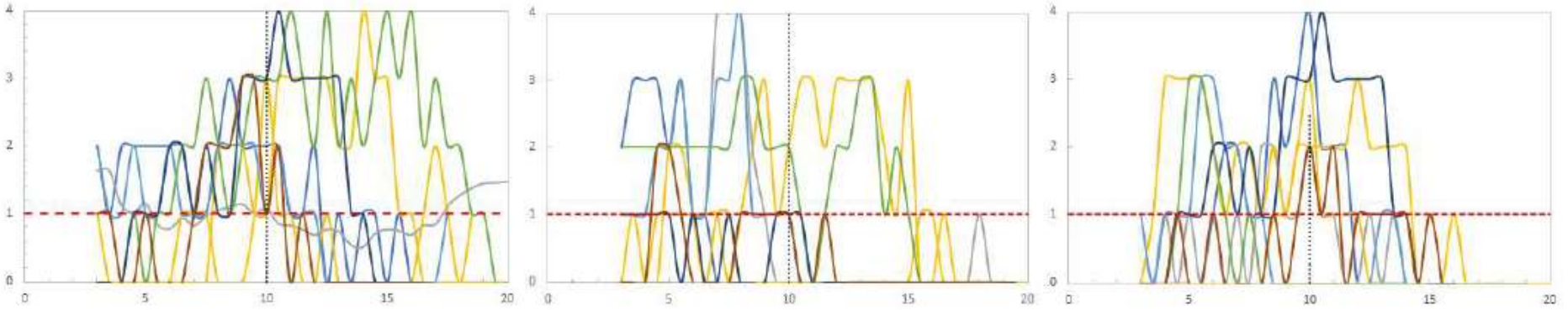
3 PathFinder – Interpersonal distancing



(Closest occupant to the leader distance in m; time advancement in s).



(Count of occupants; time advancement in s)

Distancing metrics of the leader vs nearest visitor (above) and number of occupants within 1 m of the leader (below) (each graph shows eight runs). Social distancing set to 1 m. Population of 15 occupants formed by a group of 7 visitors and a guide and 7 autonomous visitors

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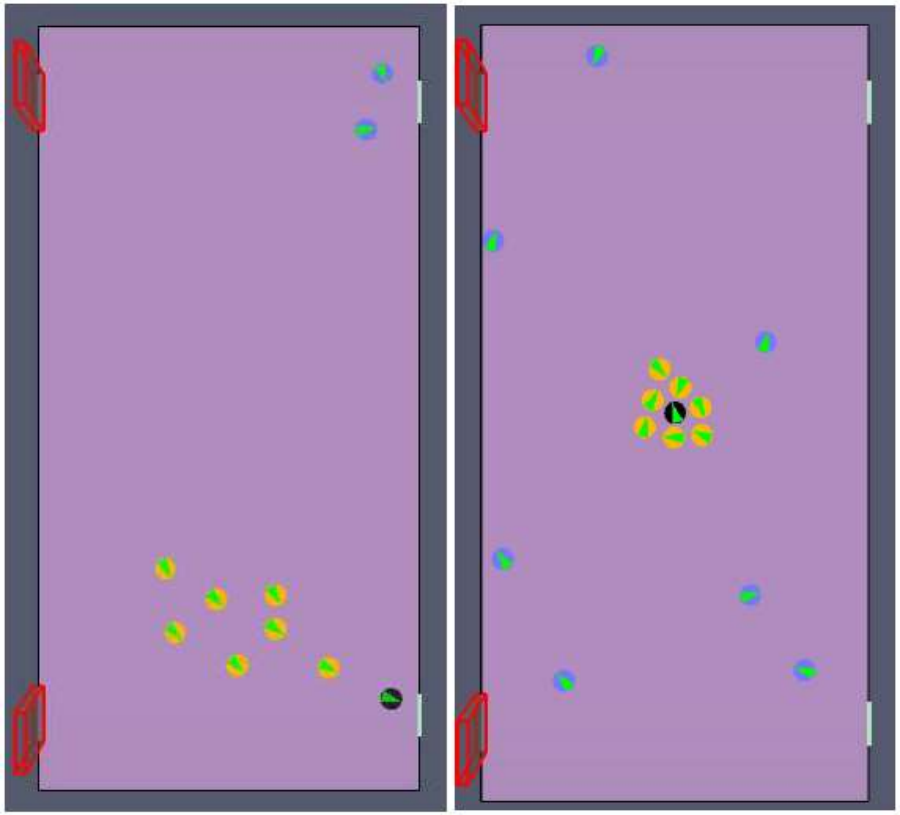
3 PathFinder – Interpersonal distancing

For each one of the 132 time series of the full social distancing scheme, discarding the first 3 seconds where the random positioning at the starting could initially put the agents too close each other, the minimum and average of the closest occupant distance have been calculated and again averaged to obtain the overall values.

The minimum distance overall is equal to 0.33 m, same as the reduction in the agent size by default implemented by PathFinder, while the average overall of the closest occupant distance is 0,86 m, lower than the specified value of 1.0 m, with peaks of 4 occupants within the 1 m radius.

3 PathFinder – Emergent pattern for group movement

V-shaped flock formation in the egress phase



Circle of visitors around the leader in the visit stage

Emergent pattern for group movement when social distancing is applied

4 Conclusion and future research work

- With the basic rules described there is no guarantee that the social distancing specified in the input will be respected bu the agents during their path. There is a need to include more advanced behavioural rules, based on human capabilities.

- In the engineering practice it is recommended to increase the input value specified for the social distancing in order to demonstrate the compliance with code requirements and include in the assessment the sensitivity to group movements.

- The model input data should be calibrated with environment/occupants specific data.

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Thank you

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