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Toward an Application of Graph Structure Analysis to a MAS-based model of Proxemic Distances in Pedestrian Systems

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Outline

MAS-based pedestrian simulations

Scope:

To introduce a MAS-based model for pedestrian simulation of multicultural crowds in which cultural and proxemic aspects can be naturally modeled over an explicitly defined spatial representation.

Proxemic theory

The model proposed explicitly represents the concept of **perceived distance**.

The perceived distance is the different perception of the same spatial distance by pedestrian with different cultural attitudes.

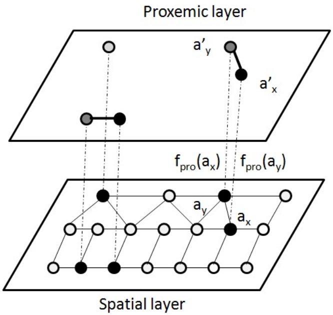
Factors that influence the perceived distance are the situation in which the pedestrian is, posture, sex identifiers, touching code, thermal code, etc.

Two Layered Model

We use a two-layered structure:

- A **spatial layer** to describe the environment in which the pedestrian simulation is performed. The space is modeled as an undirected graph of sites where the edges represents the accessibility relation between them.

- A **proxemic layer** to represent the dynamic perception of neighbouring pedestrians according to a proxemic distance.



Proxemic Layer

The proxemic layer contains a set of proxemic agents that are in a one-to-one relation with the agents of the spatial layer.

The proxemic agents are heterogeneous: every agent α has an associated type $\tau_i \in \{\tau_1, \ldots, \tau_n\}$.
Different types of agent represent different attitudes of a multicultural crowd.

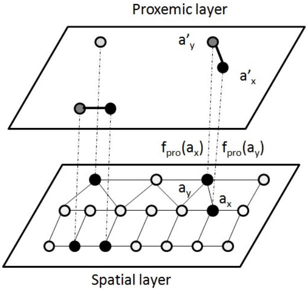
Each type τ_i is associated with a perception function $perc_i$ and a social attitute sa_i.

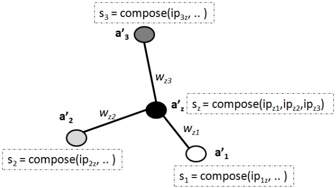
Communication between spatial and proxemic layers

When two agents are "close" in the spatial layer they notify the agents in the proxemic layer.

Proxemic agents evaluate the information received using their perception function and social attitude.

The state of the agent is updated using a composition of its perceptions of the other agents.





Proxemic Networks

It is possible to build a weighted undirected graph on the proxemic layer. We want to add an edge between two agents when they are close and the perceive each other in a different way. The weight of the edge should be bigger when the two perceptions are very different.

Formally:

1. For all pairs of agents α_x, α_y consider how α_x perceives α_y (ip_{xy}) and how α_y perceives α_x (ip_{yx}).
2. If $w_{xy} = |ip_{xy} - ip_{yx}|$ is strictly positive add the edge (x, y) with weight w_{xy}.

Network Analysis: motivations

The study of the network derived from the proxemic layer could be useful to identify crowd structures of interest.

We have defined two such structures:

- **Borders**. Inside a crowd, there are groups of people that act as single entity. The identification of these groups is based on finding the border between the group and the other pedestrians.
- **HSL-groups**. A "group of groups" where the different relations between the composing elements can be used to infer its behaviour.

Borders: definition (I)

The meanings of the property that we required are the following:

1. The group must be homogeneous.
2. Agents near the group (but outside it) must be of a different kind.
3. Agent in the border must perceive itself as an element of the border.
4. The agents inside the group must be isolated from the outside.
5. The agents inside the group must form a spatially connected entity.
6. We must take the group as a whole, not only parts of it.

Borders: definition (II)

We want to divide the set V of vertex in the proxemic network into two parts: the group (A) and everything else (B). Inside these subsets we want to identify the "contact surfaces" $\mathcal{A} \subseteq A$ (called **inner border**) and $\mathcal{B} \subseteq B$ (called the **outer border**). The property that we require for A, $\mathcal{A}$, B and $\mathcal{B}$ are the following:

1. All the agents of A must be of the same type.
2. All the agents of $\mathcal{B}$ must be of a type different from the agents of A.
3. All the agents of $\mathcal{A}$ must have an edge to an agent of $\mathcal{B}$ and vice versa.
4. The agents of $A \setminus \mathcal{A}$ must degree 0.
5. The projection of A on the spatial layer must be a connected subgraph.
6. Both $\mathcal{A}$ and $\mathcal{B}$ must the maximal w.r.t. the previous properties.

Borders: properties

Since edges in the model are weighted, it is possible to compute the **average weight of the border** $\mathcal{W}_{\mathcal{A},\mathcal{B}}$.

Every node also has a level of comfort. If we associate to every level a meaningful numerical value we can compute the **mean comfort of the inner border** C_{inner} and the **mean comfort of the outer border** C_{outer}.

We can recognize four possible conditions in which a group can be:

Inner	Outer	$\mathcal{W}_{\mathcal{A},\mathcal{B}}$	$\mathcal{C}_{\text{inner}}$	$\mathcal{C}_{\text{outer}}$	Reaction
☹	☹	small	small	small	move away
☺	☺	small	big	big	open group
☺	☹	big	big	small	outer agents: move away
☹	☺	big	small	big	group: move away

HSL-groups: motivation

In crowds there are groups of people that are not compact. In fact we can have that those "groups of groups" can be very different in their behaviour.

To identify these groups we work in the proxemic layer. We add an edge between two agents when they are of the same type and also close to each other. This graph can be easily constructed from the proxemic network.

We can see an HSL-group as two or more groups (as defined by the borders) that interact.

HSL-groups: properties

An interesting property of HSL-group is the cohesion, identified by the mean length of the shortest paths. We expect different behaviour when the cohesion is different:

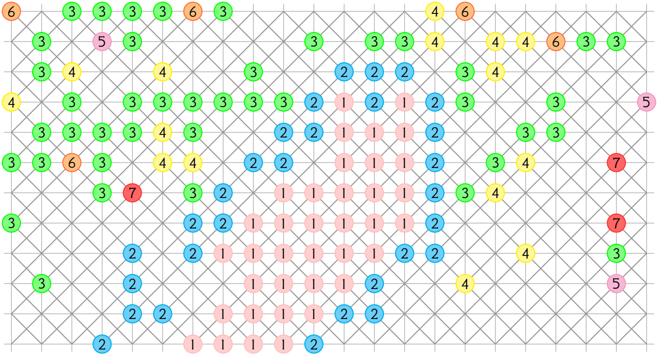
- **Small cohesion**. In this case the communication between groups is difficult. We expect the HSL-group to dissolve.
- **High cohesion**. In this case the information can be passed between group in an easy way. We expect the group to act as a single entity.

Borders: Example

From an image of the pilgrimage towards Mecca where there is a separation between pedestrian that is clearly visible. We will show how the concept of border can be used to identify this separation.

Borders: Spatial Layer

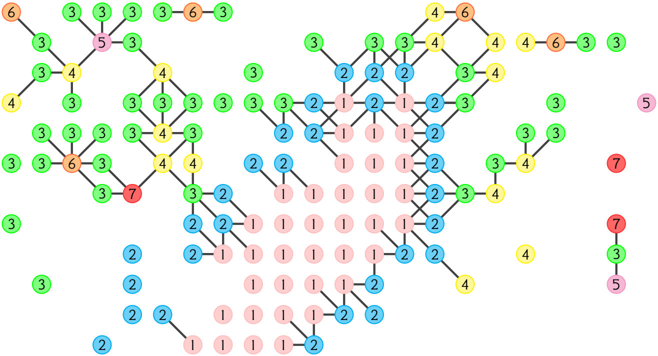
The spatial layer. Different types of agent are represented by different colors.



Color	pink	blue	green	yellow	magenta	orange	red
Type	W. alone	M. guards	M. adults	W. adults	M. elderly	W. elderly	M. westerners

Borders: Proxemic Layer

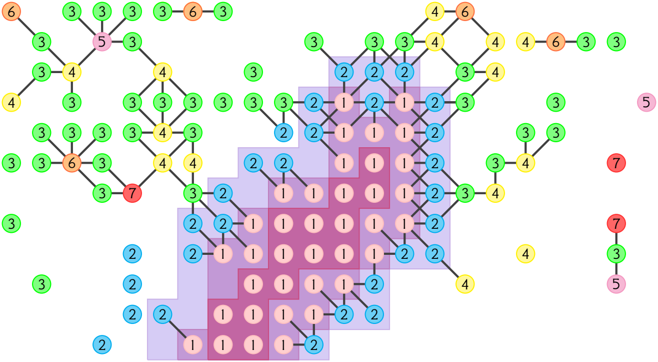
The proxemic layer. We used a quite small neighbourhood size.



Color	pink	blue	green	yellow	magenta	orange	red
Type	W. alone	M. guards	M. adults	W. adults	M. elderly	W. elderly	M. westerners

Borders: recognition

The outer border (light violet), the inner border (violet) and the internal part of the group (dark violet).



Color	pink	blue	green	yellow	magenta	orange	red
Type	W. alone	M. guards	M. adults	W. adults	M. elderly	W. elderly	M. westerners

Conclusions and future works

Conclusions:

- We have introduced a MAS-based model for pedestrian dynamic.
- We have defined some structure of interest that can be recognized in the proposed model.

Future works:

- An implementation of this model.
- As many experiments as possible.

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Thank you

for your attention

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