ODD - Egress

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1 Purpose and patterns

The purpose of the model is to simulate non-urgent egress of visitors from mass gathering events happening in real-life urban public open spaces (e.g., squares, plazas), evaluating the impact of different built environments, hypothetical exit choosing behaviors of the visitors, crowd density scenarios and number of individuals in a group in the egress times, the main values obtained from the model. The model should aid decision-makers to choose the appropriate public spaces for a specific event, and to timely deploy public utility teams (e.g., cleaning, emergency, security).

The patterns we believe our model must be able to reproduce are the following:

Pattern 1: Relation between built environment layout and egress times. The layout of the obstacles and exits, total space geometry, the total available exit width, as well as the shape of the open space should affect egress rates. E.g., a close environment with a single small exit should lead to larger egress times than the same environment, but with more, wider exits.

Pattern 2: Relation between egress choosing behavior and egress times. Chaotic exit choosing should lead to higher egress times, as a greater number of collisions between erratic pedestrians should overall reduce the egress rates. Whereas, an orderly behavior should minimize collisions, smoothing the flow of pedestrians towards the available exits.

The patterns are based on assumptions derived from rational thinking, and need further empirical study to validate.

2 Entities, state variables, and scales

2.1 Entities

There are 2 entity types partaking in this model: (i) environment entities and (ii) pedestrian agents (the model entity is not considered). The environment entities are composed of the GIS polygonal representations of the buildings that surround and delimit the open space, as well as the buildings inside the space (e.g., statues, monuments), the usable area of each public open space, which is modeled as a polygon enclosed by the surrounding buildings or borders with bodies of water (e.g., river boundaries, coast), where pedestrians will randomly spawn, and the exit geometries, which are modeled as polygons that cover the entrances to the exiting streets, bordering the open space polygons. The pedestrian agents represent the visitors of the event, who egress from it.

These were the chosen entities, as the model is intended to assess the impact of the interactions between these entities have on egress times.

2.2 State variables

The environment entities are static and passive, and serve as limits for the pedestrian agents. Thus, they do not possess state variables. The pedestrian agents inherit the attributes and behaviors from the Pedestrian skill from the GAMA 1.8.2 Alpha build, which is not documented at the moment this document was written (can be consulted in the source code) (COLOCAR NOUTRO LADO OU TIRAR). The only state variables added on top of the skill, belonging to the pedestrian agents, are *exit_target*, holding a reference of the chosen exit entity, and *speed*, of type *km/h* , representing the unrestricted pedestrian walking speed, in normal conditions.

2.3 Scale

This ABM represents both space and time. The space is two-dimensional and finite, and is represented in a continuous scale. The dimensions of the environment depend on the represented open space. The elementary unit of time represented in the model is 1 second, which is the value of a time step in the simulation. The scales were chosen in a compromise between realism (the more continuous space and time are, the more realistic the model is) and simulation execution time.

3 Process overview and scheduling

The whole process and scheduling are fairly simple. In the start of a simulation, the model agent spawns a number of pedestrians in the open space, equal to the defined number of pedestrians for the scenario. After the spawn, the pedestrian agents execute the exit choice submodel, depending on the scenario, setting their destinations. Then, at each simulation time step, and in an undefined order, each agent activates the desired velocity computation submodel, and changes position accordingly. When the distance between an agent and its chosen exit entity is lower that the defined distance threshold (COLOCAR EM INITIALIZATION), it is removed from the model. A simulation ends when the number of active pedestrians reaches 10% or less of the number of spawned pedestrians.

4 Design concepts

4.1 Basic principles

The model is set over the concept of pedestrians attending a mass gathering event, and leaving the venue after the end of the event, without urgency. It appears this particular system has not been yet addressed in the state of the art. Some studies and ABM have been developed addressing egress flow dynamics similar to the ones described in the model, but represent a much smaller scale (usually room-scale), and different contexts [**?**]. At the agent level, the interactions between the crowd members follow the established Social Force Model (SFM) first presented by Helbing et. al. [**?**]. The social force model represents repulsive and attractive forces that act upon the psychology of the pedestrians, dictating an actual velocity to be chosen by a pedestrian, in order to avoid obstacles/other pedestrians and reach the desired destination. The model tries to approximate reality by setting a continuous space, a reasonably fine-grained time scale, and the microscopic representation of all individual pedestrians.

4.2 Emergence

The main emergent phenomenon obtained from the model is the egress time. It represents the time that the pedestrians take to leave the open space, and it emerges from the interaction between the pedestrian agents, in form of social forces, and their spatial displacement towards the chosen exit. The model does not include imposed results.

4.3 Adaptation

The pedestrian agents adapt their desired velocity during each step according to the social forces acting upon them, which come from the other neighbouring agents.

4.4 Objectives

The adaptation of the agents do not have clear decision-making objectives. The agents move towards the chosen exit.

4.5 Learning

Learning is not implemented in this model.

4.6 Prediction

Prediction is not implemented in this model.

4.7 Sensing

The sensing is implemented by the Pedestrian skill built in GAMA. Pedestrian agents have access to the location and instantaneous velocity of their neighbours, in order to calculate the social forces.

4.8 Interaction

The main interaction between agents is through the calculation of the social forces they apply to each other.

4.9 Stochasticity

The stochasticity is applied in this model in the processes of pedestrian spawning, exit choosing behavior and pedestrian normal speed definition. The pedestrians are spawned inside the open space polygon with uniform random distribution, the exits are chosen with different types of random distributions in some scenarios, and the speed of the pedestrians follows a normal distribution.

4.10 Collectives

Collectives are not implemented in the model.

4.11 Observation

The only observed variables during and after the model are the count of the current pedestrians in the model (the ones who did not egress at a given time step), and the number of pedestrians who left at each time step, which are calculated dynamically by counting the agents.

5 Initialization

The model is intended to simulate multiple environmental and behavioral scenarios. Each scenario is defined in an experiment, which in GAMA represents an execution of a model, being initialized with key values to represent the scenario. The environment is built from shapefiles containing relevant geometries. For a given open space, 3 files must be passed as parameters to parameters are *buildings_file, targets_file and start_area_file* which represent the shapefiles with the geometries of, respectively, the surrounding and internal buildings of the open space, the geometries representing the available exits and the area in which the pedestrians will spawn.

The building geometries comes from the OpenStreetMap (OSM) initiative, a volunteer-based mapping project to map the entire world, offering the geographic data for free use. This data source was chosen due to its growing support, free-use data and wide and detailed coverage of accurate geographical data across the world. The exit and start area geometries are created manually with the QGIS software, using as reference the data from OSM.

nb_people is a parameter representing the number of pedestrians that will spawn in the simulation.

distance is a parameter representing the minimum distance between pedestrians and exits.

The pedestrian agents are initialized with a normal unrestricted speed of 1.34 meters/second, used in early simulations of the SFM presented by Helbing et. al. Their initial positions are randomly initialized using an two-dimensional uniform distribution inside the start area polygon.

6 Input data

The model does not use input data to represent time-varying processes.

7 Submodels

The submodels in this model are implemented in the behavior of the pedestrian agents. They consist on the (1) exit choosing behavior and (2) desired velocity computation.

7.1 Exit choosing behavior submodel

The exit choosing process depends on the selected general behavior for the simulation. There are 3 hypothetical exit choice behaviors: *Closest*, where the agents chose the closest available exit, *Random*, where the agents choose a random exit with uniform distribution, and *Weighted Random* where the exit choice is a random distribution weighted by the exit width (i.e., a wider exit is more likely to be chosen than a narrower one, proportional to the width). The choices are activated right at spawn, before the simulation begins. In each behavior, the *exit_target* variable is assigned using the selection procedure.

7.2 Desired velocity computation submodel

The social force assessment, and subsequent desired velocity computation and walking process rely on an implementation of the classic SFM by Helbing et. al, extended to adopt group behavior, developed by Moussaïd et al.