User Guide

User Guide for Panic Simulator 1.0

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Introduction: The aim of the Panic Simulator is to simulate features of human escape panic in crowded environments with a single exit e.g. baths, discotheques, stadia, lecture halls or rooms in general. The graphical user interface enables an intuitive and fast handling in all settings and features of the Panic Simulator and allows convenient research in the fields of panic behavior and room architectures. This user guide tries to help getting the Panic Simulator started and explains all features of the graphical user interface.

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1 Getting started

First make sure you have a running MATLAB R2013A or R2013B version or higher on your personal computer. Then download the PANIC SIMULATOR from the *www.studycas.com* webpage. Open a new MATLAB instance and browse to the downloaded *PanicSimulator* folder. Run the *PanicSimulator.m* file. You can do it in one of the following three ways:

- open the *PanicSimulator.m* file and press *F5*
- open the *PanicSimulator.m* file and click the *Run* button
- type 'PanicSimulator' in the Matlab comand window and press *Enter*

The main window of the PANIC SIMULATOR should now open. Please feel free to explore the PANIC SIMULATOR on your own or follow the Quick start (section 2). You can also find detailed descriptions of all provided features of the PANIC SIMULATOR in the following sections of this user guide.

2 Quick start

This section gives a short overview of the main window of the PANIC SIMULATOR and shows a first example including the most important features. Open the PANIC SIMULATOR (see section 1). The main window of the PANIC SIMULATOR provides the so-called arena (white mapped area) with a default setting of so-called agents (green dots), walls (blue lines) and an exit (green/red line). In addition a time window is included at the top, displaying the time in seconds. The three buttons on the left are:

- *Start/Stop the Panic* button (exit/stop symbol): starts the panic simulation or stops the panic simulation at any time
- *Capture the Panic* button (movie symbol): captures an *.avi* movie of the panic simulation
- *Reset* button (green circle symbol): resets the arena with current parameters

The menu provides both a *File* section to quit the *Panic Simulator* and an *Options* section including the options *Arena Editor*, *Automate* and *Settings*. The basic characteristics of these features are:

- *Automate*: statistic tool allowing automated variable sweep, averaging over multiple runs and data visualization
- *Arena Editor*: powerful editor to adjust and manipulate the environment by creating, removing or modifying the properties of agents and the arena
- *Settings*: management of the properties for *Agents* (simulated individuals), *Arena* (simulated environment), *Equation of motion* (model of pedestrian's behavior) and *Plot* (speed of simulation)

In order to get an impression of what the PANIC SIMULATOR does, please press the *Start the Panic* button. The agents (green dots) will now move towards the exit (green/red line) trying to escape. This might lead to some accumulation of the agents near the exit. At the same time the agents are repelled from the walls (blue lines) as well as they are repelled from each other. You can stop the simulation at any time by pressing the *Start the Panic* button for a second time. Once all agents passed the exit the simulation stops automatically and the individual exit times of the agents are plotted in a new window.

In the next step we change some of the simulation parameters. First open the *Settings* window by clicking *Options* $\mapsto$ *Settings*. The settings window will pop up. The parameters are grouped in *Agents*, *Arena*, *Equation of motion* and *Plot*. It is recommended to read section 7 before changing the *Equation of motion* parameters. As a first example set the *Desired velocity* up to 3 m/s, set

Time between arena refreshs to 0.1 s and enable *Show pressure* and *Plot in real time*. Setting the *Size in x* as *Automatic* ensures that the arena is large enough to contain all agents. Next click *OK* and start the simulation again. The agents are now moving with a desired velocity of 3 m/s. Thus the agents try to leave the room very fast which results in a panic behavior of the agents. For a deeper understanding of the desired velocity parameter v_{des} please see section 7. Enabling *Show pressure* colors the agents form green to red depending on the pressure they are exposed to. For a full description of the option *Settings* please see section 4. In the next step we will modify single agents and walls.

To study different geometries of the room and different start configurations of the agents, the *Panic Simulator* provides a powerful so-called *Arena Editor*. Open the *Arena Editor* by clicking *Options* $\mapsto$ *Arena Editor* in the main window of the PANIC SIMULATOR. A new window containing an exact copy of the current arena will pop up. Choose the *New column* tool in the toolbar and click the left mouse button on an empty place in the arena. A new column will appear. Switch your tool and take the *Modify object* tool. Now move the column with your left mouse button wherever you want. Then click with the left mouse button on an existing agent which is near the exit. Go to *Agent Properties* and change the agent's *Radius* to 0.6 m. Click *OK* and start the simulation again. The modified agent doesn't fit through the exit and will change its color because of the pressure it experiences due to the other agents. Stop the simulation by clicking *Stop the Panic* and open the arena editor. Choose the *Modify object* tool and click on the modified agent with the right mouse button so it will disappear. Press *OK* and continue the simulation by clicking *Start the Panic*. For a full description of the *Arena Editor* please see section 5.

3 Main window of the Panic Simulator

In this section we give a short overview of the main window of the PANIC SIMULATOR. The main window of the PANIC SIMULATOR provides the so-called arena (white mapped area) with a default setting of so-called agents (green dots), walls (blue lines) and an exit (green/red line). In addition a time window is included at the top, displaying the time in seconds. The three buttons on the left and the menu are explained in table 1.

Table 1: Panic Simulator main window properties

Menu	
File $\mapsto$ Quit	quit the PANIC SIMULATOR
Options $\mapsto$ Automate	statistic tool allowing automated variable sweep, averaging over multiple runs and data visualization, see section 6
Options $\mapsto$ Arena Editor	powerful editor to adjust and manipulate the environment by creating, removing or modifying the properties of agents and the arena, see section 5
Options $\mapsto$ Settings	management of the properties for *Agents* (simulated individuals), *Arena* (simulated environment), *Equation of motion* (model of pedestrian's behavior) and *Plot* (speed of simulation), see section 4
Buttons	
Start/Stop the Panic	exit/stop symbol, starts the panic simulation or stops the panic simulation at any time
Capture the Panic	movie symbol, captures an *.avi* movie of the panic simulation
Reset	green circle symbol, resets the arena with current parameters

4 Settings

The *Settings* option provides an overview of the key variables used in the simulation and allows the user to modify these variables in a clear way. Therefore the variables are grouped in parameters referring to *Agents* (two dimensional simulated individuals), *Arena* (simulated environment, e.g. room), *Equation of motion* (simulated agent's behavior) and *Plot* (simulation speed and display rate). The individual parameters and their default values are explained in table 2.

Table 2: Options ↦ Settings: parameter, description, default value

Agents	two-dimensional simulated individuals	
Number of agents*	quantity of agents	50
Desired velocity [m/s]	velocity each agent tries to achieve, low desired velocities result in calm behaviour, high desired velocities result in panic behavior	1
Density [kg/m^2]	two-dimensional mass density of the agents implying small (big) agents to be less (more) massive	350
Show pressure	shows the pressure experienced by each agent in a color code, green (no pressure) → yellow (acceptable pressure) → orange (uncomfortable pressure) → red (critical pressure)	on
Positions on reset*	spatial positions in two-dimensional space of all agents, either use random distribution of agents or load preset of agent's positions from file	Random
Arena	two-dimensional spatial environment	
Size in x [m]*	spatial length of the arena in x-direction (horizontal), either use automatic calculation of an appropriate length in x-direction or set manually	Automatic
Size in y [m]*	Spatial length of the arena in y-direction (vertical)	20
Wall positions on reset	spatial positions of the walls building the architectural environment, the standard architecture provides two vertical walls with a single exit in the middle, use standard wall configuration or load preset of wall positions from file	Standard
Door width [m]*	width of the exit referring to standard wall positions on reset	1
Angle of wall [°]*	angle of the two walls referring to standard wall positions on reset, 0° correspond to vertical walls, 90° correspond to horizontal walls	0
Equation of motion	details to the equation of motion please find in section 7	

A [N]	strength of repulsion between agent-agent and agent-wall, small A implies small repulsive forces, large A implies large repulsion forces	2000
B [m]	characteristic length of repulsion forces between agent-agent and agent-wall	0.08
k $\left[\frac{\text{kg}}{s^2}\right]$	determines the obstruction effects in case of physical interaction between agent-agent and agent-wall in normal direction	120000
kappa $\left[\frac{\text{kg}}{\text{m}\cdot\text{s}}\right]$	determines the obstruction effects in case of physical interaction between agent-agent and agent-wall in tangential direction	240000
tau [s]	acceleration time in which agents adapt their velocity	0.5
Plot	rate of frame update	
Time between arena refreshes [s]	time between visualization refreshes of the arena, small time steps result in smooth agent movement, large time steps results in enhanced simulation speeds	0.5
Plot in real time	check-box to plot in real time, set 'on' to display simulation and agent movement in real time, set 'off' to run simulation with maximum speed	off

All parameters with * will reset agents and walls in case of change. The *File* option in the *Settings* menu allows saving the current configuration of the settings as well as it allows loading stored setting configurations from file. Press *OK* to save the current configuration of settings or click *Cancel* to discard your changes and return to the main window of the Panic Simulator.

5 Arena editor

The *Arena Editor* is a powerful editor to adjust and manipulate the arena's environment by creating, removing or modifying the properties of agents, walls and the exit. To open the arena editor click *Options* in the menu of the main window of the Panic Simulator and choose *Arena Editor*. An exact copy of the existing arena will open in a new window which is the arena editor. The *File* option in the menu of the arena editor allows saving the current configuration of agents and walls separately as well as it allows loading any stored configuration of agents and walls from file. The *Edit* option in the menu helps to clear the arena from all agents or walls at once.

The toolbar of the arena editor provides seven useful tools to edit the arena for your personal needs. Depending on the chosen tools the corresponding properties and object information become enabled and can be readout or manipulated at the left side of the window. For better survey the available information is grouped in *Agent Properties*, *Column Properties* and *Object Info* and is shortly explained in table 3, whereas table 4 explains the tools provided by the arena editor's toolbar.

Table 3: Options ↦ Arena Editor: Information window

Agent Properties	
Radius [m]	radius of the selected agent
Velocity [m/s]	absolute value of the agent's velocity
Direction [°]	direction of the agent's velocity, angle of 0° corresponds to the positive x-direction (right) and goes counter clockwise, 90° positive y-direction (up), 180° negative x-direction (left), 270° negative y-direction (down)
Column Properties	
Radius [m]	radius of the selected column
Object Info	
ID	identification number of the selected object
X	spatial position of the object in x-direction
Y	spatial position of the object in y-direction

Table 4: Options ↦ Arena Editor: Toolbar

Modify Object	allows to select any object (agent, column, wall, exit) and enable their properties, move object with left mouse button, delete object with right mouse button
New agent	click left mouse button to place new agent
New wall	click left mouse button and drag to draw new walls
New column	click left mouse button to place new column
Line of columns	click left mouse button and drag to draw new line of columns
Circle of columns	click left mouse button and drag to draw new circle of columns
Draw a new exit	click left mouse button and drag to draw new exit, agents enter the exit at the green side and leave the exit at the red side

6 Automate

The *Automate* option is a handy and time saving statistic tool allowing automated variable sweeps, averaging over multiple runs and supports data visualization. To open the *Automate* option click *Options* in the menu of the main window of the Panic Simulator and choose *Automate*. The *File* option in the menu of the automate statistic tool allows saving the current automate settings

as well as it allows loading stored automate settings from file. The *Automate* option provides ten different setting parameters that can sweep automatically. All the parameters of the automate feature are listed and explained in table 5.

Table 5: Options ↦ Automate

Parameter to change	parameters that can be changed automatically are: desired velocity, wall angle, number of agents, door width, surface density of agents, A, B, k, kappa, tau (for explanation of these parameters please see section 7)
Min	minimum value of the selected parameter to change
Max	maximum value of the selected parameter to change
Step size	size in which the parameter to change is increased every step, if difference between max and min value divided by step size is no integer, the parameter sweep does not reach the exact maximum value
Number of averages	quantity of runs with same parameters but random agent distribution, finally the average over all runs is calculated automatically

After the automated parameter sweep is completed the statistic data is automatically plotted in a new figure displaying the averaged total exit time of all agents versus the *Parameter to change*. In addition the check-box *Plot individual exit times for all agents* can be activated resulting in a statistic plot of all agents' individual exit times. Click *OK* to confirm the current settings or click *Cancel* or *Close* to discard the settings and return to the main window of the Panic Simulator.

7 Equation of motion

This section shortly introduces the simulation model of the agent's behavior. For convenience the so-called agents represent the pedestrians as circles in a two dimensional space. The agents are defined due to their coordinates $\vec{r}_i$, velocities $\vec{v}_i$ and radii r_i which results in five parameters per agent for the two dimensional model. Variation of the agent's radii ensures a break of symmetry in the model. The Panic Simulator uses randomly generated radii ranging from 25 to 30 cm referring to empirical statistics about average shoulder breadths [2], as well as it includes a constant surface density for all agents. The default value for the surface density of 350 kg/m^2 leads to masses between 60 and 100 kg per agent. Furthermore each agent i with mass m_i experiences a force $\vec{F}_i$ such that the following equation of motion has to be solved:

$$m_i \vec{a} = \vec{F}_i \tag{1}$$

The forces $\vec{F}_i$ are calculated due to the model used by Dirk Helbing et al. [1]. Therefore the force acting on agent i is

$$\vec{F}_i = \frac{m_i \cdot v_{\text{des}}}{\tau} (\vec{e}_i - \vec{v}_i) + \sum_{j \neq i} \vec{f}_{ij} + \sum_w \vec{f}_{iw}. \tag{2}$$

The first term results of an agent's wish to reach a given desired velocity v_{des} along the normalized direction towards the exit $\vec{e}_i$ within a certain characteristic time τ. We easily see that a high desired velocity results in a high force towards the exit which means, that high values of the desired velocity are directly correlated to the panic behavior of the agents. For this reason the parameter of choice which allows to study situations under different panic behaviors is the desired velocity v_{des} in equation (2). The second part of equation (2) is the sum of all interaction forces $\vec{f}_{ij}$ between two agents i and j. The third term sums the interaction forces $\vec{f}_{iw}$ between agent i and the walls w.

$$\vec{f}_{ij} = \left[Ae^{(r_{ij}-d_{ij})/B} + kg\left(r_{ij}-d_{ij}\right) \right] \cdot \vec{n}_{ij} + \kappa g\left(r_{ij}-d_{ij}\right) \Delta v_{ji}^{t} \cdot \vec{t}_{ij} \tag{3}$$

$$\vec{f}_{iw} = \left[Ae^{(r_{i}-d_{iw})/B} + kg\left(r_{i}-d_{iw}\right) \right] \cdot \vec{n}_{iw} + \kappa g\left(r_{i}-d_{iw}\right) \left(\vec{v}_{i}\vec{t}_{iw}\right) \cdot \vec{t}_{iw} \tag{4}$$

The agent-agent interaction force consists of a long range repulsive force $A \cdot \exp\left[\left(r_{ij}-d_{ij}\right)/B\right] \cdot \vec{n}_{ij}$ which keeps the agents away from each other. Additionally a repulsive body force $kg\left(r_{ij}-d_{ij}\right) \cdot \vec{n}_{ij}$ and a tangential sliding friction force $\kappa g\left(r_{ij}-d_{ij}\right) \Delta v_{ji}^{t} \cdot \vec{t}_{ij}$ are also included but only considered if the two agents i and j do touch each other. Therefore the function $g\left(x\right)$ is equal to zero for center of mass distances larger than the sum of the agent's radii ($d_{ij} > r_{ij}$) and otherwise equal to its argument x. Here $r_{ij} = r_i + r_j$ is the sum of the radii, $d_{ij} = \|\vec{r}_i - \vec{r}_j\|$ is the center of mass distance of the two agents i and j and $\vec{n}_{ij} = \left(n_{ij}^{1}, n_{ij}^{2}\right) = \left(\vec{r}_i - \vec{r}_j\right)/d_{ij}$ is the normalized vector pointing form agent j to agent i. In addition is $\vec{t}_{ij} = \left(-n_{ij}^{2}, n_{ij}^{1}\right)$ the normalized vector in tangential direction and $\Delta v_{ji}^{t} = \left(\vec{v}_j - \vec{v}_i\right) \cdot \vec{t}_{ij}$ the tangential velocity difference of the two agents. The interaction forces of the agents with the walls $\vec{f}_{iw}$ are given in the same way as the agent-agent interaction forces with d_{iw} as the distance of agent i from the wall w, the normalized direction perpendicular to the wall $\vec{n}_{iw}$ and the tangential direction vector $\vec{t}_{iw}$.

[1] Dirk Helbing, Illes Farkas, Tamas Vicsek, *Simulating dynamical features of escape panic*, *Nature* **407**, 487-409 (2000)
[2] U.S. Department of Health and Human Services, Centers for Disease Control and Prevention National Center for Health Statistics, *Anthropometric Reference Data for Children and Adults*, *CDC* **11**, 249 (2009)

8 Agents-Matrix

The agents representing the pedestrians are defined due to their coordinates $\vec{r}_i$, velocities $\vec{v}_i$ and radii r_i which results in five parameters per agent for the two dimensional model. The five parameters per agent are arranged in a so-called agent-matrix. Each row of the agents-matrix contains the parameters for one agent so that the resulting agents-matrix has the dimensions $(\#\text{agents}) \times 5$ where #agents is the number of agents. The agents' position in x-direction (horizontal) and y-direction (vertical) is stored in the first and second column. The third and fourth column of the agents-matrix contain the agents' velocity in x- and y-direction whereas the fifth column stores the agents' radius. The values of the position and radius are assumed in units meter while the values for the agents' velocity is assumed in meter per second. In order to create your own agents-matrix either use the *Arena Editor* (section 5) or build an agents-matrix and save it as a MATLAB variable. To load the agents-matrix simply choose the *Settings* or *Arena Editor* option in the PANIC SIMULATOR.

9 Panic Simulator GUI overview

This section provides screen shots of the PANIC SIMULATOR's graphic user interface (GUI) involving the main window of the PANIC SIMULATOR, the arena-editor window, the settings window and the automate window.

10 Annotations

- Changes in locations of the folders *icons*, *videos* or *presets* lead to undefined data paths and are hence forbidden.

- Save your settings as *defaultSettings.m*-file in the *preset*-folder to reload your settings at every restart of the program.

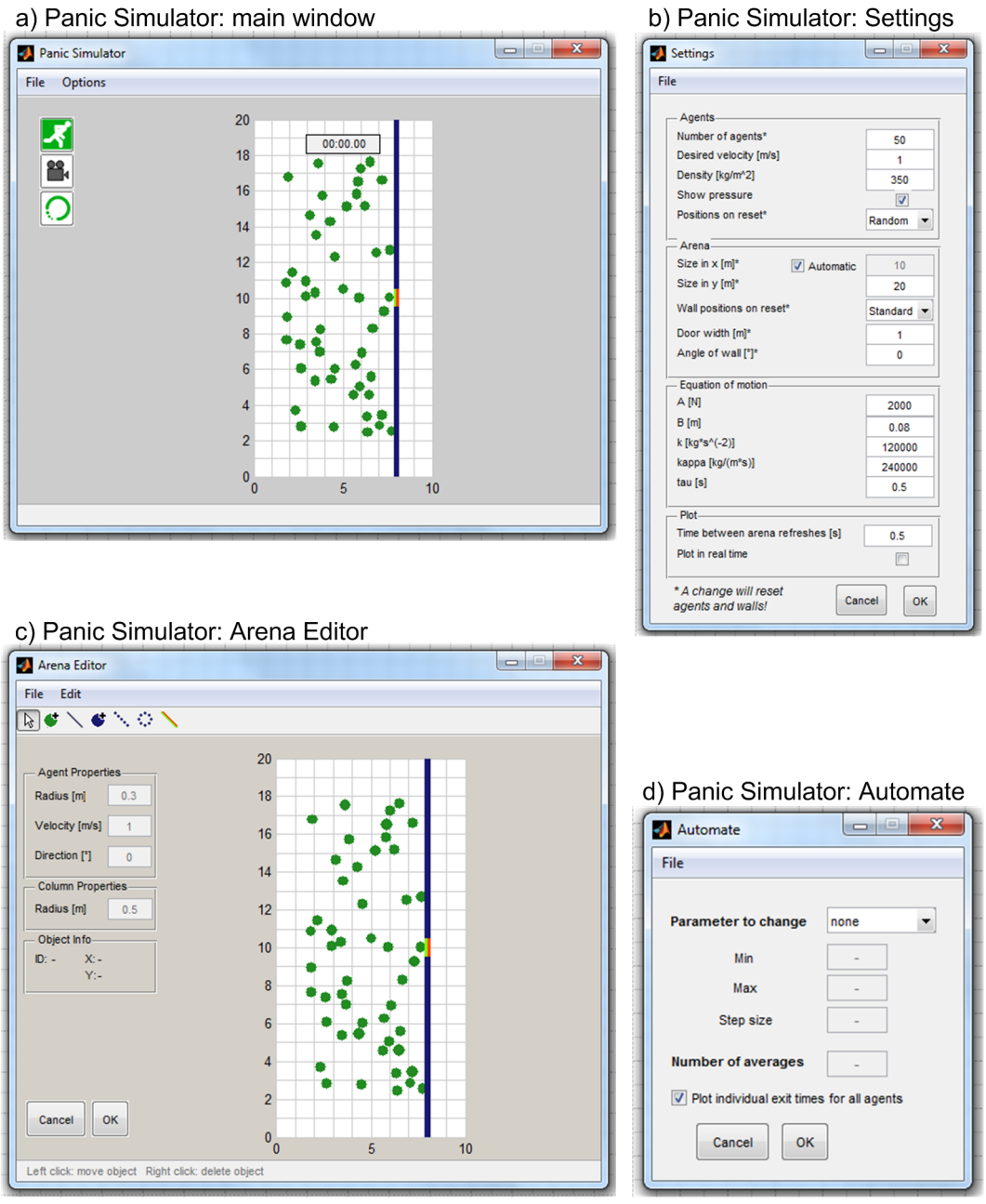

Fig. 1: Panic Simulator GUI overview: a) main window, b) settings, c) arena editor, d) automate