**EVALUATING FORCE-BASED SIMULATION MODELS BY PEDESTRIAN TYPE**

**A DEMAND FOR NOVEL DATA ACQUISITION APPROACH**

**Summary**

Force based simulation models have been used widely to simulate crowd’s micro level. Measuring the effect of model’s parameters is important to gain a better understanding on observations including escape time, flow rate, and reproducibility. This study uses Nomad and social force models to investigate crowd observations when varying crowd population with different pedestrian ages (young, adult, and elderly people) in two scenarios of unique and bio moving direction. It aims to raise a need of novel data acquisition approach to distinguish pedestrian type when simulating crowds at difference pedestrian type-oriented venues rather than using the same parameters for interchangeable pedestrians detected by camera-based capability.

1. **Introduction**

Crowd simulation plays an important role in quantitative crowd dynamics understanding and layout design assessment especially in crowd disaster (**Helbing, 2014)**. In microscopic level, the motion of each individual *p* is defined by Langevin equation:

|  |  |
| --- | --- |
|  | (1) |

where integrating the forces acting on *p* and captures random influence and uncertainty. The forces comprise subject’s desired acceleration force and repulsive forces being constituted by either or both of neighbour interaction and obstacle repulsion at time *t*. Nomad model **(Hoogendoorn, 2003)** and social force model **(Helbing, 1995)** recently attract more studies when they are efficient to simulate motion base cases and self-organization phenomena as mentioned by the latest survey in the field **(Duive and Hoorgendon, 2013)**. Each of above two models has possessed a long-life modification period in order for simulating the additional factors affecting individual’s acceleration or being easier towards calibration process. Therefore a huge number of variants increase by the time by their original authors. Main chronological variants of each model are summarized briefly below:

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Author** | **Model-based** | **Main contribution** |
| 2003 | Hoogendoorn, Bovy | Nomad | Original version of Nomad Model |
| 2009 | Campenella, Hoogendoorn, Daamen | Nomad | Add an extra repulsive force created by opposite flows |
| 2012 | Daamen, Hoogendoorn | Nomad | Omit obstacle force for calibration |
| 1995 | Helbing, Peter Molnar | Social-force | Original version of Social Force |
| 2000 | Helbing, Farkas, Vicsek | Social-force | Add Friction and Velocity dependence |
| 2005 | Helbing, Buzna, Johansson, Werner | Social-force | Add angular component on interaction force |
| 2007 | Johansson, Helbing, Shukla | Social-force | Add angular component on interaction force |
| 2010 | Moussaid, Helbing, Theraulaz | Social-force | Add Group behaviour effects |

**Table 1**. Nomad and Social Force-based variants

In this study, we only select standard variants including **(Daamen and Hoogendoorn, 2012)** and **(Johansson, Helbing, Shukla, 2007)** for our study’s purpose since they were calibrated by actual data in above author’s lab experiment. Details of variants used in this work are represented as follows:

* 1. **Nomad Model**

Nomad model **(Daamen and Hoogendoorn, 2012)** is an agent-based model that predicts walking acceleration of a pedestrian as a function of the free velocity , the current speed , the position , and distance between pedestrians *p* and *q* as follows:

|  |  |
| --- | --- |
|  | (2) |
| = | (3) |

where denotes the set of pedestrians who are standing in front of pedestrian *p* (checked by the constraint ) and where

|  |  |
| --- | --- |
|  | (4) |

and

|  |  |
| --- | --- |
|  | (5) |

and

|  |  |
| --- | --- |
|  | (6) |

where stands for desired walking direction pointing from the initial position of pedestrian *p* to the target (exit door). The model has four pedestrian-specific parameters that need to be set in simulation environment: the free speed , the acceleration time , the interaction constants , and the interaction range .

* 1. **Social Force Model**

Social force model **(Helbing, 2000)** and **(Johansson and Helbing, 2007)** assumes that a pedestrian *p* at time *t* is trying to move with a certain desired speed in a desired direction pointing from pedestrian *p*’s current position to his target position. Therefore, pedestrian *p* tends to correspondingly adapt his actual velocity with a certain acceleration time . The acceleration time represents pedestrian *p* changes its current velocity and return to its desired velocity. Pedestrian *p*’s acceleration at time *t* also depends on repulsive forces coming from surrounding pedestrians and obstacles. The repulsive force’s directions are represented in Figure 1. The model’s formula is represented in equations (7-15).



**Fig 1**. Repulsive forces and on pedestrian *p* created by pedestrian *q* and wall γ

|  |  |
| --- | --- |
|  | (7) |
| = | (8) |

where desired speed of pedestrian *p* varies over time and given by:

|  |  |
| --- | --- |
|  | (9) |
|  | (10) |

where and are the initial desired speed and the maximum desired speed of pedestrian *p*, respectively. In social force model is constrained by constant value ***c >* 1**.

In equation (9), is considered as panic parameter model of pedestrian *p*. It illustrates how strongly pedestrian *p* aligns his preferred velocity with the motion of crowd surrounding him, given by equation (7):

|  |  |
| --- | --- |
|  | (11) |

where is computed by average actual speed in the desired direction. Equation (9) is transformed into equation (12) for the condition at time *t*=0 as the suggestion by **(Andreasen, 2010)**

|  |  |
| --- | --- |
|  | (12) |

When is going down in equation (11) as pedestrian *p* is in high density place (e.g bottle neck scenario), implies → 1 which implies → as in equation (9).

When is going up, it implies → 0, which implies → . Since > by ***c >* 1**, it means that when average velocity is going up, the desired force going down, and vice versa. When is higher than desired force has negative direction to decelerate pedestrian *p*’s actual speed.

Interaction force created by neighbour pedestrian *q* is given by equation (13)

|  |  |
| --- | --- |
|  | (13) |

where is the angle between pedestrian’s *p* velocity direction and the vector pointing from *p* to *q*, and is the distance between pedestrians *p* and *q*. is an extra weight component to emphasize whether pedestrian *p* pays attention to other pedestrians behind him, the component is given by equation (14)

|  |  |
| --- | --- |
|  | (14) |

where is angular component of the model, and set , and , implies that 1. When, it means pedestrian *p* doesn’t pay attention other people behind him. When 1, the interaction force is modified by the angular component.

The interaction force is given by equation (15)

|  |  |
| --- | --- |
|  | (14) |

To summary, the social force model comprises parameters that need to be set at initial time:

**2. State of the art in the model’s parameters extracted by camera-based capability**

This section represent calibration process of above author in finding parameters

**2.1. Nomad Model**

**Pedestrian type**

-(Daamen and Hoogendoorn, 2012) study considered the different agent’s parameter in through calibration as follows. Pedestrian types include ,(children, adults, disable –3 blind folded people, elderly people). Each type wears different colour cap. Several situations had been experimented including school, building, in peak hour. On top, there have digital camera and infrared camera to observe the LED light for trajectory tracking on each above type.

Young people: reaction time, and free desired speed higher than adult. Interaction distance shorter than adult. Interaction strength higher than adult.

Calibration is performed by likelihood maximization (same meaning with minimizing error). heterogeneity might play an important role in pedestrian behaviour.

**2.2 Social Force Model**

**Desire force**:

* 1. Camera let **desired speed is maximum speed of that pedestrian and constant** in time [Johansson, 2008]. [Cross Walking, 2014] each pedestrian has the same desired speed constant in time. It’s computed by average speed people crossing the road without disturbance with a standard deviation. In [Moore, 2011 & Mehran, 2009], treating pedestrian crowd as the collection of interacting particles. Each pixel as a particle. Particle’s desired force is extracted by desired velocity of particle’s flow (grouping neighbour particles over time t) and current particle’s speed. Neighbour particles are particles starting and ending the same direction. This study simulates particle’s desire force rather than simulating pedestrian’s desire force. It’s used to detect panic rather than for constructing crowd simulation model.

Another thing is it’s work well in outdoor, but indoor, it needs a velocity direction pointing to target (exit gate) and it’s must be changed over time.

* 1. Reaction time: in [Cross Walking, 2014], reaction time is considered as the duration from lower current speed up to average speed. In **average 2.2 s** for all people. In simulation from **Helbings = 0.5 – 1** [Helbing 1995, 2000].

**Interaction force**:

1. Alpha can be discovered by camera as in [Johansson, 2008] through velocity dependence of ellipse in calibration. A,B, lamda are found through calibration process when tracking pedestrian’s trajectories in the same frame.

Videos were recorded at different place. Each video is separated into frames, and trajectories of pedestrians in each frame are detected for calibrating the force of one pedestrian alpha inside that frame. Each frame can generate a broad range of A,B, lamda.

Similarly, each video yield the broad range of A,B, lamda. It was optimized through EA with the finess function coming from distance error. The combination of these parameters at A = 0.42, B = 1.62 are used for further simulation. However, it stills confused when we consider desired speed is constant before calibrating this combination. Furthermoe, A,B, lamda are then used the same for simulation.

In simulation [Helbing, 2005], [Johansson, 2008]. **A=3.0 , B =0.2, lamda = 0.75**

**Repulsion from walls**:

There is no study on camera data acquisition for force from obstacle.

**3- Simulation scenarios between average agents from camera data acquisition approach with various agents’ attributes and analysis. Following scenarios was proved by force model**

Inspired by (Sun,2014) and (Wijermans, 2013), in agent-based model, the one clearest limitation is no standard mechanism to validate the effects of agents’ parameters in the forces’ calculation formulas

3.1. Experimental Setup

This work is inspired by **(**Hoogendoorn, 2013) and (Weijman, 2013), (Sun, 2014) when lack the validation mechanism to measure the different affecting on interaction force’s formula.

Python and C for various agent’s physical attributes.

Source code for Nomad and social force model can be found at:

+**Scenarios**: Bottleneck uni-direction, bottleneck bio-direction. With information as follow

Uni-direction: 9m,2m,2m

Bio-direction: 9m, 1m, 4m, 8m.

+**Environment Simulation**: the width, length of above scenarios.

All pedestrians start in a designated area and try to escape a bottle neck egress in indoor building.

C**artesian**  coordinator is middle, and a unit is a metre, multiple with pixel factor

+**Environment Setup**:

**Pedestrian type**: young people, adult, and elderly. (We choose around based on Hoogendoorn, 2013)

**In desired force**: Each type has different Gaussian distribution in initial desired velocity, reaction time,. Desired speed pointing current position to target position is changed over time as in the theoretical model. C is constant for different type.

By camera approach, desired speed is the same for all pedestrian types and doesn’t change over time, reaction time is the same distribution.

**Interaction repulsive force:** is measured as the same theoretical force model

Each type has different distribution force interaction strength unit, interaction range, and cutoff distance.

By camera approach, agents have the same interaction strength unit, same distribution interaction range, and cutoff distance, lamda value = 0.75 as in [Johansson, 2008].

**Obstacle repulsive force**: is measured as the same theoretical force model, with information about U.

The same for any time when considering by camera data approach because there is no studies about this in indoor.

Show the distribution of three pedestrian types, and other information when considering the same between 3 pedestrian types.

3-2. Analysis

+**Observation comparing between 5 types: (average, total children, total adult, total** **elderly**, mix 40-40-30). Increase by population number, **run 200 times** and average on below result.

Escape rate at the exit,

Bottle neck shape,

Total average travel time of a pedestrian in that scenario

Total agent’s combinatorial force change over a period (newly observation) because desired speed increase, interaction increase, obstacle increase.

Consider on proposed two scenarios. When varying 5 types

-Average by camera, total young people, total elderly people, total adult people, and a mix with the rate 40-40-20 .when varying total population.

**6-Conclusion**

Contribution in parameter acquisistion is useful for crowd virtual reality and crowd simulation in indoor building, for understanding force interacting to specific individual. Understand particular physical attributes of specific persons. Easy to simulate that agents in various infrastructure for layout design assessment, and help to define suitable evacuation plan based on current combinatorial force effecting on micro, meso, and macro levels. As well as force change of specific individuals, context-aware.

Find paper about telling disasters and simulation then. Especially in kindergarden, company or elderly hospital. It’s important to simulate correcsprondingly and find total force affecting specific person over the time. To help people aware precisely force different pedestrian types.