NSM-Goa-4 Simulating Dynamic Effects of Escape Panic

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1 Social Force Model

There are many different attempts made to model and simulate the crowd evacuations in situations of panic, The model which I have utilised in this project is the one given by Helbing, According to this Model, the characteristic features of escape panic are as follows:

1. People tend to panic and try to move faster in situations of panic
2. The Interactions quickly turn physical between the individuals since everyone wishes to exit as early as possible
3. Continuous movement of individuals creates a bottleneck situation at the exit door
4. Due to the above effect archs and cloggings are observed
5. There are jams at the exit
6. The physical interactions in the jammed crowd add up and cause dangerous pressures up to 4,450 Nm^{-1} which can bend steel barriers or push down brick walls.
7. Escape is further slowed by fallen or injured people acting as 'obstacles'.
8. People show a tendency towards mass behaviour, that is, to do what other people do
9. Alternative exits are often overlooked or not efficiently used in escape situations

2 Implementation and Physical Equations Involved

The Model proposed by Helbing is described ad follows: Each of N persons i of mass m_i likes to move with a certain desired speed v_i^0 in a certain direction $\boldsymbol{e}_i^0$, and therefore tends to correspondingly adapt his or her actual velocity $\boldsymbol{v}_i$ with a certain characteristic time τ_i. Simultaneously, he or she tries to keep a velocity-dependent distance from other pedestrians j and walls W, which can be modelled by 'interaction forces' $\boldsymbol{f}_{ij}$ and $\boldsymbol{f}_{iW}$, respectively. Mathematically this information looks like:

$$m_i \frac{d\boldsymbol{v_i}}{dt} = m_i \frac{v_i^0(t)\boldsymbol{e}_i^0 - \boldsymbol{v}_i}{\tau_i} + \sum_{j \neq i} \boldsymbol{f}_{ij} + \sum_W \boldsymbol{f}_{iW} \tag{1}$$

The forces $\boldsymbol{f}_{ij}$ and $\boldsymbol{f}_{iW}$ can be determined with:

$$\boldsymbol{f}_{ij} = \left(A_i \exp\left(\left(r_{ij} - d_{ij}\right)/B_i\right) + kg\left(r_{ij} - d_{ij}\right)\right)\vec{n}_{ij} + \kappa g\left(r_{ij} - d_{ij}\right)\Delta v_{ij}^t \vec{t}_{ij} \tag{1.1}$$

and

$$\boldsymbol{f}_{iW} = \left(A_i \exp\left(\left(r_i - d_{iW}\right)/B_i\right) + kg\left(r_i - d_{iW}\right)\right)\vec{n}_{ij} + \kappa g\left(r_{iW} - d_{iW}\right)\left(\vec{v}_i \cdot \vec{t}_{iW}\right)\vec{t}_{iW} \tag{1.2}$$

Where,

$$A_i = 2 \times 10^3 \text{ N}$$
$$B_i = 0.08 \text{ m}$$
$$k = 1.2 \times 10^5 \text{ kg s}^{-2}$$
$$\kappa = 2.4 \times 10^5 \text{ kg m}^{-1} \text{ s}^{-1}$$

The distance between two agents i, j is defined as d_{ij}, here r_{ij} denotes the sum of their shoulder radii. In 1.2 d_{iW} denotes the shortest distance from agent i to wall W and r_i is the shoulder radii of agent i.
The normalized direction vectors between agent j and i, respectively, wall W and agent i are used as $\vec{n}_{ij}$ and $\vec{n}_{iW}$. The vectors $\vec{t}_{ij} = \left(-n_{ij}^2, n_{ij}^1\right)$ and $\vec{t}_{iW} = \left(-n_{iW}^2, m_{iW}^1\right)$ are the normalized tangential direction vectors. $g(x)$ is a function which evauates to zero if $x > 0$ else x, so as to ensure that the tangential friction is of importance only if an agent is touching a wall or another agent. The tangential velocity difference is defined as $\Delta v_{ij}^t = (\vec{v}_j - \vec{v}_i) \cdot \vec{t}_{ij}$. This force model was used in this project to implement the escape simulations.

3 Integration Method Used

The Integration Method used for the simulation is dormand prince ode45, this method is a member of the Runge–Kutta family of ODE solvers. More specifically, it uses six function evaluations to calculate fourth- and fifth-order accurate solutions. The difference between these solutions is then taken to be the error of the (fourth-order) solution.

In each iteration ode45 method does the time evolution using the 4th and 5th order polynomials separately. After that, norm of the difference of the results is calculated, if the difference is within the acceptable tolerance bounds, the method saves the current value and continues the process. If the difference is unacceptable, step distance is reduced. This implies that for harder differential equations,the method does several iterations at each step, in order to lead more accurate results. Due to which the overall runtime for this method is much higher whan compared to any other integration method.

4 Results and Plots