# Realtime Crowd Crush simulations

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## 1 Description

Crowd Crush is a term for when the density of a crowd reaches a critical point and people begin to suffer from compressive asphyxiation - inability to breathe due to compression of the chest. This typically happens in situations where a lot of people want to move in a certain direction in a panicked or excited state, for example when running from a disaster. Real life experiments on the subject are hard and dangerous to set up, so to understand when and how these dangerous situations appear, one can simulate a potentially dangerous scenario using models that describe crowd dynamics and collective motion.

One such model is the MASHer model, put forth by Jesse L. Silverberg, among others, in a 2013 article [1] investigating collective motion in mosh pits - a phenomenon occurring in crowds during heavy metal concerts, where a group of people move around in an area confined by passive bystanders. With a simple force-particle-model, several emergent patterns were observed that matched real observations from such events. Figure (1) shows an example of a spontaneously created mosh pit with the model.

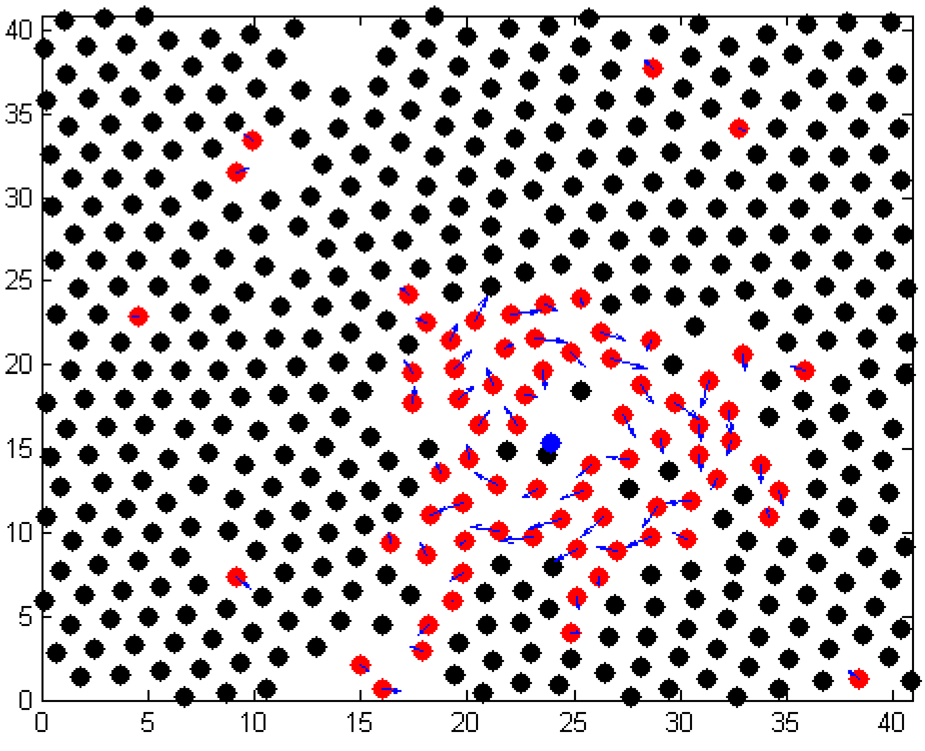


Figure 1: *Position of 500 "MASHers", of which 15% are active, that have created a vortex after* 10000 *time steps. Active "MASHers" are red and passive are black.*

In short, the model describes each person as a particle that is subject to a number of forces, referred to as a MASHer. Every MASHer is statically assigned to an active or passive state, which tells us if said MASHer wants to move or stand still. The model then takes into account repulsion, the desire to move or stand still, random noise as well as a flocking behaviour among the active participants, all modelled as forces and described by the equations

$$\overrightarrow{F}_i^{repulsion} = \begin{cases} \epsilon \left(1 - \frac{r_{ij}}{r_0}\right)^{3/2} \hat{r_{ij}} & \text{if } r_i < 2r_0 \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$\overrightarrow{F}_i^{propulsion} = \mu \left(v_0 - v_i\right) \hat{v}_i \tag{2}$$

$$\overrightarrow{F}_i^{flocking} = \alpha \sum_{j=0}^{N_i} \overrightarrow{v}_j \Bigg/ \left| \sum_{j=1}^{N_i} \overrightarrow{v}_j \right| \tag{3}$$

$$\overrightarrow{F}_i^{noise} = \overrightarrow{\eta}_i \tag{4}$$

Where $N$ is the number of MASHers, $i, j = 0, 1, 2.N - 1$. The parameters $\epsilon,\ \mu,\ \alpha\ and\ \sigma$ define the weight of each force in equation (5). In equation (1) $r_ij$ is the distance between the *i:th* and the *j:th* MASHer, $r_0$ defines the minimum distance MASHers can have between each other without any repulsion force. Equation (2) describes the innate will of the MASHers to maintain the speed $v_0$. The flocking behaviour is described by equation (3) where $\overrightarrow{v}_j$ is the velocity vector of other MASHers. Equation (4) describes the random movement of the MASHers where $\theta$ is a uniformly random angle between 0 and $\pi$, and $\gamma$ is a normally distributed random number with mean 0 and standard deviation 1.

The net force is then used to update the velocity vector of each particle, according to

$$\overrightarrow{v}_i^{k+1} = \overrightarrow{v}_i^k + \Delta t \left(\overrightarrow{F}_i^{repulsion} + \overrightarrow{F}_i^{propulsion} + \overrightarrow{F}_i^{flocking} + \overrightarrow{F}_i^{noise}\right) \tag{5}$$

The model, in itself, is fairly simple, but becomes computationally heavy when applied to larger crowds (hundreds or more individuals), thus making optimization a key part in implementing the model for use in large or real-time applications. The first goal of the project is to modify the MASHer model to suit the simulation of crowd crush events. This includes determining a suitable metric for detecting when the crowd becomes dangerously dense and introducing a more dynamic set of states, perhaps simulating varying levels of panic and if possibly taking into account various geometrical features.

Secondly, since the model becomes very computationally, the existing MATLAB implementation of the model will be translated into a compiled, lower-level, language that will allow the simulations to run much faster and thus enabling larger tests (C, C++, etc).

(Lastly, if time permits, the model will be incorporated into an interactive game that could showcase some of the crowd crush effects in an approachable way.)

# 2 Project plan

- Review concurrent material such as [2] and [3] and determine a suitable metric for measuring crowd crush effects usable with the MASHer model.
- Extend and modify existing MATLAB implementation to handle crowd crush scenarios and possibly more complex geometry.
- Choose a faster language (C, C++, C♯ etc) and implement the model in it.
- Run simulations and compare results.
- (Optional) Elect and learn the basics of a suitable language or API for a web application (HTML 5, JavaScript etc).
- (Optional) Create an interactive game based on the model.
- Prepare the poster, oral presentation and complete a full report.

# References


[1] Collective Motion of Humans in Mosh and Circle Pits at Heavy Metal Concerts, Jesse L. Silverberg,* Matthew Bierbaum, James P. Sethna, and Itai Cohen, Department of Physics and Laboratory of Atomic and Solid State Physics, Cornell University, Ithaca, New York 14853, USA, (Received 13 February 2013; published 29 May 2013).

[2] Self-organizing pedestrian movement, Dirk Helbing, Institute for Economics and Traffic, University of Technology Dresden, 01062 Dresden, Germany, Peter Molnar, Center for Theoretical Studies of Physical Systems, Clark Atlanta University, James P, Brawley Drive, Atlanta, Georgia 30314, USA, Illes J Farkas, Department of Biological Physics, Eo tvo s University, Budapest, Pazmany Peter Setany 1A, H-1117 Hungary, Kai Bolay, Tripod Inc., 160 Water St.,Williamstown, MA 01267, USA; e-mails: helbing@rcs.urz.tu-dresden.de, pmolnar@cau.edu; fij@elte-hu, kai@bolay.de Received 16 September 1999; in revised form 10 May 2000

[3] Pedestrian, Crowd and Evacuation Dynamics, DIRK HELBING, ANDERS JOHANSSON ETH Zurich, Zurich, Switzerland, Institute for Advanced Study, Collegium Budapest, Budapest, Hungary