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Modeling and Simulating Social Systems with Matlab
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Analyzing the Locations and Circumstances of Dangers in Coordinated Crowd Movements

Topic and Research Question[1]

The aim of our research will be to analyze the danger of phenomena like circle pits which often occur during metal or hard rock festivals. A circle pit is when many people inside a crowd run in a circle together. This can be motivated by a person outside of the circle (e.g. the musician on the stage) or some people inside the crowd that spontaneously start moving and animate other people in the crowd to join (= self-organization process). We want to simulate the dynamics of people in a circle pit to then determine the positions which are the most dangerous as well as the circumstances (e.g. speed, number of people) which make the circle pit more dangerous.

Possible Models and their Limits

A commonly used model of crowd behavior is the movement of particles in a two-dimensional gas, in which each individual person is likened to a particle of gas moving and interacting with other gas particles in the vicinity. In accordance to classical mechanics, the dynamics of particles in a gas, which is given by the position and momentum vectors of every single particle, is completely determined by its initial conditions (position and momentum at $t = 0$). However, in this particular case, certain other factors come into play: for example, gas particles are not affected by the "mood" of their neighbors, by peer pressure or by the quality of the music being played. The particle model will also reach its limits when discussing the simulation of the above mentioned phenomena, as these crowd movements are coordinated and the decision to start one is a collective decision (not individual), unlike with 2D particles. Therefore, we will have to consider a certain amount of additional that influences the motion of each individual. One interesting question to ask is: to what extent is a model based on a two dimensional gas consistent with the crowd movement? An interesting fact about the thermodynamical consideration of gases is that in a container with cylindrical symmetry, the state in which the particles rotate around the symmetry

[1] Source of image: http://i.imgur.com/xrWyStZ.png

axis, is a thermodynamical equilibrium state. This type of phenomenon could also be applied not only to circle pits, but also to coordinated crowd in general.

Another possibly suitable model for simulating such crowd movements is the cellular automaton model. In this approach, each person would be influenced and motivated to perform certain actions by their neighbors. In this fashion, an impulse (e.g. the impulse to start/join a crowd movement) can travel through the crowd in a fairly natural fashion. Observing the physical properties (such as velocity, acceleration, etc., see below) of the neighbors of a particular person at a particular location would then be a good indication for how dangerous that location is.

However, the limits of such a model would also be reached in cases where the actions of people not in the immediate vicinity of a particular person influence that person to act differently (e.g. if the musician encourages the crowd to start moving).

For the purpose of analysing the danger, we will first have to specify under which conditions a situation may become risky.

Conditions Contributing to Dangers

Since one danger is that two or more people collide into each other, the relative momentum between neighbouring individuals should presumably be considered.

Two groups of people adjoining each other create a risk if the people at the interface move in different directions. Mathematically seen, this means there is a discontinuity in the derivative of the momentum with respect to the position (= dp/dx). This discontinuity will happen at the border of the circle pit: At one place of the crowd, people are moving in the circle and since usually not everyone in the crowd is joining, there will be people surrounding the circle, which themselves are not moving.

Of course, if the two groups are moving at relatively low speeds, such a discontinuity in the derivative of the momentum with respect to space will not have such a dangerous effect on the two groups colliding with each other. Therefore, we also need to take into account the relative velocities of the two groups as well as the angle under which the collision occurs.

Furthermore, it could happen that a dangerous situation occurs even when a particular person x is not involved in a collision. For example, this could happen when the people around x suddenly accelerate and trample x. Therefore, our model would also have to take into account the relative accelerations of each person's neighbors.

Comparison of our Final Results

Having finished the simulation and analyzation, we will be able to compare our results with information about accidents that actually did happen. Did they take place at positions that we considered as particular risky? Do our predictions reflect reality?