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Modeling crowd dynamics during vehicle ramming attacks

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Abstract. The study of human crowd dynamics during vehicle ramming attacks is vital in designing possible escape routes to reduce casualties. The behavior of the crowd under close-range attack has been investigated based on numerical methods such as the fluid-dynamics model in which the crowd is represented as flowing fluid due to their integral movement and the social force model in which the crowd is represented by multi-particles driven by specific rules. The social force model has been successful in simulating crowd behavior in public events during an attack. However, none of the studies conducted so far consider vehicle ramming attacks on a crowd in a fully coupled manner considering the dynamics of the vehicle and the crowd together.

In this study, an Agent-Based Model (ABM) coupled with the Discrete Element Method (DEM) is proposed to model crowd dynamics during a vehicle ramming attack. The DEM is used to simulate the ramming of the vehicle over possible obstacles, road barriers, and the crowd. Here, the vehicle is represented by a rectangular particle based on the superquadric function. Once the vehicle reaches the crowd, the contact between the particle representing the vehicle with its residual intrusion velocity and multi-agents representing the crowd is detected by evaluating the position of the nearby agents in the function representing the particle surface to determine if the agents are in or outside of the particle. Agents that come in contact with the DEM particle are deactivated and considered as a casualty based on the velocity particle. The ABM and DEM are evaluated on the same time step considering the smallest critical time step of the two models. These methods are coupled one directional which means only the effect of the particle on the agents is accounted for. Here, a numerical example is presented to show the applicability of the proposed new coupling.

Keywords: agent based model, discrete element method, social force model, vehicle ramming.

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